SEL-487E Relay

Current Differential and Voltage Protection

Instruction Manual

20100118

SCHWEITZER ENGINEERING LABORATORIES, INC.

PM487E-01

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Preface

Overview

The SEL-487E Relay Instruction Manual provides specification for and describes installation, setting, testing, and operation of the device. It also includes detailed information about settings and serial port and front-panel commands.

An overview of each manual section follows.

Section 1: Introduction and Specifications. Describes the basic features and functions of the SEL-487E, and lists the specifications.

Section 2: Installation. Describes how to mount and wire the SEL-487E; illustrates wiring connections.

Section 3: PC Software. Describes how to get started with ACSELERATOR QuickSet® SEL-5030 Software, a powerful setting, event analysis, and measurement tool that aids in applying and using the SEL-487E.

Section 4: Protection and Logic Functions. Describes protection functions, together with setting descriptions for each protection function.

Section 5: Monitoring and Metering. Describes battery monitoring, breaker monitoring, through-fault monitoring, and transformer thermal monitoring. Shows the power measurement conventions used for metering, and explains Analog Signal Profiling, Math Variable Metering, and Remote Analog Metering.

Section 6: Settings. Describes how to enter and record Group, Global, Port, Front-Panel and Report settings for the device; includes setting sheets.

Section 7: Communications, Interfaces, and Protocols. Describes the hardware interfaces, hardware protocol, and software protocols in the relay such as SEL protocols, RTD operations, and MIRRORED BITS® communications.

Section 8: Front-Panel Operations. Explains the features and use of the front panel, including front-panel command menus, default displays, and target LEDs.

Section 9: Bay Control. Describes the logic and settings for the control of the transformer disconnects and circuit breakers. Includes twenty bay layouts and seven transformer types.

Section 10: Event Reports and SER. Describes event summary data, standard event reports, and Sequential Events Recorder (SER) report.

Section 11: Synchrophasors. Describes the Phasor Measurement Unit (PMU) functions of the SEL-487E; provides details on synchrophasor measurement; describes the IEEE C37.118 synchrophasor protocol settings; describes the SEL Fast Message synchrophasor protocol settings.

Section 12: SELOGIC Control Equations. Describes SELOGIC control equations and how to apply these equations; discusses expanded SELOGIC control equation features such as PLC-style commands, math functions, counters, and conditioning timers; provides a tutorial for converting older format SELOGIC control equations to new free-form equations.

Section 13: ASCII Command Reference. Provides an alphabetical listing of all ASCII commands with examples for each ASCII command option.

Section 14: Testing and Troubleshooting. Describes how to test selected protection functions, and provides techniques for testing, troubleshooting, and maintaining the SEL-487E; includes the list of status notification messages and a troubleshooting chart. Includes a description of the Commissioning Assistant.

Appendix A: Firmware and Manual Versions. Lists the current firmware versions, and details differences between the current and previous firmware and manual versions.

Appendix B: Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in Flash memory.

Appendix C: SEL Communications Processors. Describes how SEL communications processors and PC software use SEL protocols optimized for performance and reliability.

Appendix D: High-Accuracy Timekeeping. Defines the requirement of high-accuracy IRIG-B timekeeping and describes how to configure the SEL-487E for high-accuracy timekeeping.

Appendix E: DNP3 Communications Protocol. Describes the DNP3 protocol support provided by the SEL-487E.

Appendix F: IEC 61850. Describes IEC 61850 implementation in the SEL-487E.

Appendix G: Relay Word Bits. Lists and describes the Device Word bits (outputs of protection and control elements).

Appendix H: Analog Quantities. Lists and describes the Analog Word bits (outputs of analog elements).

Appendix I: Communications Card. Describes the Ethernet card provided by the SEL-487E, including FTP, Telnet, IEC 61850, and synchrophasor protocols.

SEL-487E Command Summary. Briefly describes the serial port commands that are fully described in *SEL ASCII Commands on page 7.6*.

Conventions

Typographic Conventions

There are three ways to communicate with the SEL-487E:

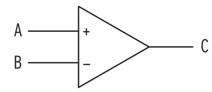
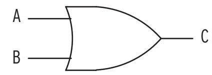
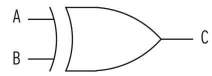
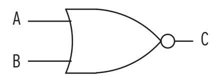
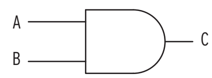
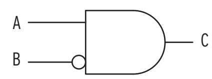
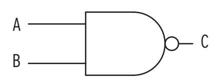
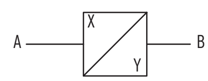
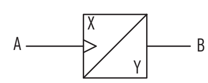
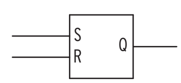
- ➤ Using a command line interface on a PC terminal emulation window.
- ➤ Using the front-panel menus and pushbuttons.
- ➤ Using ACSELERATOR QuickSet software

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions:

Example	Description
STATUS	Commands typed at a command line interface on a PC.
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
{CLOSE}	Device front-panel pushbuttons.
ENABLE	Device front- or rear-panel labels.
MAIN > METER	Device front-panel LCD menus and device responses visible on the PC screen. The > character indicates submenus.

Logic Diagrams

Logic diagrams in this manual follow the conventions and definitions shown below.

NAME	SYMBOL	FUNCTION
COMPARATOR		Input A is compared to input B. Output C asserts if A is greater than B.
INPUT FLAG		Input A comes from other logic.
OR		Either input A or input B asserted cause output C to assert.
EXCLUSIVE OR		If either A or B is asserted, output C is asserted. If A and B are of the same state, C is deasserted.
NOR		If neither A nor B asserts, output C asserts.
AND		Input A and input B must assert to assert output C.
AND W/ INVERTED INPUT		If input A is asserted and input B is deasserted, output C asserts. Inverter "O" inverts any input or output on any gate.
NAND		If A and/or B are deasserted, output C is asserted.
TIME DELAYED PICK UP AND/OR TIME DELAYED DROP OUT		X is a time-delay-pickup value; Y is a time-delay-dropout value. B asserts time X after input A asserts; B will not assert if A does not remain asserted for time X. If X is zero, B will assert when A asserts. If Y is zero, B will deassert when A deasserts.
EDGE TRIGGER TIMER		Rising edge of A starts timers. Output B will assert time X after the rising edge of A. B will remain asserted for time Y. If Y is zero, B will assert for a single processing interval. Input A is ignored while the timers are running.
SET RESET FLIP FLOP		Input S asserts output Q until input R asserts. Output Q deasserts or resets when R asserts.
FALLING EDGE		B asserts at the falling edge of input A.

Safety and General Information

Safety Information

This manual uses three kinds of hazard statements, formatted as follows:

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury or equipment damage.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

Symbols

The following symbols from EN 61010-1 are often marked on SEL products.

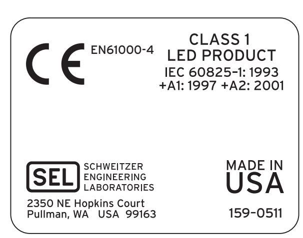
Environmental Conditions and Voltage Information

The following table lists important environmental and voltage information.

Condition	Range/Description
Indoor/outdoor use	Indoor
Altitude	Up to 2000 m
Temperature	
IEC Performance Rating (per IEC/EN 60068-Z-1 and 60068-Z-2	–40 to +85°C
UL/CSA Safety Rating	–40 to +70°C
Relative humidity	5 to 95%
Main supply voltage fluctuations	Up to ±10% of Nominal voltage
Overvoltage	Category II
Pollution	Degree 2
Atmospheric pressure	80 to 110 kPa

Laser/LED Emitter

The SEL-487E is a Class 1 LED product and complies with IEC 60825-1:1993 + A1:1997 + A2:2001. The following figure shows the compliance label that is located on the left side of the device (when facing the front of the device).

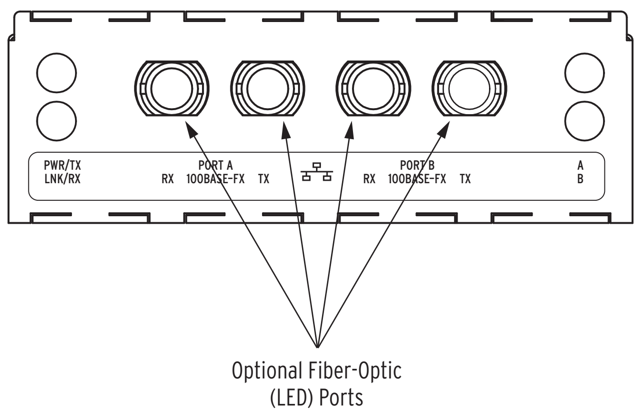


Class 1 LED Product Compliance Label and Location

The following table shows LED information specific to the SEL-487E (see *Figure 2.23*–*Figure 2.24* for the location of Port 2, the port using these LEDs, on the device).

Item	Detail
Mode	Multimode
Wavelength	820 nm
Source	LED
Connector type	ST
Output power	–11.7 to –3.7 dBm

The following figure shows LED location specific to the SEL-487E (see *Figure 2.23*–*Figure 2.24* for the rear-panel drawings).



LED Location Specific to the SEL-487E

Safety Warnings and Precautions

- Do not look into the end of an optical cable connected to an optical output.
- Do not look into the fiber ports/connectors.
- Do not perform any procedures or adjustments that are not described in this manual.
- During installation, maintenance, or testing of the optical ports only use test equipment classified as Class 1 laser products.
- Incorporated components such as transceivers and laser/LED emitters are not user serviceable. Units must be returned to SEL for repair or replacement.

Wire Sizes

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You may use the following table as a guide in selecting wire sizes.

Connection Type	Minimum Wire Size	Maximum Wire Size
Grounding (Earthing) Connection	14 AWG (2.5 mm^2)	10 AWG (4 mm^2)
Current Connection	16 AWG (1.5 mm^2)	10 AWG (4 mm^2)
Potential (Voltage) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Other Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)

Instructions for Cleaning and Decontamination

Use care when cleaning the SEL-487E. Use a mild soap or detergent solution and a damp cloth to clean the chassis. Do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any surface.

Symbol 14		Consult Documentation for Additional Information
Symbol 6		Protective (Safety) Ground Conductor Terminal
Symbol 1		Direct Current
Symbol 2		Alternating Current
Symbol 3		Direct and Alternating Current
Symbol 5		Earth (Ground) Terminal

SEL-487E Cautions, Warnings, and Dangers

The following hazard statements appear in the body of this manual in English. See the following table for a list of the English statements and the French translations.

English	French
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	⚠ATTENTION Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.
⚠CAUTION When setting IRIGC = C37.118, make sure that the input control bits are compliant with the C37.118 format.	⚠ATTENTION Quand le réglage IRIGC = C37.118, vérifier que les bits de control des entrées sont conformes avec le format C37.118.
⚠DANGER The outputs in the SEL-487E are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current interrupting capacity must clear the coil current in the disconnect motor before the output on the SEL-487E opens. Failure to observe this safeguard could result in damage to the SEL-487E output contacts.	⚠ATTENTION Les contacts de sortie du relais SEL-487E ne peuvent pas interrompre le courant de bobine du moteur de sectionneur. Un contact auxiliaire avec un pouvoir de coupure adéquat doit couper le courant de la bobine du moteur du sectionneur avant que le contact de sortie du SEL-487E ne s'ouvre. La non-conformité à cette règle de sécurité pourrait endommager les contacts de sortie du SEL-487E.
⚠DANGER Do not connect power to the relay until you have completed these procedures and receive instruction to apply power. Equipment damage can result otherwise.	⚠ AVERTISSEMENT Ne pas mettre le relais sous tension avant d'avoir complété ces procédures et d'avoir reçu l'instruction de brancher l'alimentation. Des dommages à l'équipement pourraient survenir autrement.
⚠DANGER The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.	⚠ AVERTISSEMENT Le relais contient des pièces sensibles aux décharges électrostatiques. Quand on travaille sur le relais avec les panneaux avant ou du dessus enlevés, toutes les surfaces et le personnel doivent être mis à la terre convenablement pour éviter les dommages à l'équipement.
⚠DANGER The continuous rating of the current inputs is 3 • I_{nom}. If any currents in this test will exceed this rating, reduce the TAPn values as needed, to prevent possible damage to the input circuits.	⚠ AVERTISSEMENT La capacité, en régime permanent, des entrées de courant est 3 • I_{nom}. Si un courant d'essai dépassait cette valeur, réduire la prise TAPn pour prévenir les dommages aux circuits d'entrée.
⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	⚠ AVERTISSEMENT Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠ AVERTISSEMENT Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessuers ou la mort.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠ AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.

English	French
⚠WARNING Be sure to connect both sets of CTs in the same delta configuration (AB, BC, CA, for example). When you connect the two sets of CTs in different delta configurations (AB, BC, CA and AC, BA, CB) the phase difference result in incorrect combined current values.	⚠ AVERTISSEMENT Faites en sorte de connecter les deux groupes de TC dans la même configuration delta (AB, BC, CA, par exemple). Quand vous connectez les deux groupes de TC dans des configurations delta différentes, la différence des phases produit des valeurs incorrectes de courants combinés.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠ AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠ AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.

Technical Assistance

Obtain technical assistance from the following address:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 USA
Phone: +1.509.332.1890
Fax: +1.509.332.7990
Internet: www.selinc.com
E-mail: info@selinc.com

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Section 1

Introduction and Specifications

Overview

The SEL-487E Relay, shown in *Figure 1.1*, provides a suite of current and voltage elements for the comprehensive protection of two-winding, three-winding, four-winding, and five-winding power transformers. In total, the relay consists of 24 analog channels, divided into three groups of analog inputs. The first group consists of 15 channels for phase current inputs, the second group consists of 3 channels for single-phase (neutral) current inputs, and the third group consists of 6 channels for two three-phase voltage inputs.

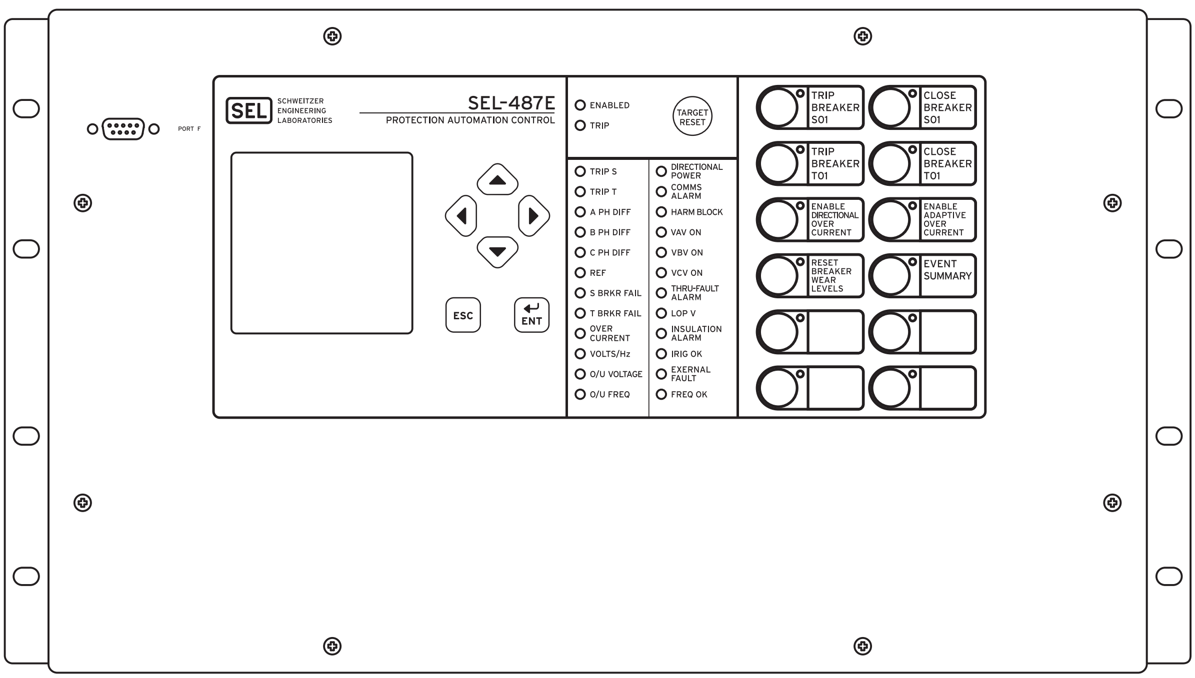


Figure 1.1 SEL-487E Current Differential Relay

In addition to transformer protection, the relay is suited for other current differential protection such as busbar protection for up to five terminals with mismatched CT ratios as high as 25:1. When installed as busbar protection, also use the relay as a PMU, to collect synchrophasor data from each of the five terminals, as well as a station-wide digital fault recorder.

As main protection for power transformers, current-operated protection includes an adaptive-slope phase percentage restraint differential element, an unrestraint differential element, a negative-sequence percentage restraint differential element, programmable restricted earth-fault elements, breaker failure protection for each winding, and several voltage polarized directional and non-directional phase, negative-sequence and zero-sequence definite-time and inverse-time overcurrent elements.

Select secondary current inputs from a combination of 1 A and 5 A on a per-winding basis for the phase input windings (Windings S through Winding X), or a combination of 1 A and 5 A on a per-phase basis on the neutral windings (Winding Y).

Voltage-operated transformer protection includes under- and over frequency elements, under- and over power elements, several phase, positive-sequence, negative-sequence and zero-sequence voltage elements, and two levels of volt-per-Hertz protection.

System measurement, monitoring, and reports include IEEE Standard C57.91:1995 thermal element, IEEE C37.118 compliant synchrophasor measurements, IEEE Standard C57.109-1993 through-fault current monitor, breaker wear monitoring for each individual pole, battery voltage monitoring, sequential event reporting (SER), and 8 kHz COMTRADE event reports. Collect data from up to 12 Temperature Measuring Elements (49) when used with the SEL-2600 RTD Module.

Select sampling rates for oscillography from 1 kHz, 2 kHz, 4 kHz, and 8 kHz. At the 1 kHz sampling rate, record two consecutive events of 5 seconds each, for a total of 10 seconds of data.

For customized protection and automation functions, use the SELOGIC® control equations with extensive programming capabilities. Because protection and automation programming require different execution times, the relay provides separate programming areas for protection and automation programming. You can organize automation SELOGIC control equation programming into 10 blocks of 100 program lines each for a total of 1000 lines of automation programming. Use up to 250 lines in the separate protection programming area to program custom protection functions.

Communications interfaces include standard SEL ASCII and enhanced MIRRORED BITS® communications protocols. Establish Ethernet connectivity with the optional Ethernet card to employ the latest industry communications tools including Telnet, FTP, DNP3 LAN/WAN or IEC-61850 Protocol Option protocols.

The SEL-487E relay provides comprehensive protection, automation, and control for transformers. The SEL-487E-2 variant is identical to the SEL-487E relay in all aspects but has been relabeled for use in phasor measurement applications that prohibit personnel from accessing protective relays.

Included with the purchase of SEL-487E is the ACSELERATOR QuickSet® SEL-5030 Software program. Use the ACSELERATOR QuickSet software to assist you in setting, controlling, and acquiring data from the relays both locally and remotely. ACSELERATOR Architect® SEL-5032 Software is included with purchase of the optional Ethernet card with IEC 61850 protocol support. ACSELERATOR Architect enables you to view and configure IEC 61850 settings, tightly integrated with ACSELERATOR QuickSet.

This section introduces the SEL-487E and provides information on the following topics:

- Functional Overview
- Models and Options
- Applications
- Specifications

Functional Overview

The SEL-487E contains many protection, automation, and control features. *Figure 1.2* presents a simplified functional overview of the relay.

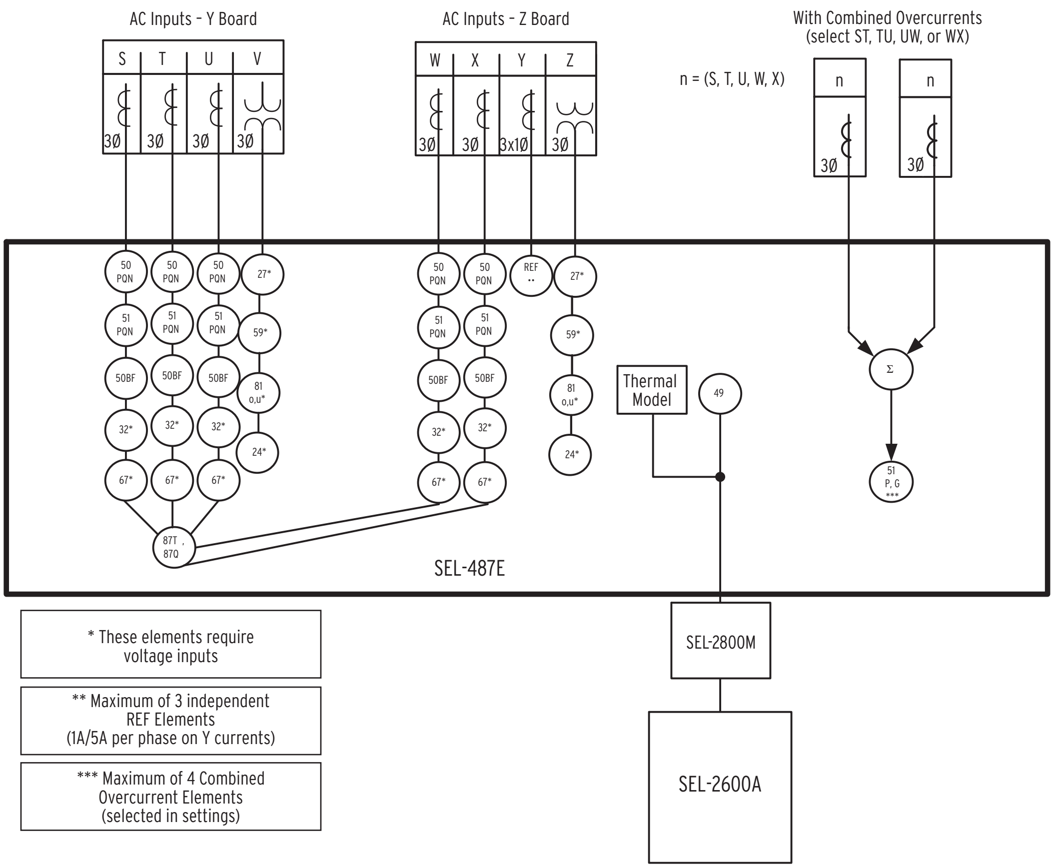


Figure 1.2 Functional Overview

The SEL-487E relay includes the following features:

Restraint Differential Element. Innovative algorithms switch the relay within 2 milliseconds to a high-security mode during through-fault conditions for maximum security. While in the high-security mode, the algorithm does not block the differential elements, thus avoiding unnecessary time delays for clearing faults evolving from external to internal faults.

CT Ratio Mismatch. Mismatched CTs of ratios as high as 25:1 can be installed. For example, one set of CTs in a breaker-and-a-half installation can have CT ratios of 2000/5 and the other set of CTs can have CT ratios of 80/5.

1 A/5 A CT Ratio Combination. Order each 3-phase winding inputs with either 1 A or 5 A CT secondary current. For the restricted earth-fault CTs, order each single-phase input with either 1 A or 5 A CT secondary current.

Unrestraint Differential Element. This element operates independent of the harmonic content of the differential current, providing fast, unrestraint tripping for high-current transformer faults, such as bushing faults. The unrestraint differential element compliments the phase differential elements, particularly during inrush conditions when harmonics in the differential current may cause the restraint differential elements to operate slower.

Negative-Sequence Differential Element. Use the negative-sequence differential element to provide greater sensitivity for turn-to-turn faults during heavy load conditions, when phase-current differential elements are less sensitive.

Restricted Earth-Fault Element. Provides fast, sensitive protection for ground faults close to the neutral for grounded wye-transformer windings.

Breaker Failure Protection. The SEL-487E provides breaker failure protection for each of the five windings, initiated by either phase current, zero-sequence current, or a combination of phase current and zero-sequence current. To reduce breaker failure coordination time, advanced open-phase detection ensures current-element reset in less than one cycle.

Non-Directional Overcurrent Elements. Compliment the differential elements with a large number of instantaneous, definite time, and adaptive inverse time phase overcurrent elements; instantaneous, definite time, and inverse time residual (zero-sequence) overcurrent elements; instantaneous, definite time, and inverse time negative-sequence overcurrent elements, as well as combined overcurrent elements (inverse time for phase and ground) for applications such as stations with breaker-and-a-half layouts.

Directional Overcurrent Elements. Convert any non-directional overcurrent element to a directional overcurrent with a range of voltage-polarized directional elements.

Voltage Elements. The SEL-487E provides phase overvoltage and undervoltage elements, phase-to-phase overvoltage and undervoltage elements, as well as positive-sequence, negative-sequence, and zero-sequence voltage elements for each of the two sets of voltage inputs.

Frequency Elements. Any of the six levels of frequency elements can operate as either an under-frequency element, or as an over-frequency element. Because the relay tracks the frequency from 40.1 Hz to 65 Hz, the frequency elements are suited for applications such as under-frequency load shedding and restoration control systems.

Volts-per-Hertz Elements. Combining the voltage elements with the frequency elements, the SEL-487E offers two levels of volts-per-Hertz elements; one levels for an unloaded transformer, and the other level for a loaded transformer.

Power Elements. Set the per-phase power elements to detect real and reactive power flow for applications such as reverse power protection/control and overpower and/or underpower protection/control.

Monitoring Elements. Use the SEL-487E to monitor a variety of items in the substation. To monitor the transformer insulation health, use the thermal element based on IEEE Standard C57.91:1995: Guide for Loading Mineral-Oil-Immersed Power Transformer; monitor the ac ripple and battery ground faults with the built-in battery monitor; calculate the percentage breaker wear and record the number of operations to optimize breaker maintenance with the breaker wear monitor. Monitor the transformer through-fault current on a per-phase basis to determine the impact of through faults on the transformer windings.

Synchrophasor. The SEL-487E collects synchrophasor data once per cycle for all 24 channels, and uses the IEEE C37.118 and SEL Fast Synchrophasor protocols to transmit the data. The SEL-487E also supports receipt of C37.118 synchrophasors and time alignment to local synchrophasors to support wide-area control.

Expanded SELOGIC Control Equations. Modify and set custom relay applications with PLC-style (programmable logic controller, IEC 61131-3) SELOGIC control equation programming that includes math and comparison functions. Use counters and multifunction timers for greater application flexibility, i.e., perform advanced PLC functions within the relay. The SEL-487E has separate protection and automation SELOGIC control equation programming areas. These programming areas provide ample protection programming capability and 10 blocks of 100-line automation programming capability (1000 lines).

Alias Settings. Use as many as 200 aliases to rename any digital or analog quantity in the relay. These aliases are then available for use in customized programming, making the initial programming and maintenance much easier.

Metering. View primary or secondary rms or fundamental metering information for phase currents and angles of all windings, phase voltages and angles, as well as the per-unit operating and restraint values from all differential elements.

Control. Open and close up to five breakers and eight disconnects from the front panel with the bay control function. Obtain custom-build screens to match your transformer layout.

Commissioning Assistant. Use the patented Commissioning Assistant to check CT polarities, cross-wired CTs, consistent CT ratio between phases, and to calculate the correct compensation matrices for all five windings.

Oscillography and Event Reporting. Record raw and/or filtered currents, voltages, and digital information (8 kHz, COMTRADE format) that you select. Investigate relay internal logic points and power system performance with event report phasor analysis.

Sequential Events Recorder (SER). Record 1000 system entries from 250 monitoring points, including settings changes, power ups, and Relay Word bit elements that you select. Set element names to easily understood aliases.

Digital Relay-to-Relay Communication. Use MIRRORED BITS communications to monitor internal element conditions between relays within a substation and between substations using communication channels (SEL fiber-optic transceivers to send a direct transfer trip, for example).

Ethernet Communications Capability. Implement control and data gathering capabilities via substation LANs (local area networks) and company WANs (wide area networks) with the optional Ethernet card. Employ the FTP protocol for system data acquisition.

Computer Software and Settings Reduction. Use the rules-based settings editor, the ACSELERATOR QuickSet software, to develop settings offline. Internal relay programming shows only the settings for the functions and elements you have enabled.

Standard Features and Ordering Options

Depending on the number of interface boards, the SEL-487E is available in either 6U (one interface board) or 7U sizes (two interface boards) (U is one rack unit in height—44.45 mm or 1.75 inches). Select I/O boards from a choice of four interface boards, each board designed to provide a wide range of input and output combinations to tailor the relay for your specific application. If your application requires more I/O, add contact I/O with the SEL-2505/SEL-2506 Remote I/O Module.

Current Channel Options

Select the CT secondary current for any one of the five windings (S, T, U, W, X) from 1 Amp or 5 Amp (all three phases 1 Amp or 5 Amp). For neutral windings (the three inputs of Winding Y), you can separately select the CT secondary current for each of the three inputs. For example, select 1 Amp secondary currents for the three phases of Winding S, 5 Amp secondary currents for the three phases of Winding T, 1 Amp secondary currents for the three phases of Winding U, 1 Amp secondary current for REF 1 (first neutral current input), and 5 Amp secondary current for REF 2 (second neutral current input).

Although each three-phase winding (S, T, U, W, and X) can be either 1 A or 5 A, and the Y-windings either 1 A or 5 A on a per-phase basis, the SEL-487E supports only the combinations shown in *Table 1.1*.

Table 1.1 Supported 1 A/5 A Windings Combinations

Windings S, T, U	Windings W, X, IY1, IY2, IY3
Winding S = 5 A Winding T = 5 A Winding U = 5 A	Winding W = 5 A Winding X = 5 A Winding IY1, IY2, IY3 = 5 A, 5 A, 5 A
Winding S = 5 A Winding T = 5 A Winding U = 1 A	Winding W = 5 A Winding X = 5 A Winding IY1, IY2, IY3 = 5 A, 5 A, 1 A
Winding S = 5 A Winding T = 1 A Winding U = 1 A	Winding W = 5 A Winding X = 5 A Winding IY1, IY2, IY3 = 5 A, 1 A, 1 A
Winding S = 1 A Winding T = 1 A Winding U = 1 A	Winding W = 5 A Winding X = 5 A Winding IY1, IY2, IY3 = 1 A, 1 A, 1 A
	Winding W = 1 A Winding X = 1 A Winding IY1, IY2, IY3 = 5 A, 5 A, 5 A
	Winding W = 1 A Winding X = 1 A Winding IY1, IY2, IY3 = 5 A, 5 A, 1 A
	Winding W = 1 A Winding X = 1 A Winding IY1, IY2, IY3 = 5 A, 1 A, 1 A
	Winding W = 1 A Winding X = 1 A Winding IY1, IY2, IY3 = 1 A, 1 A, 1 A

Interface Board (I/O) Options

Select from four interface boards to provide flexibility with the diverse I/O requirements when installing the SEL-487E at power plants, Transmission and Distribution networks. You can install the interface boards in any combination in the relay. *Table 1.2* provides I/O information about the main board and the four interface boards.

Table 1.2 Main Board and Interface Board Information

Board Name	Inputs	Description	Outputs	Description
Main	5	Optoisolated, independent, level-sensitive	3	High current interrupting, Form A
	2	Optoisolated, common, level-sensitive		
			2	Standard Form A
			3	Standard Form C
INT2	8	Optoisolated, independent, level-sensitive	13	Standard Form A
			2	Standard Form C
INT4	18	Two sets of 9 common optoisolated, level-sensitive	6	High-speed, high current interrupting, Form A
	6	Optoisolated, independent, level-sensitive	2	Standard Form A
INT7	8	Optoisolated, independent, level-sensitive	13	High current interrupting, Form A
			2	Standard Form C
INT8	8	Optoisolated, independent, level-sensitive	8	High-speed, high current interrupting, Form A

- Voltage ranges for the inputs on the main board as well as for the inputs on the four interface boards are as follows:
  - 48 Vdc
  - 110 Vdc
  - 125 Vdc
  - 220 Vdc
  - 250 Vdc
- Power Supply options
  - 48/125 Vdc or 120 Vac
  - 125/250 Vdc or 120/240 Vac
- Communications cards option

  Ethernet card with combinations of 100 Mbps copper and fiber jacks on each of two ports providing FTP, Telnet, DNP3 LAN/WAN, and IEC 61850 protocols.
- Communications Protocols
  - SEL ASCII
  - SEL Compressed ASCII
  - SEL Fast Messaging (SEL Fast Meter, SEL Fast Operate, SEL Fast SER)
  - Ymodem File Transfer
  - Enhanced MIRRORED BITS
  - C37.118 server and client
  - FTP (ordering option)
  - Telnet (ordering option)

- DNP3 LAN/WAN (ordering option)
- DNP3 Level 2 Slave, Serial (ordering option)
- IEC 61850 (ordering option)

Contact the SEL factory or your local Technical Service Center for ordering information (see *Factory Assistance on page 14.65*). You can also view the latest ordering information on the SEL website at www.selinc.com.

Applications

Use the SEL-487E for up to five-winding transformers at power plants, transmission stations, distribution stations, and industrial plants. For information on connecting the relay, see *Section 2: Installation*. The figures in this subsection illustrate selected relay applications.

Autotransformer

Figure 1.3 shows the SEL-487E applied to an autotransformer with both HV and LV busbars configured as breaker-and-a-half busbars. In this application, the relay accepts current transformer inputs from four phase current transformers, and one neutral current transformer, and PT inputs from both HV and LV busbars.

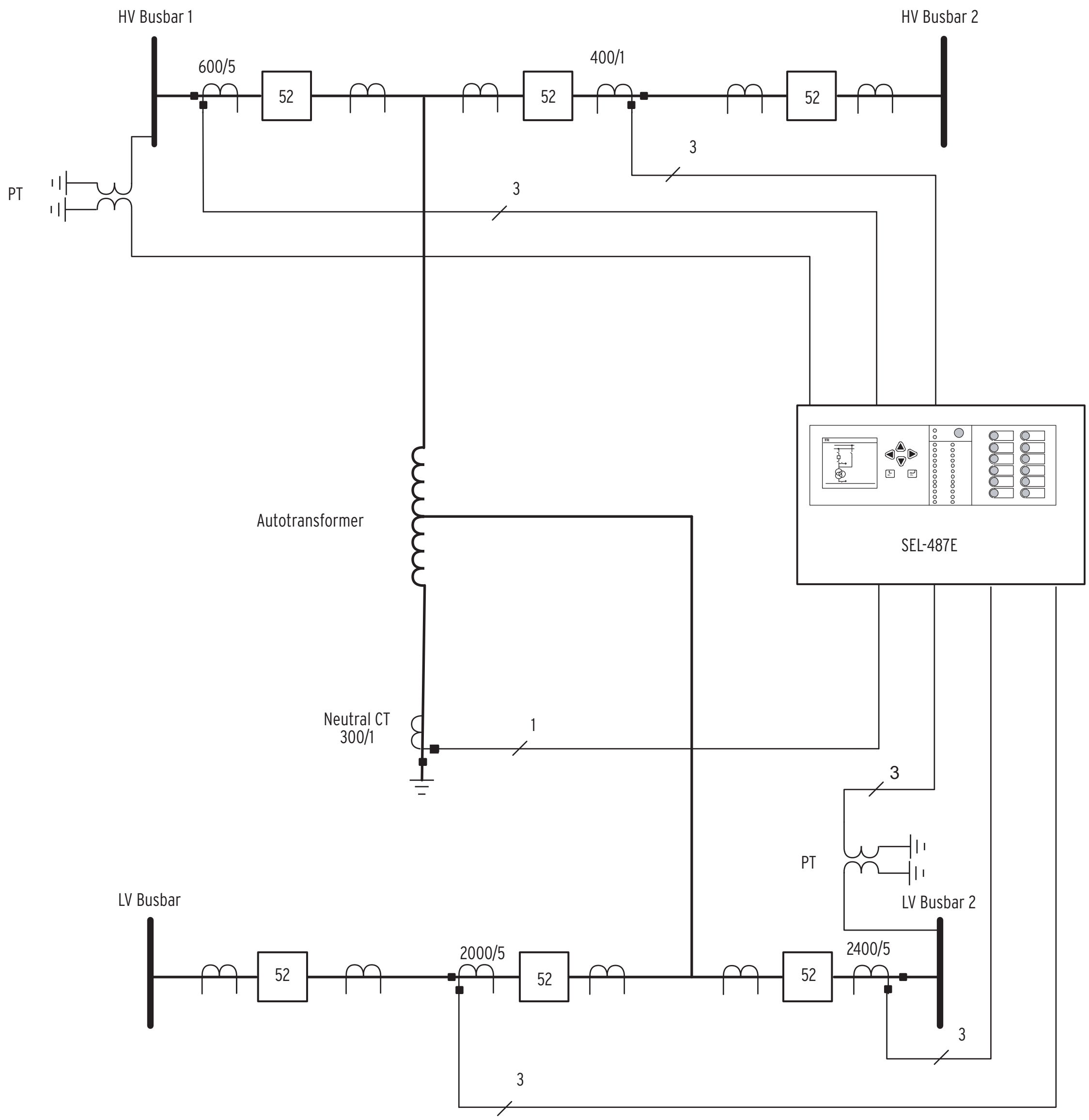


Figure 1.3 Autotransformer Application

By wiring the potential transformers into the relay, all protection elements requiring voltage inputs such as volts/hertz, under-and overpower elements, and directional elements become available. In addition to these protection functions, control functions, and data collection functions such as the frequency elements (under-frequency load shedding), synchrophasors (system data), and power metering data (real power, reactive power, energy, and power factor) also become available with the PT input.

Transformer With Grounding Bank

Figure 1.4 shows a wye-delta transformer with a grounding bank on the delta side. This installation calls for restricted earth-fault protection (REF) on both the grounded wye winding and the grounding bank. Winding Y of the SEL-487E is dedicated to REF protection, and includes three independent REF elements. In this application, the HV side has phase CT ratios of 800/1 and a neutral CT ratio of 800/5. On the LV side, the phase CT ratio is 2000/5 and the neutral CT of the grounding bank (NEC/R/T) is 100/1. Note that the ratio of the phase CT to the neutral CT on the LV side is 2000/100 = 20, well within the 25:1 CT mismatch capability of the relay.

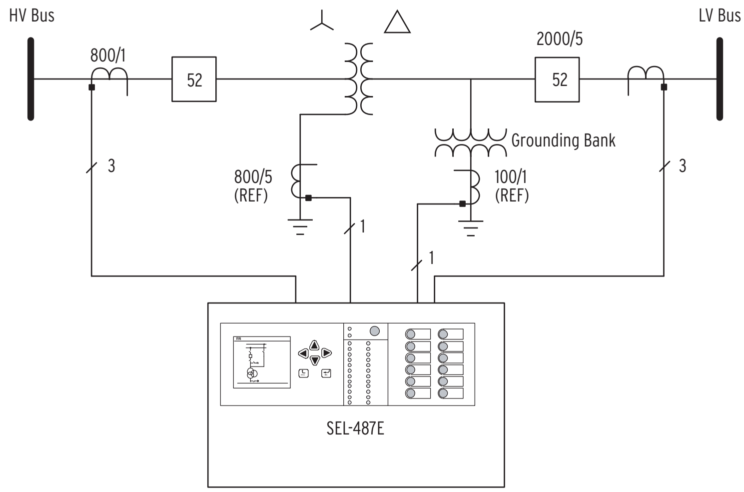


Figure 1.4 Wye-delta Transformer With Grounding Bank

Remote Breaker Application

Figure 1.5 shows an application where the transformer HV breaker is at a remote location. In this application, protect the power transformer with the SEL-487E relay, then use MIRRORED BITS communication to trip the remote HV breaker when the relay operates. After relay operation, the MIRRORED BITS trip information reaches the remote HV breaker in four milliseconds, ensuring fast clearance of the faulty transformer.

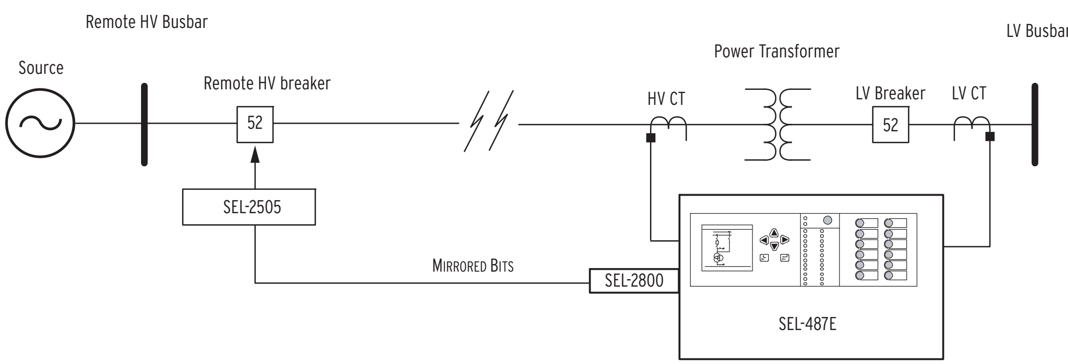


Figure 1.5 Installation With Remote HV Breaker

Table 1.3 Application Highlights (Sheet 1 of 2)

Application	Key Feature
Installation at power plants, transmission, and distribution stations	➤ Unique combination of protection (including V/Hz), control, and monitoring makes the relay suitable for most transformer applications. ➤ Patented dual-slope differential characteristic provides fast tripping time.
Impedance-grounded systems	Three independent restricted earth-fault elements provide sensitive ground fault protection.
Wye-delta transformers.	The standard matrix settings compensate for all 30-degree transformer winding phase shifts.
Unit transformers, co-generation.	➤ Two separate V/Hz settings; one setting for a loaded transformer and one setting for an unloaded transformer. ➤ Use the built-in synchrophasors to synchronize the generator with the power system. ➤ Reverse power elements controls power flow.

Table 1.3 Application Highlights (Sheet 2 of 2)

Application	Key Feature
1 A CT secondary (HV REF) 5 A CT secondary (LV REF) or vice versa.	Provides a choice of 1 A or 5 A CT secondary currents among the phases of Winding Y, or vice versa.
Large CT ratio mismatch among windings.	The SEL-487E accepts a ratio mismatch of 25:1 among CTs; i.e., CT ratios of 2500/5 and 100/5.
Backup protection feeder overcurrent protection.	Numerous voltage polarized directional and non-directional phase, negative-sequence, and zero-sequence 50 and 51 elements.
Optimize circuit breaker maintenance.	Use the per-phase circuit breaker monitoring to calculate the circuit breaker contact wear.
Balance transformer insulation life ageing with temporary overloading.	Calculate the accelerated ageing factor of the insulation with the IEEE Standard C57.91:1995 transformer thermal model.
Collect through-fault data, and the calculated damage on the transformer windings.	Based on IEEE C57.109-1993, the through-fault monitor calculates mechanical and electrical damage to the transformer resulting from through faults.

Specifications

General

AC Current Inputs (Secondary Circuits)

Note: Current transformers are Measurement Category II.

Continuous Thermal Rating	
5 A nominal:	15 A
1 A nominal:	3A
Saturation Current (Linear) Rating	
5 A nominal:	100 A
1 A nominal:	20 A
One-Second Thermal Rating	
5 A nominal:	500 A
1 A nominal:	100 A
One-Cycle Thermal Rating	
5 A nominal:	1250 A-peak
1 A nominal:	250 A-peak
Burden Rating	
5 A nominal:	≤0.5 VA at 5 A 2.51 VA at 15 A
1 A nominal:	≤0.1 VA at 1 A 1.31 VA at 3 A
Minimum A/D Current Limit (peak)	
5 A nominal:	247.5 A
1 A nominal:	49.5 A
Sampling Rate:	Analog input signals shall be sampled at a rate of 8 kHz.
Rated Voltage (U_e):	240 Vac
Rated Insulation Voltage (U_i):	300 Vac
Sampling Rate Analog inputs:	8 kHz
Rotation:	ABC, ACB

AC Voltage Inputs

300 $V_{L\text{-}N}$ continuous (connect any voltage up to 300 Vac)

600 Vac for 10 seconds

Burden:	<0.5 VA @ 67 V
Sampling Rate Analog inputs:	8 kHz
Rotation:	ABC ACB
Nominal Frequency Rating:	50 ±5 Hz 60 ±5 Hz
Frequency Tracking (requires PTs):	Tracks between 40.0–65.0 Hz Below 40 Hz = 40 Hz Above 65.0 Hz = 65 Hz
Maximum Slew Rate:	15 Hz/s

Power Supply

125/250 Vdc or 120/230 Vac

DC Range:	85–300 Vdc
DC Burden:	<35 W
AC Range:	85–264 Vac
AC Burden:	<180 VA @ pf = 0.2
Nominal Frequency:	50/60 Hz
Range:	30–120 Hz
Burden:	<35 W
Interruption:	250 ms @ 250 Vdc per IEC 60255-11

48/125 Vdc or 120 Vac

DC Range:	38–140 Vdc
DC Burden:	<35W
AC Range:	85–140 Vac
AC Burden:	<170 VA @ pf = 0.2
Nominal Frequency:	50/60 Hz
Range:	30–120 Hz
Interruption:	160 ms @ 125 Vdc per IEC 60255-11
Vdc Ripple:	5% per IEC 60255-11

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20° and above +70°C.

Control Outputs

Rated Insulation Voltage (U_i):	300 Vac 470 Vdc (300 Vdc for UL)
Dielectric Test Voltage:	2500 Vac
Rated Impulse Voltage (U_{imp}):	5000 V
Continuous Carry:	6 A at 70°C 4 A at 85°C
Make:	30 A @ 250 Vdc per IEEE C37.90
Thermal:	50 A for 1 s
Contact Protection:	360 Vdc, 40 J MOV protection across open contacts

Operating Time (coil energization to contact closure, resistive load)

Pickup time (resistive load):	≤6 ms maximum
Dropout time (resistive load):	≤6 ms maximum

Break Capacity (10000 operations) per IEC 60255-0-20:1974:

24 Vdc	0.75 A	L/R = 40 ms
48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 40 ms

Cyclic Capacity (2.5 cycles/second) per IEC 60255-0-20:1974:

24 Vdc	0.75 A	L/R = 40 ms
48 Vdc	0.50 A	L/R = 40 ms
125 Vdc	0.30 A	L/R = 40 ms
250 Vdc	0.20 A	L/R = 40 ms

Mechanical Durability:	10,000 no-load operations
Minimum Current Rating:	10 mA
Update Rate:	1/8 cycle

High-Current Contact Output Ratings

Rated Insulation Voltage (U_i):	300 Vac 470 Vdc (300 Vdc for UL)
Rated Carry:	6 Amps continuous carry at 70°C 4 Amps continuous carry at 85°C

Note: dc control signals only.

Rated Make:	30 A @ 250 Vdc per IEEE C37.90
One Second Thermal Rating:	50 A
Contact Protection:	330 Vdc, 40J, MOV protection across open contacts

Operating Time (coil energization to contact closure, resistive load)

Pickup time (resistive load):	≤6 ms maximum
Dropout time (resistive load):	≤8 ms maximum

Inductive Breaking Capacity (10,000 operations):

24 Vdc	10 A	L/R = 40 ms
48 Vdc	10 A	L/R = 40 ms
125 Vdc	10 A	L/R = 40 ms
250 Vdc	10 A	L/R = 20 ms

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

24 Vdc	10 A	L/R = 40 ms
48 Vdc	10 A	L/R = 40 ms
125 Vdc	10 A	L/R = 40 ms
250 Vdc	10 A	L/R = 20 ms

Mechanical Durability: 10,000 no-load operations

High-Speed, High-Current Interrupting Contact Output Ratings

Rated Insulation Voltage (U_i):	300 Vac 470 Vdc (300 Vdc for UL)
Rated Carry:	6 Amps continuous carry at 70°C 4 Amps continuous carry at 85°C
Rated Make:	30 A @ 250 Vdc per IEEE C37.90
One Second Thermal Rating:	50 A

Operating Time (coil energization to contact closure, resistive load)

Pickup time (resistive load):	≤10 µs maximum
Dropout time (resistive load):	≤8 ms maximum

Inductive Breaking Capacity (10,000 operations):

24 Vdc	10 A	L/R = 40 ms
48 Vdc	10 A	L/R = 40 ms
125 Vdc	10 A	L/R = 40 ms
250 Vdc	10 A	L/R = 20 ms

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

24 Vdc	10 A	L/R = 40 ms
48 Vdc	10 A	L/R = 40 ms
125 Vdc	10 A	L/R = 40 ms
250 Vdc	10 A	L/R = 20 ms

Update Rate: 1/8 cycle

Optoisolated Digital Inputs

General

Sampling Rate:	2 kHz
Rated Insulation Voltage (U_i):	300 Vac
Dielectric Test Voltage:	2500 Vac or 3100 Vdc
Rated Impulse Voltage (U_{imp}):	5000 V
Main Board:	5 independent, 2 common, level-sensitive optoisolated
INT2:	8 independent, level-sensitive optoisolated
INT4:	18 common, 6 independent, level-sensitive optoisolated
INT7:	8 independent, level-sensitive optoisolated
INT8:	8 independent, level-sensitive optoisolated

DC Digital Input Ratings

Voltage Options: 48, 110, 125, 220, 250 V standard

DC Thresholds

48 Vdc:	Pickup 38.4–60.0 Vdc; Dropout below 28.8 Vdc
110 Vdc:	Pickup 88.0–132.0 Vdc; Dropout below 66.0 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout below 75 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout below132 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout below 150 Vdc

Current Drawn: 5 mA at nominal voltage
8 mA for 110 V option

AC Digital Input Ratings

Rated Frequency: 50±5 Hz, 60±5 Hz

48 Vdc:	Pickup 32.8–60.0 Vac; Dropout below 20.3 Vac
110 Vdc:	Pickup 75.1–132.0 Vac; Dropout below 46.6 Vac
125 Vdc:	Pickup 89.6–150.0 Vac; Dropout below 53.0 Vac
220 Vdc:	Pickup 150.3–264.0 Vac; Dropout below 93.2 Vac
250 Vdc:	Pickup 170.6–300.0 Vac; Dropout below 106.0 Vac

Current Drawn: 5 mA at nominal voltage
8 mA for 110 V option

Frequency and Rotation

System frequency:	50/60 Hz
Phase rotation:	ABC or ACB

Communications Ports

EIA-232:	1 Front and 3 Rear
Serial Data Speed:	300–57600 bps

Communications Card Slot for Optional Ethernet card

Ordering Options (Fiber Optic)

Mode:	Multi	Single
Wavelength (nm):	820	1300
Source:	LED	LED
Connector type:	ST	ST
Sys. Gain (dB):	5	13

Min. TX Pwr. (dBm): –15.8 to +19

Max. TX Pwr. (dBm): 12–14

RX Sens. (dBm): –34.4 to +32

Sys. Gain (dB): 5 13

Class 1 LED Product Safety (optional Ethernet card): IEC 60825-1:1993 + A1:1997 + A2:2001,
IEC 60825-1:1993
ANSI Z136.1-1993, Class 1,
ANSI Z136.2-1988, Service Group 1

IRIG Time Input

Demodulated IRIG-B time code

Nominal Voltage: 5 Vdc ± 10%

Maximum Voltage: 8 Vdc

Input Impedance: 332 ohms ± 10%

Isolation: 1.5 kV_{RMS} for 1 minute

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum: 1.0 Nm (9 in-lb)

Maximum: 2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Sizes

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. You can use the following table as a guide in selecting wire sizes:

Connection Type	Minimum Wire Size	Maximum Wire Size
Grounding (Earthing) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Current Connection	16 AWG (1.5 mm^2)	12 AWG (4 mm^2)
Potential (Voltage) Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Other Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)

Type Tests

Electromagnetic Compatibility (EMC)

Electromagnetic Emissions: EN 50263:1999
IEC 60255-25:2000

Electromagnetic Compatibility Immunity

Conducted RF Immunity: IEC 61000-4-6:1996, 10 V rms
IEC 60255-22-6:2001, 10 V rms

Digital Radio Telephone RF: ENV 50204:1995, 10 V/m at 900 MHz and 1.89 GHz

Electrostatic Discharge: IEC 60255-22-2:1996, Levels 1, 2, 3, 4
IEC 61000-4-2:1995, Levels 1, 2, 3, 4
IEEE C37.90.3-2001,
Levels 2, 4, and 8 kV contact;
Levels 4, 8, and 15 kV air

Fast Transient Disturbance: IEC 61000-4-4:1995,
IEC 60255-22-4:2002, 4 kV at 2.5 and 5 kHz

Magnetic Field Immunity: IEC 61000-4-8:1993
1000 A/m for 3 s (50G set to 0.1)
410 A/m for 3 s (50G set to 0.05)
IEC 61000-4-9:1993
1000 A/m for 3 s (50G set to 0.1)
410 A/m for 3 s (50G set to 0.05)

Power Supply Immunity: IEC 61000-4-11:1994, 5 cycles
IEC 60255-11:1979

Radiated Radio Frequency: IEC 60255-22-3:2002
IEC 61000-4-3:1998, 10 V/m
IEEE C37.90.2-1995, 35 V/m

Surge Immunity: IEC 60255-22-5:2002
IEC 61000-4-5:1995
1kV line-to-line,
2kV line-to-earth

Surge Withstand: IEC 60255-22-1:1988,
2.5 kV peak common mode
2.5 kV peak differential mode
IEEE C37.90.1-1989,
3.0 kV oscillatory
5.0 kV fast transient
IEEE C37.90.1-2002,
2.5 kV oscillatory
4 kV fast transient

Environmental

Cold: IEC 60068-2-1:1990
[EN 60068-2-1:1993]
Test Ad: 16 hours at –40°C

Dry Heat: IEC 60068-2-2:1974
[EN 60068-2-2:1993],
Test Bd: Dry heat, 16 hours at +85°C

Damp Heat, Cyclic: IEC 60068-2-30:1980,
Test Db: 55°C, 6 cycles, 95% humidity

Object Penetration: IEC 60529:1989, IP30

Vibration: IEC 60255-21-1:1988, Class 1
IEC 60255-21-2:1988, Class 1
IEC 60255-21-3:1993, Class 2

Safety

Dielectric Strength: IEC 60255-5:2000,
IEEE C37.90-1989,
2500 Vac on control inputs, control outputs, and analog inputs
3100 Vdc on power supply

Impulse: IEC 60255-5:2000, 0.5 J, 5 kV

Insulation Resistance: IEC 60255-5:2000,
Resistance @ 500 V >1 minute.
Resistance 10 MΩ–100 MΩ

Certifications

Emissions:	EN 50263:1999
ISO:	Relay is designed and manufactured using ISO 9001 certified quality program.
Product Safety:	IEC 60255-6:1988 [EN 60255-6:1994] IEC 61010 UL: 3111-1 CSA: IEC C22.2 No. 1010-1

Event Reports

High-Resolution Data

Rate:	8000 samples/second 4000 samples/second 2000 samples/second 1000 samples/second
Output Format:	Binary COMTRADE

Note: Per IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111-1999.

Event Reports

Length:	15/30 cycles
Maximum Duration:	2 seconds of back-to-back event reports and a total of 5 seconds.
Resolution:	1/4 and 1/8 samples/cycle
Digital Inputs:	2 kHz

Event Summary

Storage:	100 summaries

Breaker History

Storage:	128 histories

Sequential Events Recorder

Storage:	1000 entries
Trigger Elements:	250 relay elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency at 646 Hz, ±5%
Digital Filtering
Full-cycle cosine after low-pass analog filtering

Protection and Control Processing

4, 8, and 32 times per power system cycle

Control Points

32 remote bits
32 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

Relay Element Pickup Ranges and Accuracies

Differential Elements (General)

Number of Zones:	1 (A, B, and C elements)
Number of Windings:	5
TAP Pickup:	(0.1–32.0) • I_{NOM} A secondary
TAP Range:	$TAP_{MAX}/TAP_{MIN} \le 35$
Time-Delay Accuracy:	±0.1% plus ±0.125 cycle

Differential Elements (Restraint)

Pickup Range:	0.1–4.0 per unit
Pickup Accuracy:	1 A nominal: ±5% ±0.02 A 5 A nominal: ±5% ±0.10 A
Pickup Time:	1.25 minimum cycle 1.38 typical cycle 1.5 maximum cycle
Slope 1	
Setting range:	5–100%
Accuracy:	±5% ±0.02 • I_{NOM}
Slope 2	
Setting Range:	5–100%
Accuracy:	±5% ±0.02 • I_{NOM}

Differential Elements (Unrestraint)

Pickup Range:	(1.0–20.0) • TAP
Pickup Accuracy:	±5% of user setting, ±0.02 • I_{NOM} A
Pickup Time:	0.7 minimum cycle 0.85 typical cycle 1.2 maximum cycle

Harmonic Elements (2nd, 4th , 5th)

Pickup Range:	OFF, 5–100% of fundamental
Pickup Accuracy:	1 A nominal ±5% ±0.02 A 5 A nominal ±5% ±0.10 A
Time-Delay Accuracy:	±0.1% plus ±0.125 cycle

Negative-Sequence Differential Element

Pickup Range:	0.05–1 per unit
Slope Range:	5–100%
Pickup Accuracy:	±5% of user setting, ±0.02 • I_{NOM} A
Maximum Pickup/ Dropout Time:	4 cycles
Winding Coverage:	2%

Incremental Restraint and Operating Threshold Current Supervision

Setting Range:	0.1–10.0 per unit
Accuracy:	±5% ±0.02 • I_{NOM}

Open-Phase Detection Logic

3 elements per winding (S, T, U, W, X)

Pickup Range	
1 A nominal:	0.05–1.00 A
5 A nominal:	0.25–5.00 A
Maximum Pickup/ Dropout Time:	0.625 cycle

Restricted Earth Fault (REF)

Elements

Three independent elements:	REF1, REF2, REF3

REF1F, REF1R (Element 1, forward and reverse)
REF2F, REF2R (Element 2, forward and reverse)
REF3F, REF3R (Element 3, forward and reverse)

Operating Quantity

Select:	IY1, IY2, IY3

Restraint Quantity

Select:	3I0S, 3I0T, 3I0U, 3I0W and 3I0X
Pickup Range:	0.05–5 per unit 0.02–0.05 positive-sequence ratio factor (I0/I1)
Pickup Accuracy	
1 A nominal:	0.01 A
5 A nominal:	0.05 A
Maximum Pickup/ Dropout Time:	1.75 cycles

Instantaneous/Definite-Time Overcurrent Elements (50)

Phase- and Negative-Sequence, Ground-Residual Elements

Pickup Range	
5 A nominal:	0.25–100.00 A secondary, 0.01 A steps
1 A nominal:	0.05–20.00 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A nominal:	±0.05 A plus ±3% of setting
1 A nominal:	±0.01 A plus ±3% of setting
Transient Overreach (phase and ground residual)	
5 A nominal:	±5% of setting, ±0.10 A
1 A nominal:	±5% of setting, ±0.02 A
Transient Overreach (negative sequence)	
5 A nominal:	±6% of setting, ±0.10 A
1 A nominal:	±6% of setting, ±0.02 A
Time-Delay Range:	0.00–16000.00 cycles, 0.125 cycle steps
Timer Accuracy:	±0.25 cycle plus ±0.1% of setting
Maximum Pickup/ Dropout Time:	1.5 cycles

Adaptive Time-Overcurrent Elements (51)

Pickup Range (Adaptive within the range)	
5 A nominal:	0.25–16.00 A secondary, 0.01 A steps
1 A nominal:	0.05–3.20 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A nominal:	±0.05 A plus ±3% of setting
1 A nominal:	±0.01 A plus ±3% of setting
Transient Overreach	
5 A nominal:	±5% of setting, ±0.10 A
1 A nominal:	±5% of setting, ±0.10 A
Time Dial Range (Adaptive within the range)	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles plus ±4% of curve time (for current between 2 and 30 multiples of pickup.

Curves operate on definite time for current greater than 30 multiples of pickup

Reset:	1 power cycle or Electromechanical Reset Emulation time

Combined Time-Overcurrent Elements (51)

Pickup Range	
5 A nominal:	0.25–16.00 A secondary, 0.01 A steps
1 A nominal:	0.05–3.20 A secondary, 0.01 A steps
Accuracy (Steady State)	
5 A nominal:	±0.05 A plus ±3% of setting
1 A nominal:	±0.01 A plus ±3% of setting
Transient Overreach	
5 A nominal:	±5% of setting, ±0.10 A
1 A nominal:	±5% of setting, ±0.20 A
Time Dial Range	
U.S.:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps

Curve Timing Accuracy: ±1.50 cycles plus ±4% of curve time (for current between 2 and 30 multiples of pickup)

Curves operate on definite time for current greater than 30 multiples of pickup

Reset:	1 power cycle or electromechanical reset emulation time

Phase Directional Elements (67)

Number:	5 (1 each for S, T, U, W, X)
Polarization:	Positive-sequence memory voltage Negative-sequence voltage
Time-Delay Range:	0.000–16,000 cycles, 0.125 cycle increment
Time-Delay Accuracy:	±0.1% of setting ±0.25 cycle

Phase-to-Phase Directional Elements

Number:	5 (1 each for S, T, U, W, X)
Polarization Quantity:	Negative-sequence voltage
Operate Quantity:	Negative-sequence current ($3I_2$)
Sensitivity:	0.05 • I_{NOM} A of secondary $3I_2$
Accuracy:	±0.05 Ω secondary
Transient Overreach:	+5% of set reach
Max. Delay:	1.75 cycles
Time-Delay Range:	0.000–16,000 cycles, 0.125 cycle increment
Time-Delay Accuracy:	±0.1% of setting ±0.25 cycle

Ground Directional Elements

Number:	5 (1 each for S, T, U, W, X)

Zero-Sequence Ground Directional Elements

Outputs:	Forward and Reverse
Polarization Quantity:	Zero-sequence voltage
Operate Quantity:	Zero-sequence current 3I0, where 3I0 = IA + IB + IC
Sensitivity:	0.05 • I_{NOM} of secondary 3I0
Accuracy:	±0.05 Ω secondary
Transient Overreach:	+5% of set reach
Max. Delay:	1.75 cycles

Phase Under- and Overvoltage Elements—Wye-Connected PTs

Based on maximum of the VA, VB, and VC phase voltages.

Setting range:	2.00–300 VLN in 0.1 steps
Accuracy:	±3% of setting, ±0.5 V
Transient overreach:	±5% of pickup
Maximum delay:	1.5 cycles

Sequence Undervoltage/Overvoltage Wye-Connected PTs

Pickup Range:	2.00–300 V_{LN} in 0.1 steps
Pickup Accuracy, Steady State:	±5% of setting 1 V
Pickup Accuracy, Transient Overreach:	±5%
Maximum Pickup/ Dropout Time:	1.5 cycles

Phase-Phase Undervoltage/Overvoltage Delta-Connected PTs

Pickup Range:	4–520 V
Pickup Accuracy:	±2% of setting, ±1 V
Pickup Accuracy, Transient Overreach:	±5%
Maximum Pickup/ Dropout Time:	1.5 cycles

Positive-Sequence Undervoltage/Overvoltage Delta-Connected PTs

Pickup Range:	2–520 V
Pickup Accuracy:	±5% of setting, ±2 V
Pickup Accuracy, Transient Overreach:	±5%

Negative-Sequence Undervoltage/Overvoltage Delta-Connected PTs

Pickup Range:	2–520 V
Pickup Accuracy:	±5% of setting, ±2 V
Pickup Accuracy, Transient Overreach:	±5%

Under- and Overfrequency Elements

Pickup Range:	40.00–70.00 Hz, 0.01 Hz steps
Accuracy, Steady State plus Transient:	±0.005 Hz for frequencies between 40.00 and 70.00 Hz
Maximum Pickup/ Dropout Time:	3.0 cycles
Time Delay Range:	0.04–300.00 s, 0.001 s increment
Time Delay Accuracy:	±0.1% ±0.0042 s
Pickup Range, Undervoltage Blocking:	25.00–300.00 V_{LN} (Wye) or V_{LL} (Open-Delta)
Pickup Accuracy, Undervoltage Blocking:	±2% ±2 V

Volts/Hertz Elements (24)

Definite-Time Element

Pickup Range:	100–200% Steady-State
Pickup Accuracy, Steady-State:	±1% of setpoint
Maximum Pickup/ Dropout Time:	1.5 cycles
Time-Delay Range:	0.0–400.00 s
Time-Delay Accuracy:	±0.1% ±4.2 ms @ 60 Hz
Reset Time-Delay Range:	0.00–400.00 s

User-Definable Curve Element

Pickup Range:	100–200%
Pickup Accuracy:	±1% of setpoint
Reset Time-Delay Range:	0.00–400.00 s

Breaker Failure Instantaneous Overcurrent

Setting Range	
5 A nominal:	0.50–50 A, 0.01 A steps
1 A nominal:	0.10–10.0 A, 0.01 A steps
Accuracy	
5 A nominal:	±0.05 A, ±3% of setting
1 A nominal:	±0.01 A, ±3% of setting
Transient Overreach	
5 A nominal:	±5%, ±0.10 A
1 A nominal:	±5%, ±0.02 A
Maximum Pickup Time:	1.5 cycles
Maximum Dropout Time:	less than 1 cycle
Maximum Reset Time:	less than 1 cycle
Timers	
Setting range:	0–6000 cycles, 0.125 cycle steps
Time-delay accuracy:	±0.1% of setting ±0.125 cycle

Directional Overpower/Underpower Element

Operating Quantities:	OFF, 3P*m*F, 3Q*m*F,3P*qp*F, 3Q*qp*F (*m* = S, T, U, W, X, *qp* = ST, TU, UW, WX)
Pickup Range:	–20000.00 VA (secondary) to 20000.00 VA (secondary, 0.01 steps
Pickup Accuracy:	±3% of setting and ±5 VA, power factor > ±0.5 at nominal frequency
Time Delay Range:	0.000 - 16,000 cycles, 0.25 cycle increment
Time Delay Accuracy:	±0.1% of setting ±0.25 cycle

Bay Control

Breakers:	5 (maximum)
Disconnects (Isolators):	8 (maximum)
Timers	
Setting range:	1–99999 cycles, 1 cycle steps
Time-delay accuracy:	±0.1% of setting ±0.25 cycle

Station DC Battery System Monitor Specifications

Operating Range:	0–350 Vdc (300 Vdc for UL)
Processing Rate:	1/8 cycle
Maximum Pickup/ Dropout Time:	1.5 seconds (element dc ripple) 1.5 cycles (all elements but dc ripple)
Setting Range	
DC settings:	OFF, 15–300 Vdc, 1 Vdc steps
AC ripple setting:	1–300 Vac, 1 Vac steps
Pickup Accuracy:	±10%, ±2 Vdc (dc ripple) ±3%, ±2 Vdc (all elements but dc ripple)

Metering Accuracy

All metering accuracies are based on an ambient temperature of 20°C and nominal frequency.

Absolute Phase-Angle Accuracy

IA, IB and IC per terminal:	±0.5° (both 1 and 5 A)
VA, VB, and VC per terminal :	±0.125°

Currents

Phase Current Magnitude

5 A Model:	5 A nominal ±0.2% plus ± 4 mA (0.5–100 A sec)
1 A Model:	1 A nominal ±0.2% plus ± 0.8 mA (0.1–20 A sec)

Sequence Current Magnitude

5 A Model:	±0.3% plus ± 4 mA (0.5–100 A sec)
1 A Model:	±0.3% plus ± 0.8 mA (0.1–20 A sec)

Sequence Current Angle

All Models:	±0.3°
Phase Current Angle	±0.5° in the current range (0.1–20) • I_{NOM}

Voltages

Phase and Phase-to-Phase Voltage Magnitude:	±2.5%, ±1 V (5–33.5) V ±0.1% (33.5–300) V
Phase and Phase-to-Phase Angle:	±1° (5–33.5) V ±0.5° (33.5–300) V
Sequence Voltage Magnitude (V1, V2, 3V0):	±2.5%, ±1 V (5–33.5) V ±0.1% (33.5–300) V
Sequence Voltage Angle (V1, V2, 3V0):	±1.0° (5–33.5) V ±0.5° (33.5–200) V

Power

MW (P), per phase (wye), 3ϕ (wye or delta) per terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

MVAr (Q), per phase (wye), 3ϕ (wye or delta) per terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (3ϕ)

MVA (S), per phase (wye), 3ϕ (wye or delta) per terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

PF, per phase (wye), 3ϕ (wye or delta) per terminal

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

Energy

MWh (P), per phase (wye), 3ϕ (wye or delta)

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3ϕ)

MVARh (Q), per phase (wye), 3ϕ (wye or delta)

±1% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (1ϕ)
±0.7% (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 0, 0.5 lead, lag (3ϕ)

Demand/Peak Demand Metering

Time Constants:	5, 10, 15, 30, and 60 minutes
IA, IB and IC per Terminal:	±0.2% ±0.008 • I_{NOM}, (0.1–1.2) • I_{NOM}
3I2 per Terminal 3I0 (IG) per Terminal (wye-connected only):	±0.3% ±0.008 • I_{NOM}, (0.1–1.2) • I_{NOM}

Optional RTD Elements (Models Compatible With SEL-2600 Series RTD Module)

12 RTD inputs via SEL-2600 Series RTD Module and SEL-2800 Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

PT 100, NI 100, NI 120, and CU 10 RTD-Types Supported, Field Selectable

Up to 500 m Fiber-Optic Cable to SEL-2600 Series RTD Module

Synchrophasor Metering

24 channels (6 voltage and 18 currents)

20 messages per second via SEL Fast Message protocol

Up to 60-messages/second via IEEE Standard C37.118 protocol.

Voltage Accuracy:	range 30–150 V ±1% Total Vector Error (TVE) as specified in C37.118 at f_{NOM} ±5 Hz
Current Accuracy (Current range 0.1–20 • I_{NOM}):	±1% TVE at f_{NOM} ±5 Hz
Voltage Magnitude Accuracy:	±0.1%
Voltage Angle Accuracy:	±0.125°

Breaker Monitoring

Running Total of Interrupted Current (kA) per Pole:	±5% ±0.02 • I_{NOM}
Percent kA Interrupted for Trip Operations:	±5%
Percent Breaker Wear per Pole:	±5%
Compressor/Motor Start and Run Time:	±1 s
Time Since Last Operation:	±1 day

Section 2
Installation

Overview

The first steps in applying the SEL-487E Relay are installing and connecting the relay. This section describes installation requirements for the physical configurations of the SEL-487E Relay.

To install and connect the relay safely and effectively, you must be familiar with relay configuration features and options and relay jumper configuration. You should carefully plan relay placement, cable connections, and relay communication. This section also contains drawings of typical ac and dc connections to the SEL-487E Relay (AC/DC Connection Diagrams). Use these drawings as a starting point for planning your particular relay application. Consider the following when installing the SEL-487E Relay:

- *Relay Sizes and Mounting on page 2.2*
  - *Rack Mount on page 2.2*
  - *Panel Mount on page 2.2*
  - *Dimensions and Cutout on page 2.3*
  - *Connector Types on page 2.3*
  - *Secondary Circuits on page 2.4*
- *Control Inputs on page 2.5*
- *Control Outputs on page 2.6*
- *Main Board I/O on page 2.9*
- *Communications Interfaces on page 2.13*
- *TIME Inputs on page 2.13*
- *Battery-Backed Clock on page 2.13*
- *Jumpers on page 2.14*
  - *Main Board Jumpers on page 2.14*
  - *Password and Circuit Breaker Jumpers on page 2.14*
  - *I/O Interface Board Jumpers on page 2.19*

Shared Configuration Attributes

Relay Sizes and Mounting

You can order the relay in rack-mount or panel-mount versions, in either 6U or 7U size. Both 6U and 7U versions are available in horizontal orientation only. Note that the 6U size is available with or without an additional I/O board. When you order the 6U size without an additional I/O board, the slot for the I/O board is present but empty, so that the size of the relay remains 6U. The 7U version has provision for two additional I/O boards.

When mounting the SEL-487E in a rack, use the reversible front flanges to either semiflush-mount or projection mount the relay.

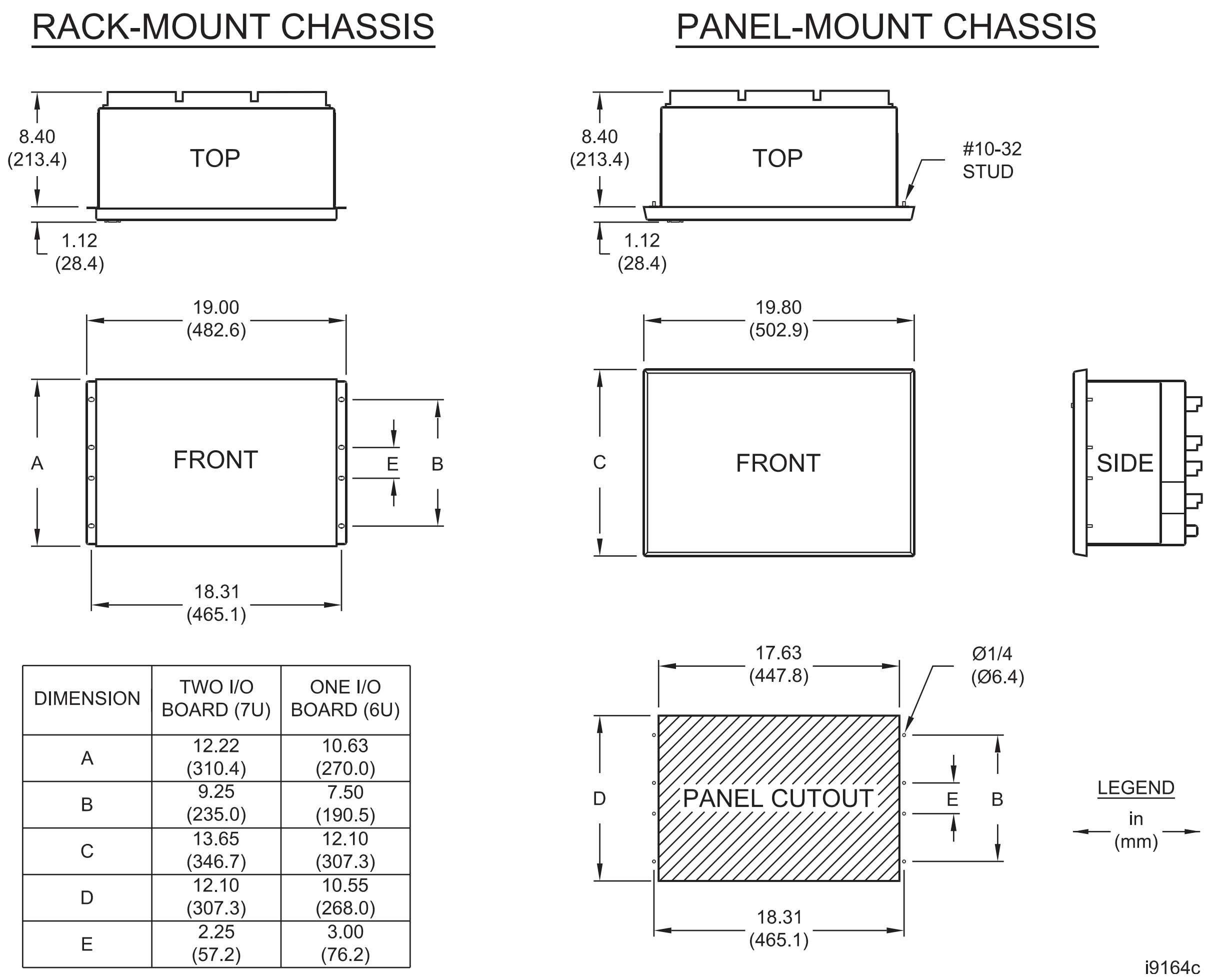
Rack Mount

Figure 2.1 shows the SEL-487E relay in a rack-mount version that bolts easily into a standard 19-inch rack. From the front of the relay, insert eight rack screws (four on each side) through the holes on the relay mounting flanges. Reverse the relay mounting flanges to cause the relay to project 2.75 inches (69.9 mm) from the front of your mounting rack and provide additional space at the rear of the relay for applications where the relay might otherwise be too deep to fit.

Panel Mount

Figure 2.1 also shows the SEL-487E Relay in a panel-mount version. Panel-mount relays have sculpted front-panel molding that covers all installation holes. Cut your panel and drill mounting holes according to the dimensions in *Figure 2.1*. Insert the relay into the cutout, aligning eight relay mounting studs on the rear of the relay front panel with the drilled holes in your panel, and use nuts to secure the relay to your panel. The projection panel-mount option covers all installation holes and maintains the sculpted look of the panel-mount option; the relay projects 2.75 inches (70 mm) from the front of your panel. This ordering option increases space at the rear of the relay for applications where the relay would ordinarily be too deep to fit your cabinet.

Dimensions and Cutout



DIMENSION	TWO I/O BOARD (7U)	ONE I/O BOARD (6U)
A	12.22 (310.4)	10.63 (270.0)
B	9.25 (235.0)	7.50 (190.5)
C	13.65 (346.7)	12.10 (307.3)
D	12.10 (307.3)	10.55 (268.0)
E	2.25 (57.2)	3.00 (76.2)

Figure 2.1 Relay Dimensions and Panel-Mount Cutout, 6U

Physical Location

You can mount the SEL-487E in a sheltered indoor environment (a building or an enclosed cabinet) that does not exceed the temperature and humidity ratings for the relay. The relay is IEC EN61010-1 rated at Installation/ Overvoltage Category II and Pollution Degree 2. This rating allows mounting the relay indoors or in an outdoor (extended) enclosure where the relay is protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity are controlled. You can place the relay in extreme temperature and humidity locations. The temperature range over which the relay operates is –40° to +185°F (–40° to +85°C, see *Operating Temperature on page 1.12*). The relay operates in a humidity range from 5 percent to 95 percent, no condensation. For EN61010 certification, the SEL-487E rating is 2000 m (6560 feet) above mean sea level.

Connector Types

Connectors for I/O, power, and battery monitor are of the screw terminal type, as well as the CT and PT connections.

When connecting the SEL-487E Relay, refer to your company plan for wire routing and wire management. Be sure to use wire that is appropriate for your installation with an insulation rating of at least 90°C.

DC Connectors—I/O and Monitor/Power

Connect to the relay I/O and Monitor/Power terminals on the rear panel through screw-terminal connectors. These terminals provide #8 screws for #8 ring terminals that support 22–8 AWG wire sizes. Terminate connections to the SEL-487E screw-terminal connectors with ring-type crimp lugs. Use a #8 ring lug with a maximum width of 0.360 in. (9 mm). The screws in the rear-panel screw-terminal connectors are #8-32 binding head, slotted, nickel-plated brass screws. Tightening torque for the terminal connector screws is 9 in-lb. to 18 in-lb. (1.0 Nm to 2.0 Nm).

CT and PT Connectors

The SEL-487E offers the conventional fixed-terminal block for both CT and PT connections. These terminals offer a secure high-reliability connection for PT and CT secondaries.

Connect PT and CT inputs to the fixed terminal blocks in the two bottom rows of the relay rear panel. These terminals provide #8 screws for #8 ring terminals that support 22–8 AWG wire sizes. You cannot remove fixed terminal blocks from the relay rear panel. *Figure 2.2* shows the 6U rear panel with fixed terminal block analog inputs. For clarity, the figure does not show a communications card installed in PORT 5.

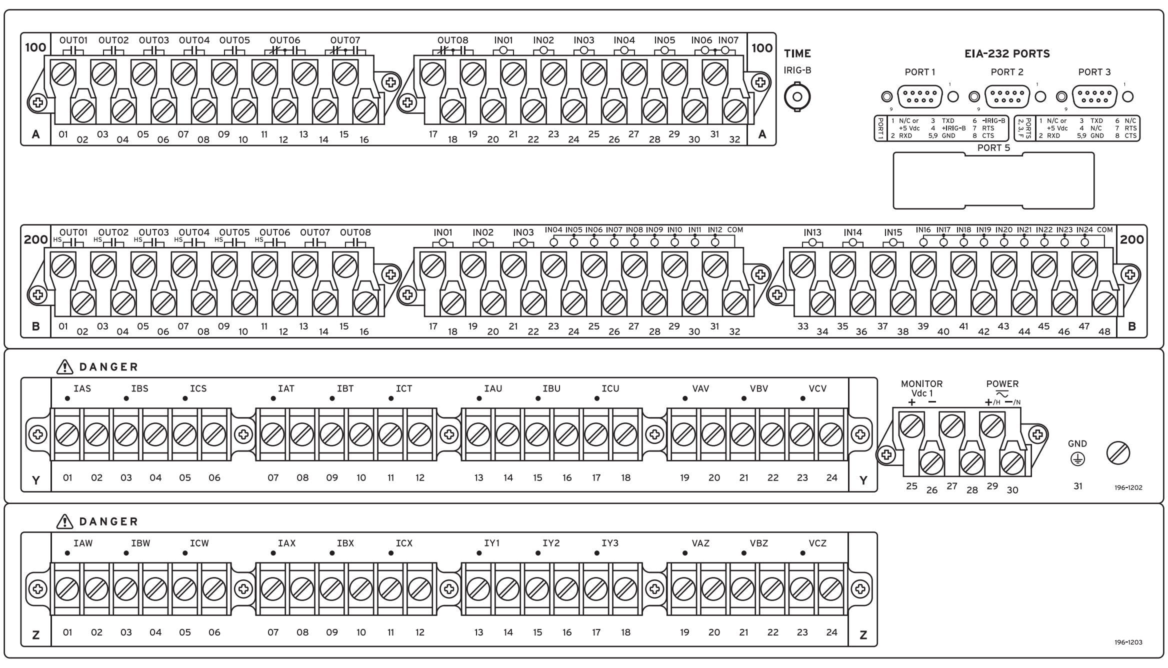


Figure 2.2 Rear Panel With Fixed Terminal Blocks (6U) With INT4 I/O Board

Secondary Circuits

The SEL-487E presents a low burden load on the CT secondaries and PT secondaries. For both the CT and PT inputs, the frequency range is 40–65 Hz. The relay accepts the following five sets of three-phase CT inputs:

- IAS, IBS, and ICS
- IAT, IBT, and ICT
- IAU, IBU, and ICU

- IAW, IBW, and ICW
- IAX, IBX, and ICX

The relay also accepts the following three single-phase CT inputs, primarily for restricted earth-fault protection:

IY1, IY2, and IY3

Input current range for both 5 A and 1 A nominal input current is 20 • I_{nom}. The CT burden for each rating is the following:

- 5 A CT: 0.27 VA @ 5 A and 2.51 VA @ 15 A
- 1 A CT: 0.13 VA @ 1 A and 1.31 VA @ 3A

The relay also accepts two sets of three-phase potentials from power system PT or CCVT (capacitor-coupled voltage transformer) secondaries:

- VAV, VBV, and VCV
- VAZ, VBZ, and VCZ

The nominal line-to-neutral input voltage for the PT inputs is 67 volts with a range of 0–300 volts, and a burden of less than 0.5 VA at 67 volts, L-N. PT connections can be four-wire (wye) or open delta connections.

Control Inputs

The SEL-487E Main Board inputs and the inputs on the optional I/O interface boards (INT2, INT4, INT7, or INT8 I/O boards) are fixed pickup threshold, optoisolated, control inputs. Specify the pickup voltage level for each board when you order the relay. Use these inputs for monitoring change-of-state conditions of power system equipment. Contacts marked with a plus (+) are polarity sensitive (see *Figure 2.4*). Those contacts not marked with a plus (+) high-isolation control inputs are ground-isolated circuits and are not polarity sensitive. In other words, the relay will detect input changes with voltage applied at either polarity. Inputs can be independent or common. Independent inputs have two separate ground-isolated connections, with no internal connections among inputs. Common inputs share one input leg in common; all input legs of common inputs are ground isolated. Each group of common inputs is isolated from all other groups.

Nominal current drawn by these inputs is 8 mA or less with 5 voltage options covering a wide range of voltages, as listed below *Interface Board (I/O) Options on page 1.7*. You can debounce the control input pickup delay and dropout delay separately for each input, or you can use a single debounce setting that applies to all the contact input pickup and dropout times—see *Global Settings on page 6.3*.

AC Control Signals

Optoisolated control inputs can be used with ac control signals, within the ratings shown in *Interface Board (I/O) Options on page 1.7*. *Table 2.1* shows the specific pickup and dropout time-delay settings necessary when applying ac to the inputs.

Table 2.1 Required Settings for Use With AC Control Signals[a]

Global Settings	Description	Entry[b]	Relay Recognition Time for AC Control Signal State Change
IN*nmm*PU[c]	Pickup Delay	0.5 cycles	0.5–30 ms (assertion)
IN*nmm*DO[c]	Dropout Delay	0.5 cycle	0.5–30 ms (deassertion)

[a] First set Global setting EICIS := Y to gain access to the individual input pickup and dropout timer settings.
[b] These are the only setting values that SEL recommends for detecting ac control signals. Other values may result in inconsistent operation.
[c] Where n is 1 for Main Board, 2 for Interface Board 1, and 3 for Interface Board 2; mm is number of available contact inputs depending on the type of board.

Furthermore, you can mix ac and dc control signals on the same interface board with optoisolated contact inputs, provided that the two signal types are not present on the same set of combined inputs. Use standard debounce time settings (usually the same value in both the pickup and dropout settings) for the inputs being used with dc control voltages.

The recognition times listed in *Table 2.1* are only valid when:

- ➤ The ac signal applied is at the same frequency as the power system.
- ➤ The signal is within the ac threshold pickup ranges defined in Optoisolated (use with ac or dc signals)
- ➤ The signal contains no dc offset.
- ➤ The SEL-487E samples the optoisolated inputs at 2kHz.

Control Outputs

I/O control outputs from the relay include Standard outputs, Hybrid (high current-interrupting) outputs, and Fast Hybrid (fast high-current-interrupting) outputs. Form A (normally open) and Form B (normally closed) output contacts are individually isolated, but Form C outputs share a common connection between the NC (normally closed) and NO (normally open) contacts. The relay updates control outputs eight times per cycle. Updating of relay control outputs does not occur when the relay is disabled. When the relay is reenabled, the control outputs assume the state that reflects the protection processing at that instant.

Standard Control Outputs

The Standard control outputs are “dry” Form A (NO) contacts rated for tripping duty. Ratings for Standard outputs are 30 A make, 6 A continuous, and 0.5 A or less break (depending on circuit voltage). Standard contact outputs have a maximum voltage rating of 250 Vac/330 Vdc. Maximum break time is 6 ms (milliseconds) with a resistive load. The maximum pickup time for the Standard control outputs is 6 ms. *Figure 2.3* shows a representative connection for a Form A Standard control output on the main board I/O terminals.

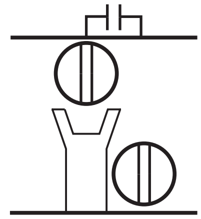


Figure 2.3 Standard Control Output Connection

See *Control Outputs on page 1.12* for complete standard control output specifications.

Hybrid (High-Current-Interrupting) Control Outputs

The Hybrid (high-current-interrupting) control outputs are polarity dependent and are capable of interrupting high-current, inductive loads. Hybrid control outputs use an IGBT (Insulated Gate Bipolar Junction Transistor) in parallel with a mechanical contact to interrupt (break) highly inductive dc currents.

The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients. With any hybrid output, break time varies according to the L/R (circuit inductive/resistive) ratio. As the L/R ratio increases, the time needed to interrupt the circuit fully increases also. The reason for this increased interruption delay is that circuit current continues to flow through the output MOV after the output deasserts, until all of the inductive energy dissipates. Maximum dropout (break) time is 6 ms with a resistive load, the same as for the Standard control outputs. The other ratings of these control outputs are similar to the Standard control outputs, except that the Hybrid outputs can break current as great as 10 A. Hybrid contact outputs have a maximum voltage rating of 330 Vdc. The maximum contact closing time for the Hybrid control outputs is 6 ms. *Figure 2.4* shows a representative connection for a Form A Hybrid control output on the main board I/O terminals.

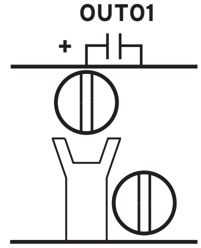


Figure 2.4 Hybrid Control Output Connection

Fast Hybrid (Fast High-Current-Interrupting) Control Outputs

In addition to the Standard control outputs and the Hybrid control outputs, the INT4 and INT8 I/O interface boards offer Fast Hybrid (fast high current-interrupting) control outputs. An MOV (metal-oxide varistor) protects against excess voltage transients for each contact. These control outputs have a resistive load contact closing time of 10 µs (microseconds), which is much faster than the 6 ms contact closing time of the Standard and Hybrid control outputs. The Fast Hybrid control outputs open at a maximum time of 8 ms. The maximum voltage rating is 250 Vac/330 Vdc. See *Control Outputs on page 1.12* for more information.

Fast Hybrid control output specifications. *Figure 2.5* shows a representative connection for a Form A Fast Hybrid control output on the INT4 I/O interface terminals. The HS marks are included to indicate that this is a high-speed control output.

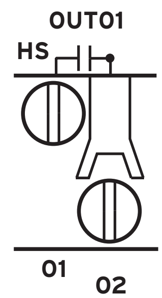


Figure 2.5 INT4 Fast Hybrid Control Output Connection (Three Terminals)

Figure 2.6 shows a representative connection for a Form A Fast Hybrid control output on the INT8 I/O interface terminals.

The INT8 Fast Hybrid control output uses three terminal positions, while the INT4 Fast Hybrid uses two. The third terminal of each INT8 Fast Hybrid control output is connected to precharge resistors that can be used to mitigate transient inrush current conditions, as explained below. A similar technique can be used with INT4 board Fast Hybrid control outputs using external resistors. Short transient inrush current can flow at the closing of an external switch in series with open Fast Hybrid contacts. This transient will not energize the circuits in typical relay-coil control applications (trip coils and close coils), and standard auxiliary relays will not pick up. However, an extremely sensitive digital input or light-duty, high-speed auxiliary relay can pick up for this condition. This false pick-up transient occurs when the capacitance of the Fast Hybrid output circuitry charges (creating a momentary short circuit that a fast, sensitive device sees as a contact closure). A third terminal (03 in *Figure 2.7*) provides an internal path for precharging the Fast Hybrid output circuit capacitance when the circuit is open.

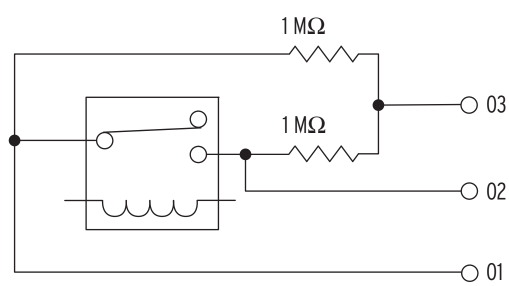


Figure 2.6 Fast Hybrid Control Output Typical Terminals, INT8

Figure 2.9 shows some possible connections for this third terminal that will eliminate the false pick-up transients when closing an external switch. In general, you must connect the third terminal to the dc rail (positive or negative) that is on the same side as the open external switch condition. If an open switch exists on either side of the output contact, then you can accommodate only one condition because two open switches (one on each side of the contact) defeat the precharge circuit.

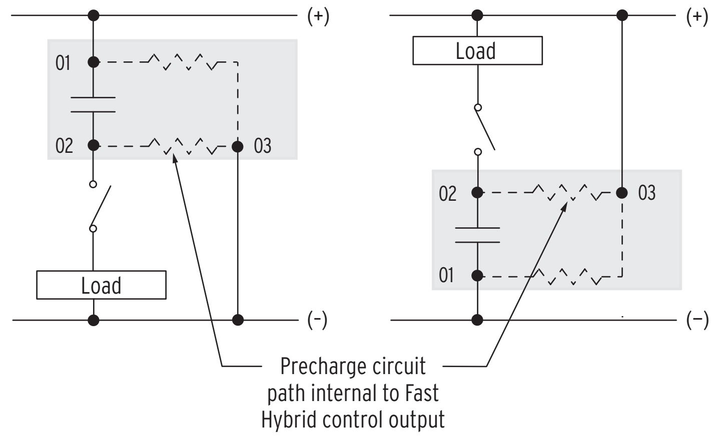


Figure 2.7 Precharging Internal Capacitance of Fast Hybrid Output Contacts, INT8

For wiring convenience, on the INT8 I/O Interface Board, the precharge resistors shown in *Figure 2.7* are built-in to the I/O board, and connected to a third terminal. On the INT4 I/O Interface Board, there are no built-in precharge resistors, and each Fast Hybrid control output has only two terminal connections.

Main Board I/O

Every SEL-487E configuration includes the main board I/O and features these connections:

- Two Standard Form A outputs
- Three Hybrid (high-current-interrupting) Form A outputs
- Three Standard Form C outputs
- Seven level-sensitive optoisolated control inputs (five independent and two with a common leg)

Interface Boards I/O

The SEL-487E relay is available in either 6U (option of one interface board) or 7U (option of two interface boards) An optional Ethernet plug-in communications card allows you to use TCP/IP, FTP, Telnet, DNP3 LAN/WAN, and IEC 61850 applications on an Ethernet network. This card is only available at the time of purchase of a new SEL-487E as a factory-installed option or as a factory-installed conversion to an existing relay.

In addition to the main board I/O, you can choose among four input/output interface boards (INT2, INT4, INT7, and INT8) for additional I/O. *Figure 2.8*, *Figure 2.9*, *Figure 2.10*, and *Figure 2.11* show the rear screw-terminal connectors of these interface boards.

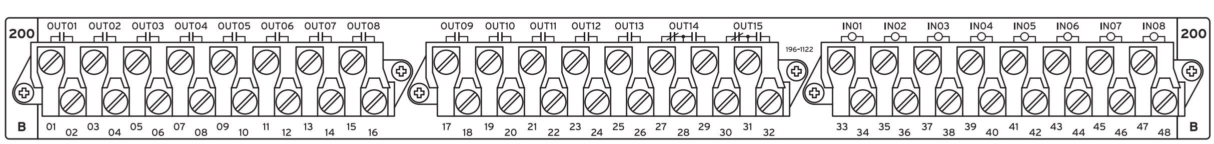


Figure 2.8 I/O Interface Board INT2

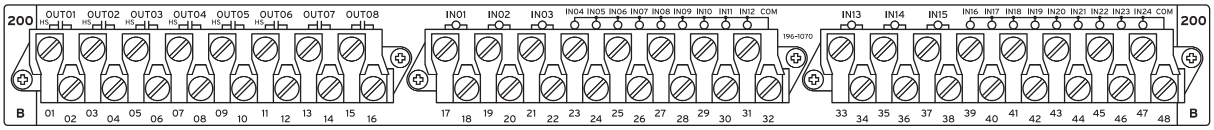


Figure 2.9 I/O Interface Board INT4

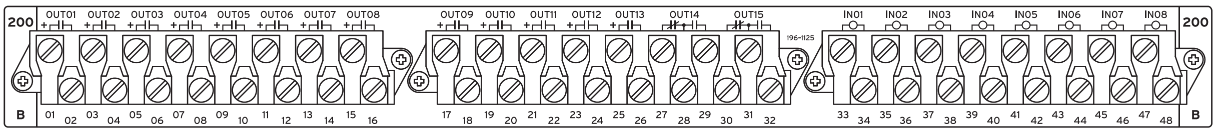


Figure 2.10 I/O Interface Board INT7

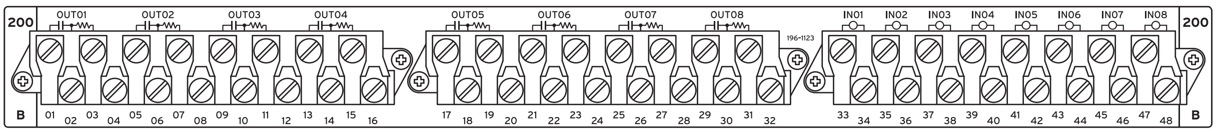


Figure 2.11 I/O Interface Board INT8

I/O Summary

I/O of the main board and interface boards vary by the type and amount of output capabilities. *Table 2.2* lists the inputs of the main board and additional I/O interface boards, and *Table 2.3* lists the outputs of the main board and additional I/O interface boards.

Table 2.2 I/O Control Inputs

Board Number	Independent Contact Pairs	Common Contacts
Main Board	5	2
INT2	8	
INT4	18	Two sets of 9
INT7	8	
INT8	8	

Table 2.3 Control Outputs

Board Number	Standard		Fast Hybrid[a]	Hybrid[b]
	Form A	Form C	Form A	Form A
Main Board	2	3		3
INT2	13	2		
INT4	2		6	
INT7		2		13
INT8			8	

[a] High-speed/high-current interrupting.
[b] High-current interrupting.

Installing Optional I/O Interface Boards

Perform the following steps to expand the capability of the SEL-487E with additional I/O interface boards:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-487E.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Loosen the eight front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 6. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 7. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 8. Confirm proper installation of address jumpers on the interface board (see *Jumpers*).

Step 9. Confirm drawout tray keying. The relay chassis and the drawout trays for the 200-addresses slot and the 300-addresses slot are keyed (see *Figure 2.12*).

The keys are two round plug-in/plug-out discs on the bottom of the drawout tray.

The 200-addresses slot keys go to the left, and the 300-addresses slot keys go to the right (when viewed from the top and front of the drawout tray).

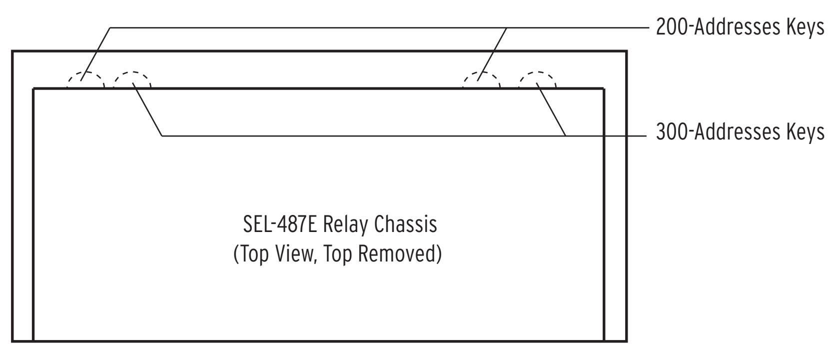


Figure 2.12 Chassis Key Positions for I/O Interface Boards

Step 10. Move a key on the bottom of the drawout tray to the correct position by prying the key from the tray and reinserting the key in the proper position.

Do this for both keys.

Step 11. Install the drawout tray with the I/O interface board, using the following precautions:

a. Position the drawout tray edges into the left-side and right-side internally mounted slots.

b. Slide the I/O interface board into the SEL-487E by pushing the front edge of the board drawout tray.

c. Apply firm pressure to fully seat the I/O interface board.

If you encounter resistance, stop, and withdraw the board.

Inspect the drawout tray edge guide slots for damage.

If you see no damage, take all of the precautions outlined above and try again to insert the board.

Step 12. If this is a new I/O interface board installation, remove the **INTERFACE BOARD EXPANSION SLOT** self-sticking label from the rear panel. Lift a corner of the label with a sharp tool and peel away the label from the rear panel.

Step 13. Confirm screw-terminal connector keying. SEL supplies three new screw-terminal connectors with new I/O interface boards.

a. Inspect the screw-terminal connector receptacles on the rear of the I/O interface board.

b. Refer to *Figure 2.18* for the corresponding key positions inside the receptacle.

c. If the keys inside the I/O interface board receptacles are not in the positions indicated in *Figure 2.18*, grasp the key edge with long-nosed pliers to remove the key and reinsert the key in the correct position.

d. Break the webs of the screw-terminal connectors in the position that matches the receptacle key (see *Figure 2.17*).

Step 14. Attach the screw-terminal connector.

a. Mount the screw-terminal connectors to the rear panel of the SEL-487E.

b. Tighten the screw-terminal connector mounting screws to between 7 in-lb. and 12 in-lb. (0.8 Nm to 1.4 Nm).

Step 15. Reinstall the SEL-487E main board, and reconnect the power, the interface board, and the analog input board cables.

Step 16. Reconnect the cable removed in *Step 6* and reinstall the relay front-panel cover.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 Ports** in the disassembly process.

Step 18. Apply power.

Step 19. Enter Access Level 2.

Step 20. Issue the **STA** command and answer **Y <Enter>** to accept the new hardware configuration.

Step 21. Inspect the relay targets to confirm that the relay reads the added I/O interface board(s). You can see the new control inputs in the target listings by using a terminal, the ACSELERATOR QuickSet® SEL-5030 Software program, or the front panel.

Step 22. Use a communications terminal to issue the commands **TAR IN201 <Enter>** (for the 200-addresses slot) or **TAR IN301 <Enter>** (for the 300-addresses slot). Alternatively, from the front-panel **MAIN** menu, select **RELAY ELEMENTS**, and press the **{DOWN ARROW}** pushbutton to go to ROW 196 (for the 200-addresses slot) or ROW 200 (for the 300-addresses slot).

Step 23. Follow your company standard procedure to return the relay to service.

Communications Interfaces

The SEL-487E has several communications interfaces you can use to communicate with other IEDs (intelligent electronic devices) via EIA-232 ports: **PORT 1**, **PORT 2**, **PORT 3**, and **PORT F**. See *Section 7: Communications, Interfaces, and Protocols* for more information and options for connecting your relay to the communications interfaces.

You can add an Ethernet card with IEC 61850 support to the SEL-487E by purchasing the Ethernet card option. The Ethernet card option is only available at purchase as a factory-installed option. Factory-installed in the rear relay **PORT 5**, the communications card gives the relay access to popular Ethernet networking standards including TCP/IP, FTP, Telnet, DNP3, and IEC 61850 over local area and wide area networks. For information on DNP3 applications, see *Appendix E: DNP3 Communications Protocol*. For more information on IEC 61850 applications, see *Appendix F: IEC 61850*.

TIME Inputs

The SEL-487E has a regular IRIG timekeeping mode, and a high-accuracy IRIG (HIRIG) timekeeping mode. The IRIG-B serial data format consists of a 1-second frame containing 100 pulses divided into fields, from which the relay decodes the second, minute, hour, and day fields and sets the internal time clock upon detecting valid time data in the IRIG time mode. There is one IRIG-B input on the SEL-487E rear panel, capable of supporting the HIRIG mode.

IRIG-B BNC Connector

This IRIG-B input is capable of both modes of timekeeping. If the connected timekeeping source is qualified as high-accuracy, the relay enters the HIRIG mode, which has a timing accuracy of 1 µs. If both inputs are connected, the SEL-487E will use the IRIG-B BNC connector signal if a signal is detected.

IRIG-B Pins of Serial Port 1

This IRIG-B input is capable of regular IRIG mode timekeeping only. Timing accuracy for the IRIG time mode is 500 µs.

Battery-Backed Clock

If relay input power is lost or removed, a lithium battery powers the relay clock, providing date and time backup. The battery is a 3 V lithium coin cell, Ray-O-Vac® No. BR2335 or equivalent. If power is lost or disconnected, the battery discharges to power the clock. At room temperature (25°C), the battery will operate for approximately 10 years at rated load. When the SEL-487E is operating with power from an external source, the self-discharge rate of the battery is very small. Thus, battery life can extend well beyond the nominal 10-year period because the battery rarely discharges after the relay is installed. The battery cannot be recharged. *Figure 2.19* shows the clock battery location (at the front of the main board). If the relay does not maintain the date and time after power loss, replace the battery (see *Replacing the Lithium Battery*).

Jumpers

The SEL-487E contains jumpers that configure the relay for specific operating modes. These jumpers are located on the main board (the top board) and the I/O interface boards (one or two boards located immediately below the main board).

Main Board Jumpers

The jumpers on the main board of the SEL-487E perform these functions:

- Temporary/emergency password disable
- Circuit breaker control enable
- Rear serial port +5 Vdc source enable

The main board jumpers are in two locations. The password disable jumper and circuit breaker control jumper are at the front of the main board. The serial port jumpers are near the rear-panel serial ports; each serial port jumper is directly in front of the serial port that it controls.

Password and Circuit Breaker Jumpers

You can access the password disable jumper and circuit breaker control jumper without removing the main board from the relay cabinet. Remove the SEL-487E front cover to view these jumpers (use appropriate ESD precautions). The password and circuit breaker jumpers (position number J21) are located on the front of the main board, immediately left of the power connector (see *Figure 2.13*). There are four jumpers denoted D, BREAKER, PASSWORD, and A from left to right (position D is on the left). Position PASSWORD is the password disable jumper; position BREAKER is the circuit breaker control enable jumper. Positions D and A are for SEL use. *Figure 2.13* shows the jumper header with the circuit breaker/control jumper in the ON position and the password jumper in the OFF position; these are the normal jumper positions for an in-service relay. *Table 2.4* lists the jumper positions and functions.

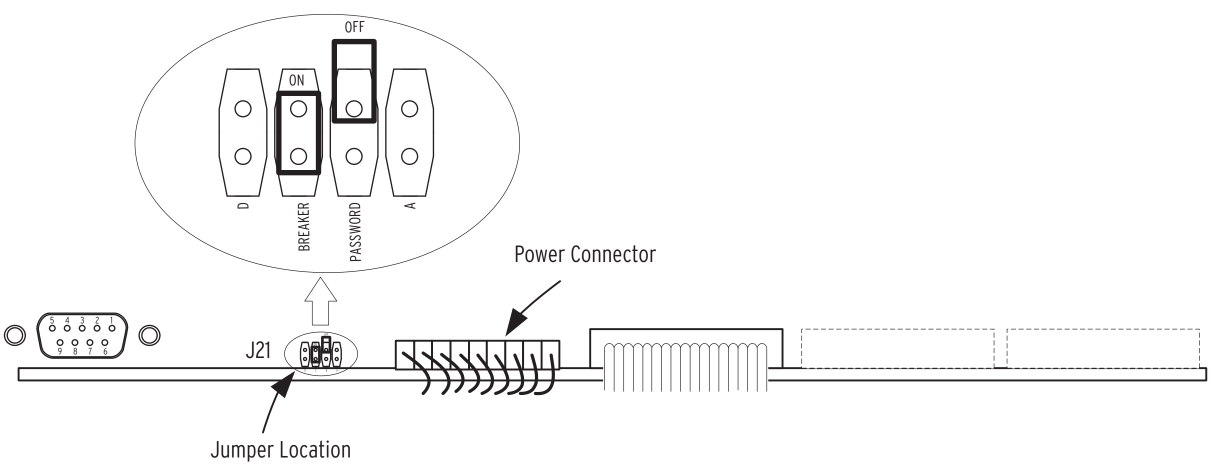


Figure 2.13 Jumper Location on the Main Board

Table 2.4 Main Board Jumpers[a]

Jumper	Jumper Location	Jumper Position	Function
A	Front	OFF	For SEL use only
PASSWORD	Front	OFF	Enable password protection (normal and shipped position)
		ON	Disable password protection (temporary or emergency only)
BREAKER	Front	OFF	Disable circuit breaker commands (**OPEN** and **CLOSE**) and output **PULSE** commands[b] (shipped position)
		ON	Enable circuit breaker commands (**OPEN** and **CLOSE**) and output **PULSE** commands[b]
D	Front	OFF	For SEL use only

[a] ON is the jumper shorting both pins of the jumper. Place the jumper over one pin only for OFF.
[b] Also affects the availability of the Fast Operate Breaker Control Messages and the front-panel LOCAL CONTROL > BREAKER CONTROL, and front-panel LOCAL CONTROL > OUTPUT TESTING screens.

The password disable jumper, PASSWORD, is for temporary or emergency suspension of the relay password protection mechanisms. Under no circumstance should you install PASSWORD on a long-term basis. The SEL-487E ships with password disable jumper PASSWORD OFF (passwords enabled). For temporary unprotected access to a particular access level, use the **PAS *n* DISABLE** command (**n** is the access level: **n = 1, B, P, A, O, 2**). For more information on this command and setting passwords, see *Password on page 8.8*.

The circuit breaker control enable jumper, BREAKER, supervises the **CLOSE *n*** command, the **OPEN *n*** command, the **PULSE OUT*nnn*** command, and front-panel local bit control. To use these functions, you must install Jumper BREAKER. The relay checks the status of the circuit breaker control jumper when you issue **CLOSE *n***, **OPEN *n***, **PULSE OUT*nnn***, and when you use the front panel to close or open circuit breakers, control a local bit, or pulse an output. The SEL-487E ships with circuit breaker Jumper BREAKER OFF. For commissioning and testing of the SEL-487E contact outputs, it may be convenient to set BREAKER ON, so that the **PULSE OUT*nnn*** commands can be used to check output wiring. BREAKER must also be set ON if SCADA control of the circuit breaker via Fast Operate is required, or if the LOCAL CONTROL > BREAKER CONTROL screens are going to be used.

IRIG Jumper

The IRIG-B jumper, JMP1, determines the terminating impedance of the IRIG-B connection, as shown in *Figure 2.14*. With jumper JMP1 inserted, JMP1 shorts across the 2500 Ω resistor so that the terminating impedance is 50 Ω. With jumper JMP1 not inserted, the terminating impedance is the sum of the two resistors, i.e., 2550 Ω.

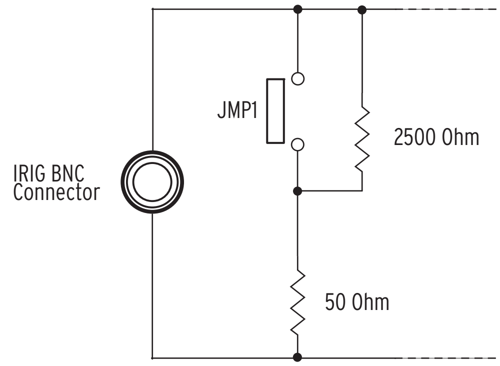


Figure 2.14 IRIG-B Terminating Resistors

Serial Port Jumpers

Place jumpers on the main board to connect +5 Vdc to Pin 1 of each of the three rear-panel EIA-232 serial ports. The maximum current (sum of all three ports) available from the Pin 1 source is 0.5 A. The Pin 1 source is useful for powering an external modem. *Table 2.5* describes the JMP2, JMP3, and JMP4 positions.

Table 2.5 Main Board Jumpers—JMP1, JMP2, and JMP3

Jumper	Jumper Location	Jumper Position	Function
JMP2	Rear	OFF	Serial PORT 3, Pin 1 = not connected
		ON	Serial PORT 3, Pin 1 = +5 Vdc
JMP3	Rear	OFF	Serial PORT 2, Pin 1 = not connected
		ON	Serial PORT 2, Pin 1 = +5 Vdc
JMP4	Rear	OFF	Serial PORT 1, Pin 1 = not connected
		ON	Serial PORT 1, Pin 1 = +5 Vdc

Refer to *Figure 2.15* for the locations of these jumpers.

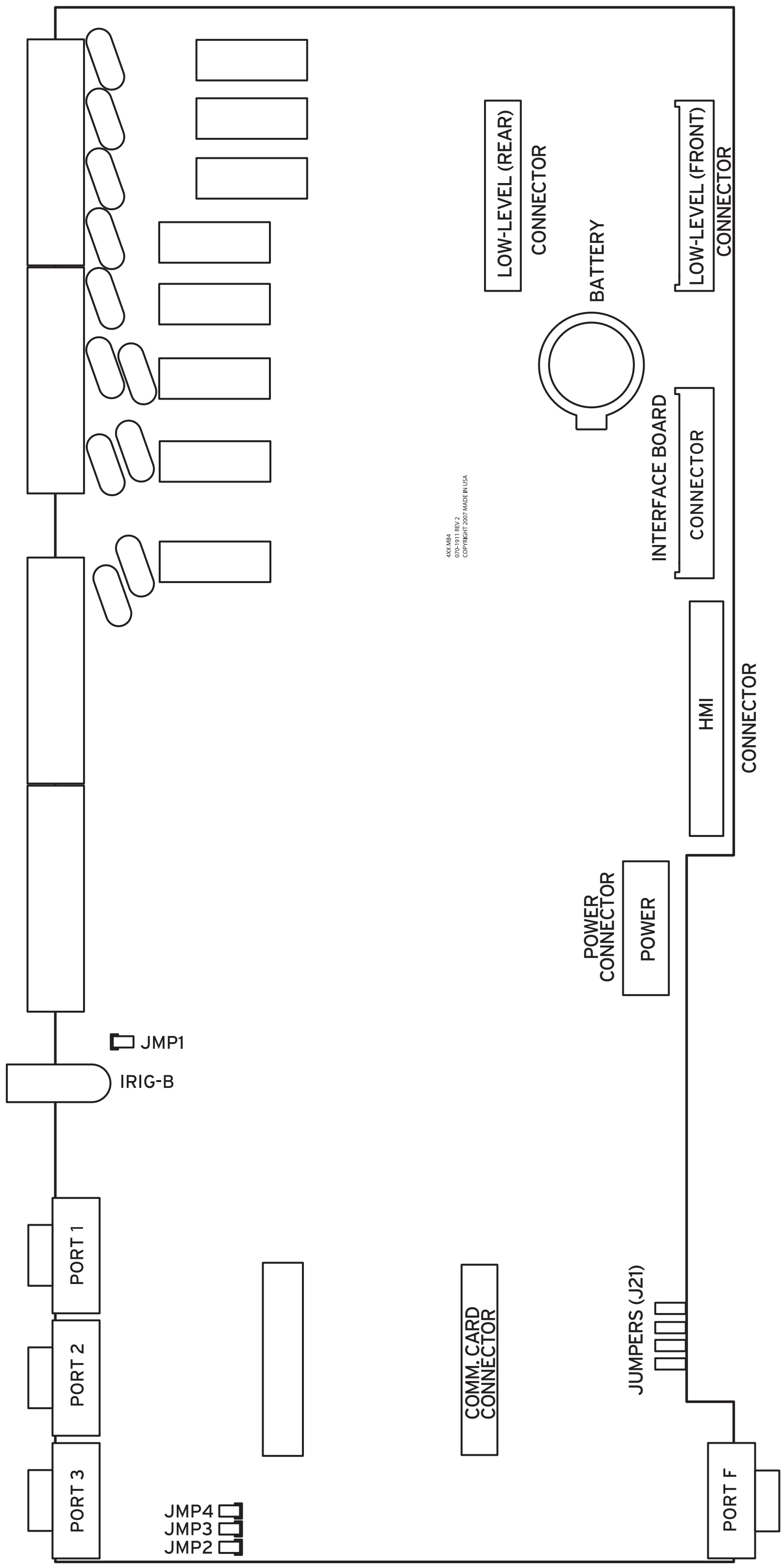


Figure 2.15 Major Component Locations on the SEL-487E Main Board

Changing Serial Port Jumpers

You must remove the main board to access the serial port jumpers. Perform the following steps to change the JMP1, JMP2, and JMP3 jumpers in an SEL-487E:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-487E.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Remove the rear-panel **EIA-232 PORTS** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles, as well as the BNC and Ethernet connectors.

Step 6. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 7. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 8. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 9. Remove the screw-terminal connectors.

a. Loosen the attachment screws at each end of the 100-addresses screw-terminal connectors.

b. Pull straight back to remove.

Step 10. Carefully pull out the drawout assembly containing the main board.

Step 11. Locate the jumper you want to change.

Jumpers JMP2, JMP3, and JMP4 are located at the rear of the main board, directly in front of **PORT 3**, **PORT 2**, and **PORT 1**, respectively (see *Figure 2.15*).

Step 12. Install or remove the jumper as needed (see *Table 2.5* for jumper position descriptions).

Step 13. Reinstall the SEL-487E main board, and reconnect the power, the interface board, and the analog input board cables.

Step 14. Reconnect the cable removed in *Step 7* and reinstall the relay front-panel cover.

Step 15. Reattach the rear-panel connections.

Step 16. Affix the screw-terminal connectors to the appropriate 100-addresses locations on the rear panel.

Step 17. Reconnect any serial cables, BNC, and Ethernet that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 18. Follow your company standard procedure to return the relay to service.

I/O Interface Board Jumpers

Jumpers on the I/O interface boards identify the particular I/O board configuration and I/O board control address. Four I/O interface boards are available:INT2, INT4, INT7, and INT8. The jumpers on these I/O interface boards are at the front of each board, as shown in *Figure 2.16*.

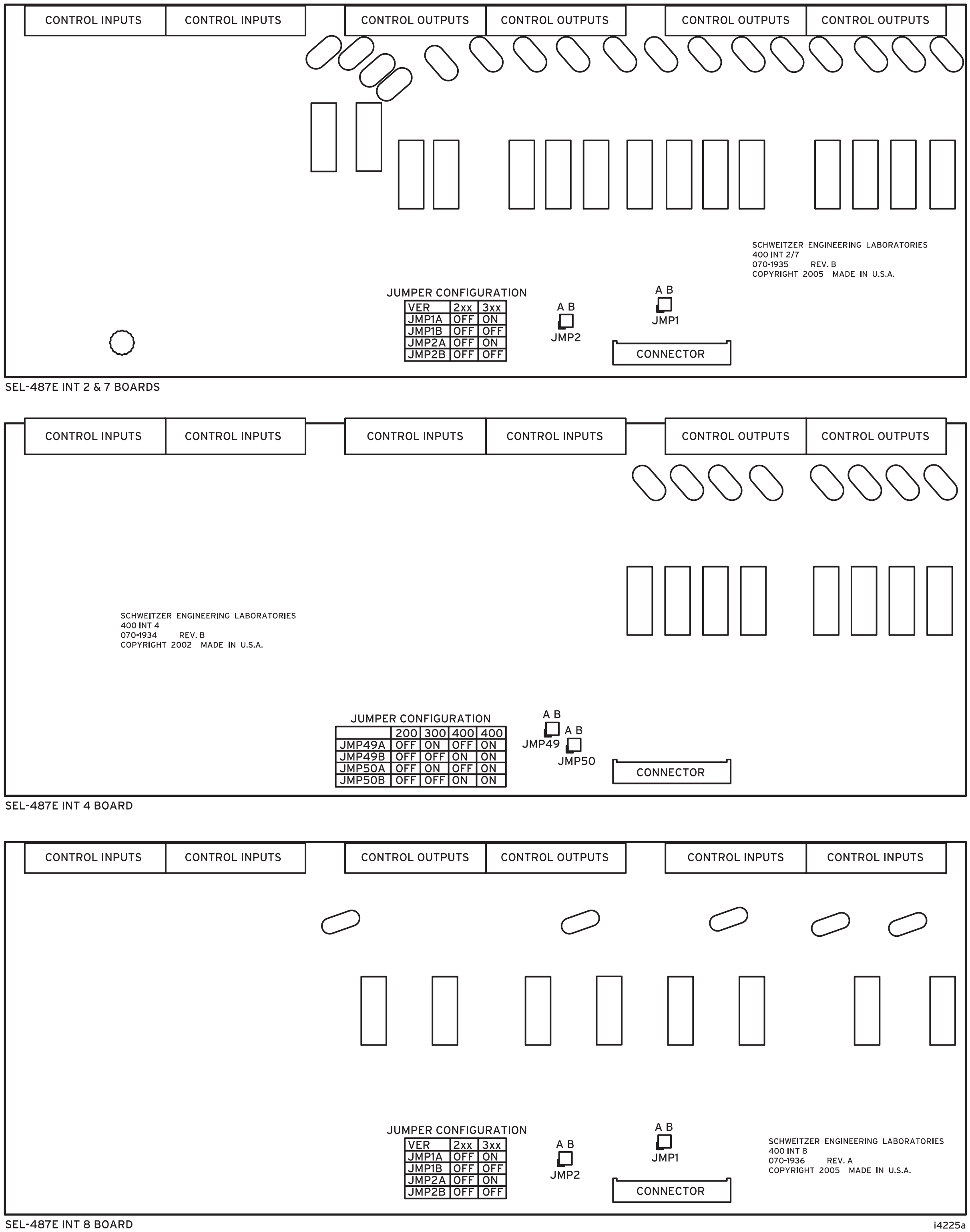


Figure 2.16 Top to Bottom: INT2 and INT7, INT4, and INT8 With Jumper Locations Indicated

To confirm the positions of your I/O board jumpers, remove the front panel and visually inspect the jumper placements. *Table 2.6* lists the four jumper positions for I/O interface boards. Refer to *Figure 2.16* for the locations of these jumpers.

The I/O board control address has a hundreds-series prefix attached to the control inputs and control outputs for that particular I/O board chassis slot. A 6U chassis has a 200-addresses slot for inputs IN201, IN202, etc., and outputs OUT201, OUT202, etc. A 7U chassis has a 200-addresses slot and a 300-addresses slot. The drawout tray on which each I/O board is mounted is keyed. See *Installing Optional I/O Interface Boards* for information on the key positions for the 200-addresses slot trays and the 300-addresses slot trays.

Table 2.6 I/O Board Jumpers

I/O Board Control Address	JMP1 A/ JMP49A[a]	JMP1B/ JMP49B[a]	JMP2A/ JMP50A[a]	JMP2B/ JMP50B[a]
2XX	OFF	OFF	OFF	OFF
3XX	ON	OFF	ON	OFF

[a] INT4 I/O interface board jumper numbering.

Changing I/O Interface Board Jumpers

Change the I/O interface board jumpers only when you move the slot position of an I/O board. You must remove the I/O interface boards to access the jumpers. Perform the following steps to change jumpers on an SEL-487E I/O interface board:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-487E.

Step 3. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 4. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 5. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 6. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 7. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 8. Pull out the drawout assembly containing the I/O interface board.

Step 9. Locate the jumper you want to change (see *Figure 2.16*).

Step 10. Install or remove the jumper as needed (see *Table 2.6* for jumper position descriptions).

Step 11. Reinstall the interface board, and reconnect the power, the interface board, and the analog input board cables.

Step 12. Reconnect the cable removed in *Step 6* and reinstall the relay front-panel cover.

Step 13. Replace any cables previously removed from serial ports.

Step 14. Follow your company standard procedure to return the relay to service.

Step 15. At relay power-up, confirm that the relay does not display a status warning about I/O board addresses. For information on this status warning, see *Relay Self-Tests on page 14.59*.

Connection

You can remove the screw-terminal connectors from the rear of the SEL-487E by unscrewing the screws at each end of the connector block. Perform the following steps to remove a screw-terminal connector:

Step 1. Remove the connector by pulling the connector block straight out. Note that the receptacle on the relay circuit board is keyed; you can insert each screw-terminal connector in only one location on the rear panel.

Step 2. To replace the screw-terminal connector, confirm that you have the correct connector and push the connector firmly onto the circuit board receptacle.

Step 3. Reattach the two screws at each end of the block.

Changing Screw-Terminal Connector Keying

You can rotate a screw-terminal connector so that the connector wire dress position is the reverse of the factory-installed position (for example, wires entering the relay panel from below instead of from above). In addition, you can move similar function screw-terminal connectors to other locations on the rear panel. To move these connectors to other locations, you must change the screw-terminal connector keying. Inserts in the circuit board receptacles key the receptacles for only one screw-terminal connector in one orientation. Each screw-terminal connector has a missing web into which the key fits (see *Figure 2.17*). If you want to move a screw-terminal connector to another circuit board receptacle or reverse the connector orientation, you must rearrange the receptacle keys to match the screw-terminal connector block. Use long-nosed pliers to move the keys. *Figure 2.18* shows the factory default key positions.

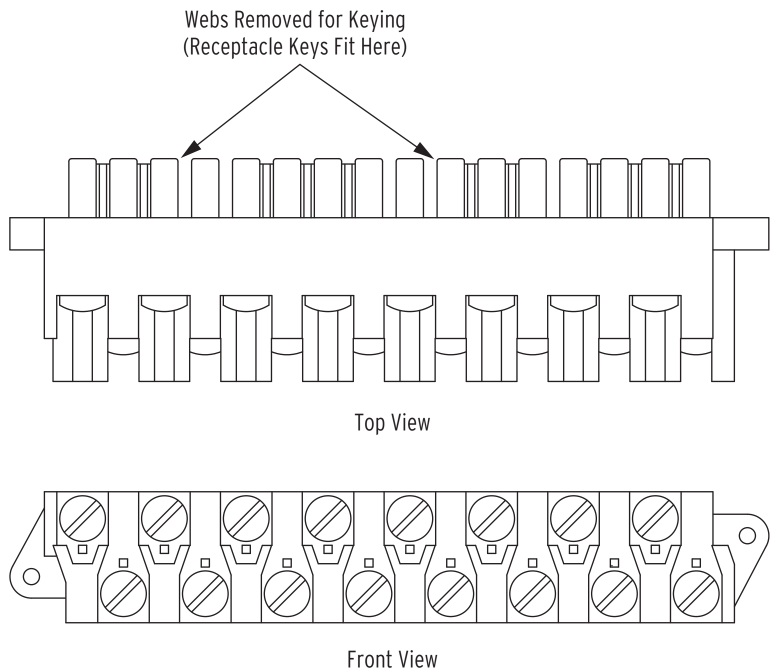


Figure 2.17 Screw-Terminal Connector Keying

Grounding

Connect the grounding terminal (#Y31) labeled GND on the rear panel to a rack frame ground or main station ground for proper safety and performance. This protective earthing terminal is in the lower right side of the relay panel. The symbol that indicates the grounding terminal is shown in *Symbols on page xxix in the Preface*. Use 12–10 AWG (4 mm^2–6 mm^2) wire less than 6.6 feet (2 m) in length for this connection. This terminal connects directly to the internal chassis ground of the SEL-487E.

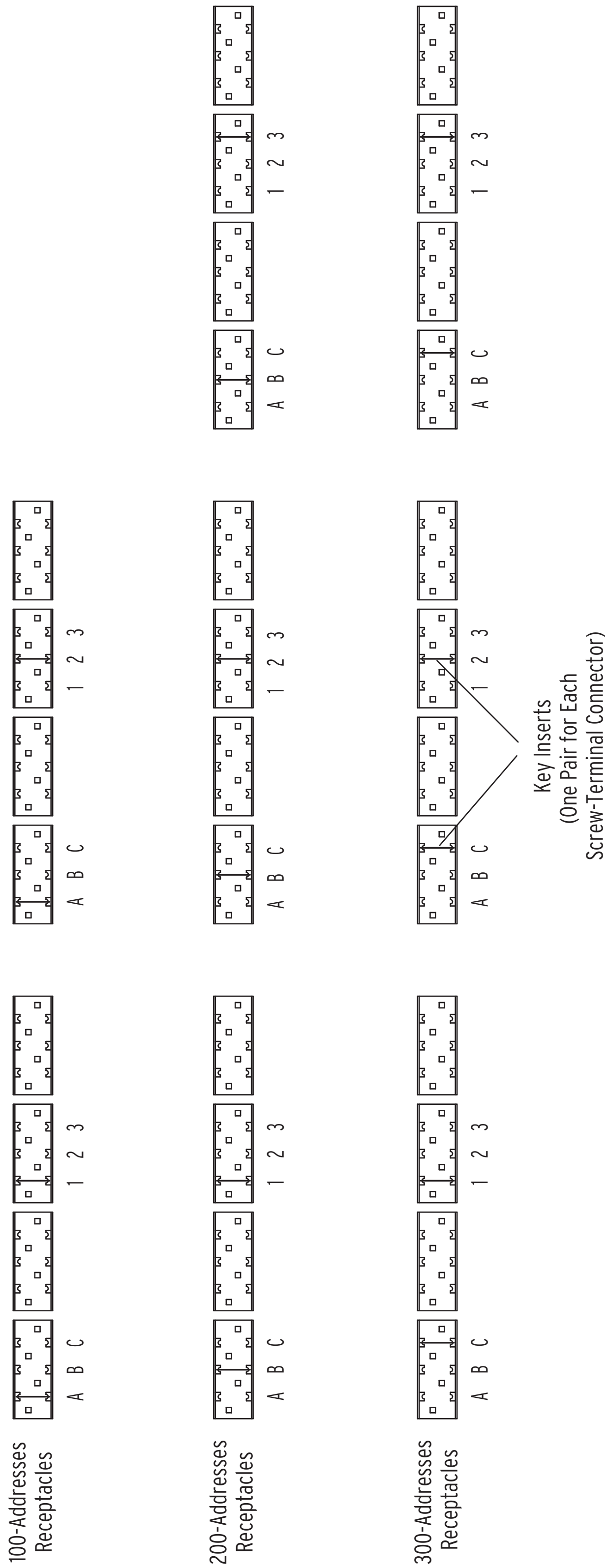


Figure 2.18 Rear-Panel Receptacle Keying, SEL-487E

Power Connections

The terminals labeled **POWER** on the rear panel (**#Y29** and **#Y30**) must connect to a power source that matches the power supply characteristics that your SEL-487E specifies on the rear-panel serial number label. (See *Power Supply* on page 1.12, for complete power input specifications.) For the relay models that accept dc input, the serial number label specifies dc with the symbol shown in Figure 2.18.

The POWER terminals are isolated from chassis ground. Use 16–14 AWG (1.5 mm^2–2.1 mm^2) size wire to connect to the POWER terminals. Connection to external power must comply with IEC 60947-1 and IEC 60947-3 and must be identified as the disconnect device for the equipment. Place an external disconnect device, switch/fuse combination, or circuit breaker in the POWER leads for the SEL-487E; this device must interrupt both the hot (H/+) and neutral (N/–) power leads. The current rating for the power disconnect circuit breaker or fuse must be 20 A maximum. Be sure to locate device within 9.8 feet (3.0 m) of the relay.

Operational power is internally fused by power supply Fuse F1. Table 2.7 lists the SEL-487E power supply fuse requirements. Be sure to use fuses that comply with IEC 127-2.

You can order the SEL-487E with one of two operational power input ranges listed in Table 2.7. Each of the two supply voltage ranges represents a power supply ordering option. As noted in Table 2.7, model numbers for the relay with these power supplies begin 0487E0*n* (or 0487E1*n*), where *n* is 4 or 6. Note that each power supply range covers two widely used nominal input voltages. The SEL-487E power supply operates from 30 Hz to 120 Hz when ac power is used for the POWER input.

Table 2.7 Fuse Requirements for the SEL-487E Power Supply

Nominal Power Supply Voltage Rating	Power Supply Voltage Range	Fuse F1	Fuse Description	Model Number
48/125 V	38–140 Vdc or 85–140 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	0487EX24
125/250 V	85–300 Vdc or 85–264 Vac (30–120 Hz)	T3.15AH250V	5x20 mm, time-lag, 3.15 A, high break capacity, 250 V	0487EX26

The SEL-487E accepts dc power input for all power supply models. The 48/125 Vdc supply also accepts 120 Vac; the 125/250 Vdc supply also accepts 120/240 Vac. When connecting a dc power source, you must connect the source with the proper polarity, as indicated by the + (Terminal #Y29) and – (Terminal #Y30) symbols on the power terminals. When connecting to an ac power source, the + Terminal #Y29 is hot (H), and the – Terminal #Y30 is neutral (N). Each model of the SEL-487E internal power supply exhibits low power consumption and a wide input voltage tolerance. For more information on the power supplies, see Power Supply on page 1.12.

Power Supply Fuse Replacement

You can replace a bad fuse in an SEL-487E power supply, or you can return the SEL-487E to SEL for fuse replacement. If you decide to replace the fuse, perform the following steps to replace the power supply fuse:

Step 1. Follow your company standard to remove the relay from service.

Step 2. Disconnect power from the SEL-487E.

Step 3. Remove the relay from the rack or panel.

Step 4. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 5. Remove the communications cable, BNC, and Ethernet connected to the front-panel serial port, if applicable.

Step 6. Remove the rear-panel **EIA-232 PORTS** mating connectors.

Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 7. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 8. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 9. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 10. Remove the screw-terminal connectors.

a. Loosen the attachment screws at each end of the 100-addresses, 200-addresses, and 300-addresses screw-terminal connectors.

b. Pull straight back to remove.

Step 11. Remove the top chassis plate by unscrewing seven screws from the chassis.

Step 12. Pull out the drawout tray containing the main board.

Step 13. Pull out the drawout tray containing the I/O interface board(s).

Step 14. Locate the power supply. Fuse F1 is at the rear of the power supply circuit board (see *Figure 2.19*).

Step 15. Examine the power supply for blackened parts or other damage. If you can see obvious damage, reinstall all boards and contact SEL to arrange return of the relay for repair.

Step 16. Remove the spent fuse from the fuse clips.

Step 17. Replace the fuse with an exact replacement (see *Table 2.7* for the proper fuse for your power supply).

Step 18. Reinstall the interface board.

Step 19. Reinstall the SEL-487E main board, and reconnect the power, the interface board, and the analog input board cables.

Step 20. Replace the chassis top on the relay and secure it with seven screws.

Step 21. Reconnect the cable removed in *Step 8* and reinstall the relay front-panel cover.

Step 22. Reattach the rear-panel connections.

Affix the screw-terminal connectors to the appropriate 100-addresses, 200-addresses, and 300-addresses locations on the rear panel.

Step 23. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 24. Follow your company standard procedure to return the relay to service.

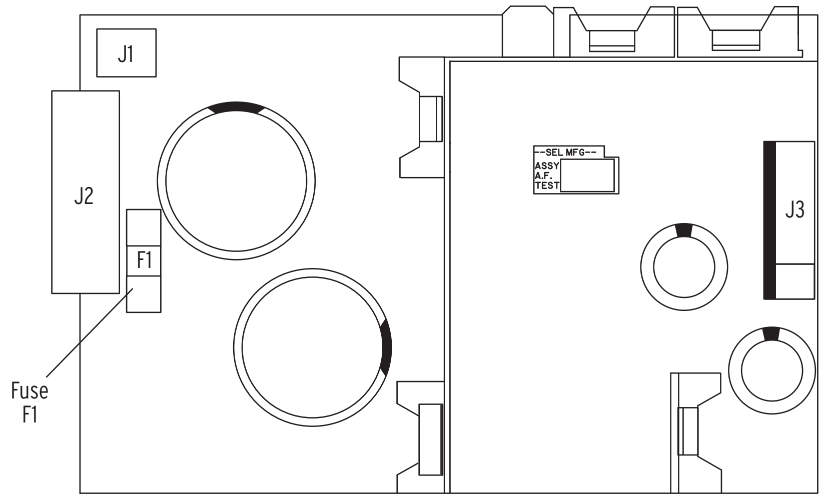


Figure 2.19 PS30 Power Supply Fuse Location

Monitor Connections

DC Battery

The SEL-487E monitors one dc battery system. For information on the battery monitoring function, see *Station DC Battery System Monitor on page 5.14*. Connect the positive lead of the battery system to Terminal **#Y25** and the negative lead to Terminal **#Y26**. (Usually the battery system is also connected to the rear-panel **POWER** input terminals).

Alarm Output

The SEL-487E monitors internal processes and hardware in continual self-tests. If the relay senses an out-of-tolerance condition, the relay declares a Status Warning or a Status Failure. The relay signals a Status Warning by pulsing the HALARM Relay Word bit (hardware alarm) to a logical 1 for five seconds. For a Status Failure, the relay latches the HALARM Relay Word bit at logical 1. To provide remote alarm status indication, connect the b contact of OUT108 to your control system remote alarm input. *Figure 2.20* shows the configuration of the a and b contacts of control output OUT108.

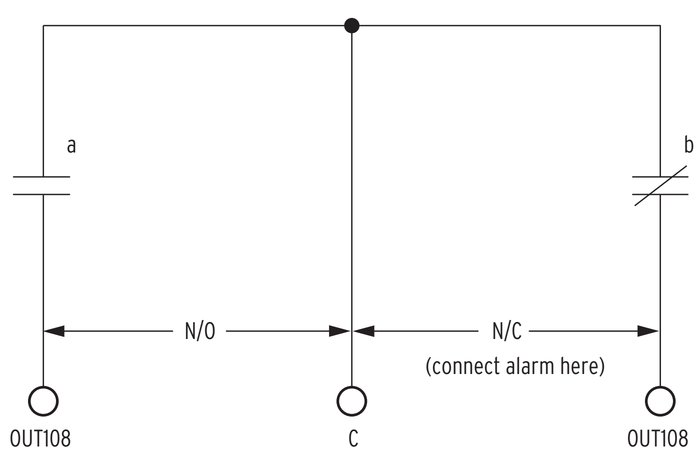


Figure 2.20 Control Output OUT108

Program OUT108 to respond to NOT HALARM by entering the following SELOGIC® control equation with a communications terminal, with ACSELERATOR QuickSet:

OUT108 := **NOT HALARM**

When the relay is operating normally, the NOT HALARM signal is at logical 1 and the b contacts of control output OUT108 are open. When a status warning condition occurs, the relay pulses the NOT HALARM signal to logical 0 and the b contacts of OUT108 close momentarily to indicate an alarm condition. For a status failure, the relay disables all control outputs and the OUT108 b contacts close to trigger an alarm. Also, when relay power is off, the OUT108 b contacts close to generate a power-off alarm. The relay pulses the SALARM Relay Word bit for software programmed conditions; these conditions include settings changes, access level changes, and alarming after three unsuccessful password entry attempts. The SEL-487E also pulses the BADPASS Relay Word bit after three unsuccessful password entry attempts. You can add the software alarm SALARM to the alarm output by entering the following SELOGIC control equation:

OUT108 := **NOT (HALARM OR SALARM)**

TIME Input Connections

IRIG-B Input Connection

The SEL-487E accepts a demodulated IRIG-B signal through two types of rear-panel connectors. These IRIG-B inputs are through the BNC connector labeled TIME IRIG-B or through Pin 4 (+) and Pin 6 (–) of the rear-panel 9-pin D-subminiature connector PORT 1 (see *Communications Ports Connections* for other DB-9 connector pinouts and additional details). These inputs accept the dc shift time code generator output (demodulated) IRIG-B signal with positive edge on the time mark. The PORT 1 IRIG-B input circuit connects to a 2.5 kΩ resistor to ground. (See *Figure 2.14*.)

Driver circuits should source approximately 10 mA through the circuit for the ON state. When you are using the PORT 1 input, ensure that you connect Pins 4 and 6 with the proper polarity. Where distance between the SEL-487E and the IRIG-B sending device exceeds the cable length recommended for conventional EIA-232 metallic conductor cables, you can use transceivers to provide isolation and to establish communication to remote locations.

Conventional fiber-optic and telephone modems do not support IRIG-B signal transmission. Use the SEL-2810 transceiver to provide long distance delivery of the IRIG-B signal to the SEL-487E. The SEL-2810 includes a channel for the IRIG-B time code. These transceivers enable you to synchronize time precisely from IRIG-B time code generators (such as the SEL-2032 Communications Processor) over a fiber-optic communications link.

Use the IRIG-B BNC connector for synchrophasor and high-accuracy timekeeping applications. Make the connection using a 50 Ω coaxial cable assembly with a male BNC connector.

Replacing the Lithium Battery

You can replace a bad lithium battery in the SEL-487E. Perform the following steps to replace the lithium battery.

Step 1. Follow your company standard procedure to remove a relay from service.

Step 2. Disconnect power from the SEL-487E.

Step 3. Remove the relay from the rack or panel.

Step 4. Retain the **GND** connection, if possible, and ground the equipment to an ESD mat.

Step 5. Remove the communications cable connected to the front-panel serial port, if applicable.

Step 6. Remove the rear-panel **EIA-232 PORTS** mating connectors.

Step 7. Unscrew the keeper screws and disconnect any serial cables connected to the **PORT 1**, **PORT 2**, and **PORT 3** rear-panel receptacles.

Step 8. Loosen the four front-panel screws (they remain attached to the front panel), and remove the relay front panel.

Step 9. Remove the 34-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 10. Disconnect the power, the interface board, and the analog input board cables from the main board.

Step 11. Pull out the drawout tray containing the main board.

Step 12. Locate the lithium battery. The lithium battery is at the front of the main board (see *Figure 2.15*).

Step 13. Remove the spent battery from beneath the clip of the battery holder.

Step 14. Replace the battery with an exact replacement. Use a 3 V lithium coin cell, Ray-O-Vac® No. BR2335 or equivalent. The positive side (+) of the battery faces up.

Step 15. Reinstall the SEL-487E main board, and reconnect the power, the interface board, and the analog input board cables.

Step 16. Reconnect the cable removed in Step 9 and reinstall the relay front-panel cover.

Step 17. Reconnect any serial cables that you removed from the **EIA-232 PORTS** in the disassembly process.

Step 18. Set the relay date and time via the communications ports or front panel.

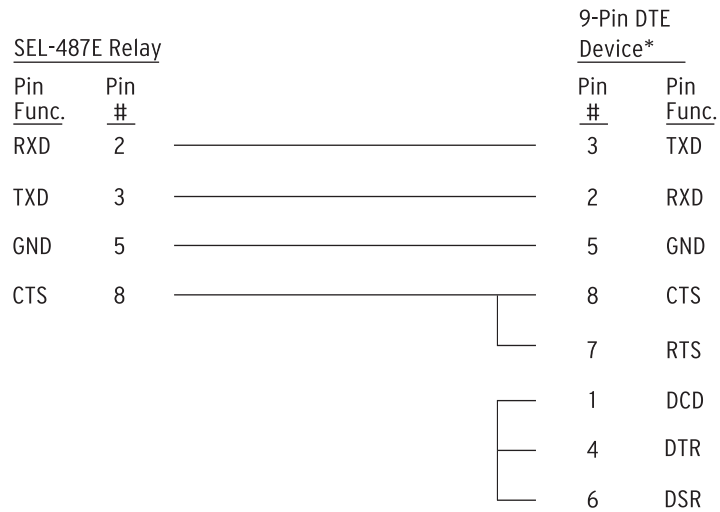
Step 19. Follow your company standard procedure to return the relay to service.

Communications Ports Connections

The SEL-487E has three rear-panel EIA-232 serial communications ports labeled **PORT 1**, **PORT 2**, and **PORT 3** and one front-panel port, **PORT F** (see *Section 7: Communications, Interfaces, and Protocols*) In addition, the rear panel features PORT 5 for an optional communications card. For additional information about communications topologies and standard protocols that are available in the SEL-487E, see *Appendix C: SEL Communications Processors* *Appendix E: DNP3 Communications Protocol*, and *Appendix F: IEC 61850*.

Serial Ports

The SEL-487E serial communications ports use EIA-232 standard signal levels in a D-subminiature 9-pin connector. To establish communication between the relay and a DTE device (a computer terminal, for example) with a D-subminiature 9-pin connector, use an SEL Cable C234A. *Figure 2.21* shows the configuration of SEL Cable C234A that you can use for basic ASCII and binary communication with the relay. A properly configured ASCII terminal, terminal emulation program, or ACSELERATOR QuickSet along with the C234A cable provide communication with the relay in most cases. See *Section 7: Communications, Interfaces, and Protocols* for more information.



*DTE = Data Terminal Equipment (Computer, Terminal, etc.)

Figure 2.21 Cable Configuration for Basic ASCII and Binary Communication

Serial Cables

Using an improper cable can cause numerous problems or failure to operate, so you must be sure to specify the proper cable for application of your SEL-487E. Several standard SEL communications cables are available for use with the relay. The following list provides additional rules and practices you should follow for successful communication using EIA-232 serial communications devices and cables:

- Route communications cables well away from power and control circuits. Switching spikes and surges in power and control circuits can cause noise in the communications circuits if power and control circuits are not adequately separated from communications cables.
- Keep the length of the communications cables as short as possible to minimize communications circuit interference and also to minimize the magnitude of hazardous ground potential differences that can develop during abnormal power system conditions.
- Ensure that EIA-232 communications cable lengths never exceed 50 feet, and always use shielded cables for communications circuit lengths greater than 10 feet.
- Modems provide communication over long distances and give isolation from ground potential differences that are present between device locations (examples are the SEL-28XX-series transceivers).
- Lower data speed communication is less susceptible to interference and will transmit greater distances over the same medium than higher data speeds. Use the lowest data speed that provides an adequate data transfer rate.

Network Connections

The optional Ethernet card for the SEL-487E can use either the connection on Port A or Port B to operate on a network. These ports work together to provide a primary and backup interface, as described in *Network Port Fail-Over Operation on page I.3*. The following list describes the Ethernet card port options.

- 10/100BASE-T. 10 Mbps or 100 Mbps communications using CAT 5 cable (category 5 twisted-pair) and an RJ-45 connector
- 100BASE-FX. 100 Mbps communications over multimode fiber-optic cable using an ST connector

Ethernet Card Rear-Panel Layout

Rear-panel layouts for the three Ethernet card port configurations are shown in *Figure 2.22–Figure 2.24*.

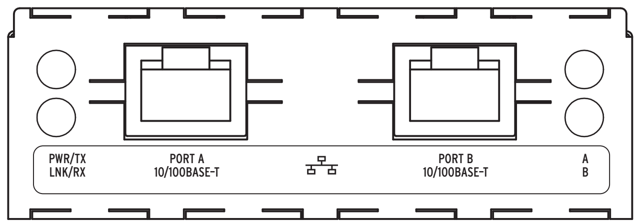


Figure 2.22 Two 10/100BASE-T Port Configuration

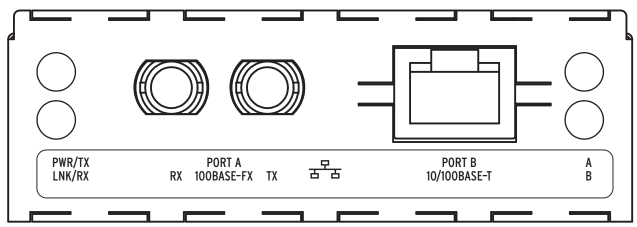


Figure 2.23 100BASE-FX and 10/100BASE-T Port Configuration

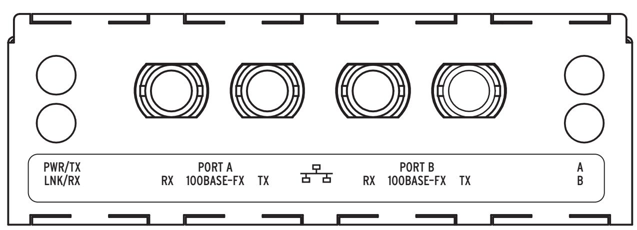


Figure 2.24 Two 100BASE-FX Port Configuration

Twisted-Pair Networks

While Unshielded Twisted Pair (UTP) cables dominate office Ethernet networks, Shielded Twisted Pair (STP) cables are often used in industrial applications. The SEL-487E Ethernet card is compatible with standard UTP cables for Ethernet networks as well as STP cables for Ethernet networks.

Typically UTP cables are installed in relatively low-noise environments including offices, homes, and schools. Where noise levels are high, you must either use STP cable or shield UTP using grounded ferrous raceways such as steel conduit.

Several types of STP bulk cable and patch cables are available for use in Ethernet networks. If noise in your environment is severe, you should consider using fiber-optic cables. We strongly advise against using twisted-pair cables for segments that leave or enter the control house.

If you use twisted-pair cables, you should use care to isolate these cables from sources of noise to the maximum extent possible. Do not install twisted-pair cables in trenches, raceways, or wireways with unshielded power, instrumentation, or control cables. Do not install twisted-pair cables in parallel with power, instrumentation, or control wiring within panels, rather make them perpendicular to the other wiring.

You must use a cable and connector rated as Category 5 (CAT 5) to operate the twisted-pair interface (10/100BASE-T) at 100 Mbps. Because lower categories are becoming rare and because you may upgrade a 10 Mbps network to 100 Mbps, we recommend using all CAT 5 components. Some industrial Ethernet network devices use 9-pin connectors for STP cables. The Ethernet card RJ-45 connectors are grounded so you can ground the shielded cable using a standard, externally shielded jack with cables terminating at the Ethernet card.

Inspecting a New Relay

The following items are included in your shipment from SEL:

- SEL-487E Relay
- CD-ROM containing the electronic version of the entire SEL-487E Relay Instruction Manual and the Configurable Label Templates
- CD-ROM containing the ACSELERATOR QuickSet SEL-5030 Software program
- SEL Contact Card
- Configurable Front-Panel Label Kit

⚠CAUTION
Do not connect power to the relay until you have completed these procedures and received instructions to apply power. Equipment damage can result otherwise.

If any item is missing or damaged, please contact your distributor or SEL immediately.

Initial Inspection

Perform the following initial inspection when the relay arrives:

- Remove the protective wrapping from the SEL-487E.
- Observe the outside of the front cover and the rear panel.
- Check that no significant scratches or dents are evident on any outer surface.
- Confirm that all terminal strips on the rear panel are secure.

Cleaning

Perform the following steps and use care when cleaning the SEL-487E:

Step 1. Use a mild soap or detergent solution and a damp cloth to clean the relay chassis.

Be careful cleaning the front and rear panels because a permanent plastic sheet covers each panel; do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any relay surface.

Step 2. Allow the relay to air dry, or wipe dry with a soft dry cloth.

Verify Relay Configuration

When you first inspect the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. Examine the serial number label on the relay rear panel; *Figure 2.25* shows a sample rear-panel serial number label.

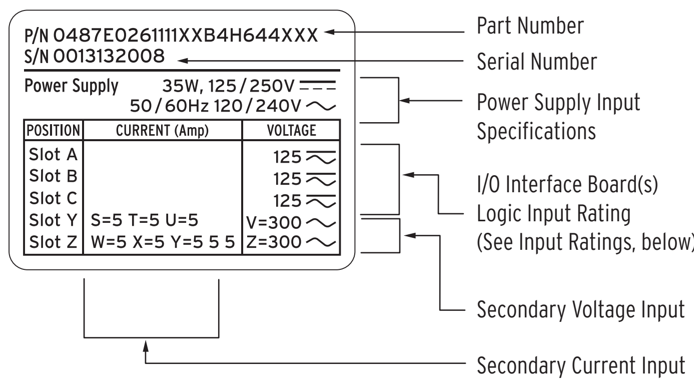


Figure 2.25 SEL-487E Serial Number Label

Figure 2.25 shows a serial number label for an SEL-487E with additional I/O in a 7U horizontal chassis. This example serial number label is for a 5 A-per-phase secondary current transformer input relay.

The serial number label does not list power system phase rotation and frequency ratings, because you can use relay settings to configure these parameters.

The power supply specification in *Figure 2.25* indicates that this relay is equipped with a power supply that accepts a nominal 125/250 Vdc input. This power supply also accepts a 120 Vac input. Refer to the serial number label affixed to the back of your relay to determine the power supply voltage you should apply to the relay power supply input terminals. As this label indicates, the voltage source should be capable of providing at least 35 W. See *Power Supply on page 1.12* for more information on power supply specifications.

Input Ratings

The serial number label in *Figure 2.25* lists control input voltages for I/O, which is determined at ordering time. In the sample shown, Slot B and Slot C contain an Interface board.

AC/DC Connection Diagrams

You can apply the SEL-487E in many power system protection schemes. *Figure 2.26* shows an autotransformer with both HV and LV sides configured as breaker-and-a-half. This figure does not show any PT or dc connections. For more applications examples, see *Applications on page 1.8*.

Figure 2.27 shows typical dc connections for the SEL-487E. Because the application has Bay Control for both the HV and LV side (only HV disconnect connections shown), this example includes an INT4 interface board (the INT4 interface board provides two groups of nine input contacts and six high-speed output contacts, see *Figure 2.11*).

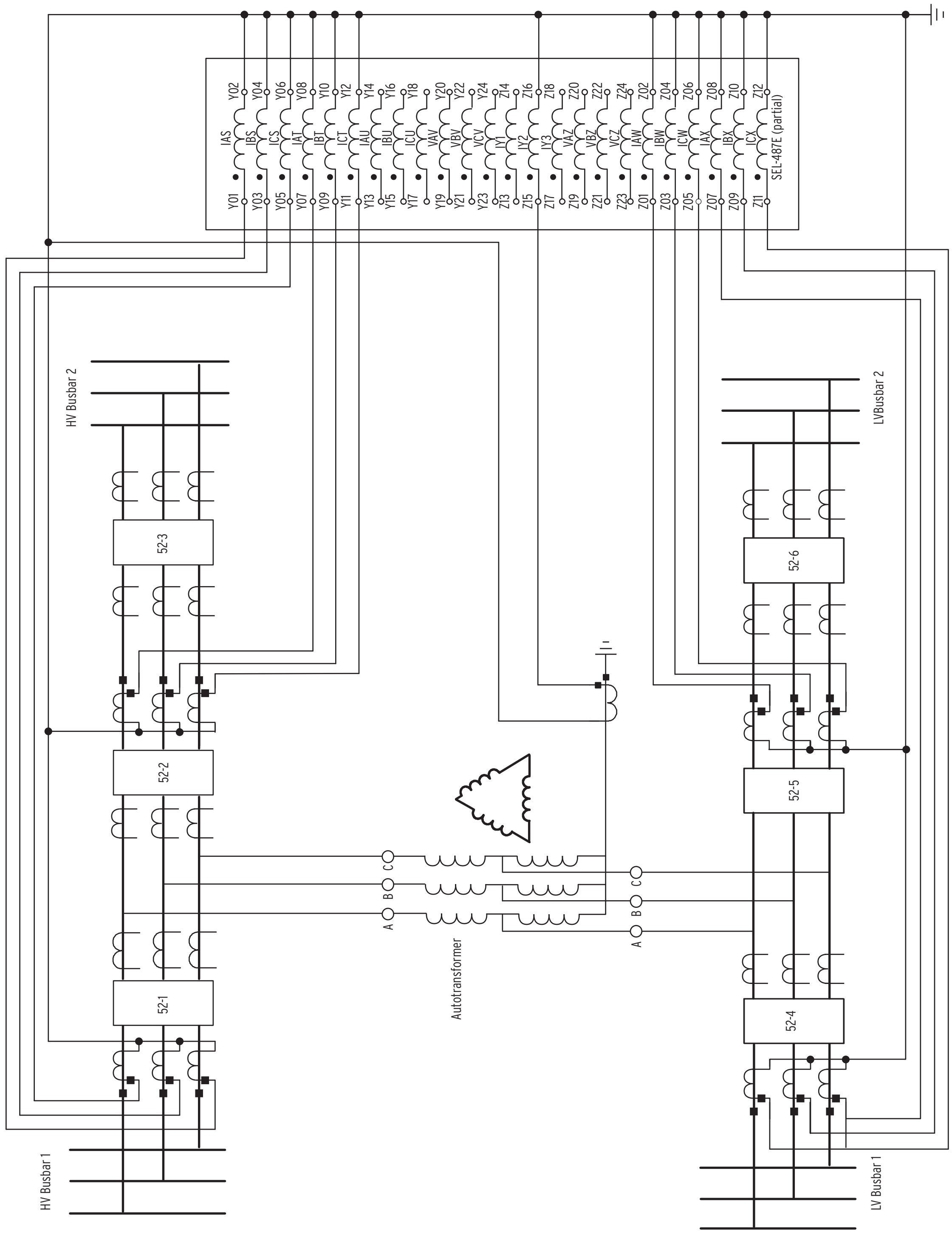
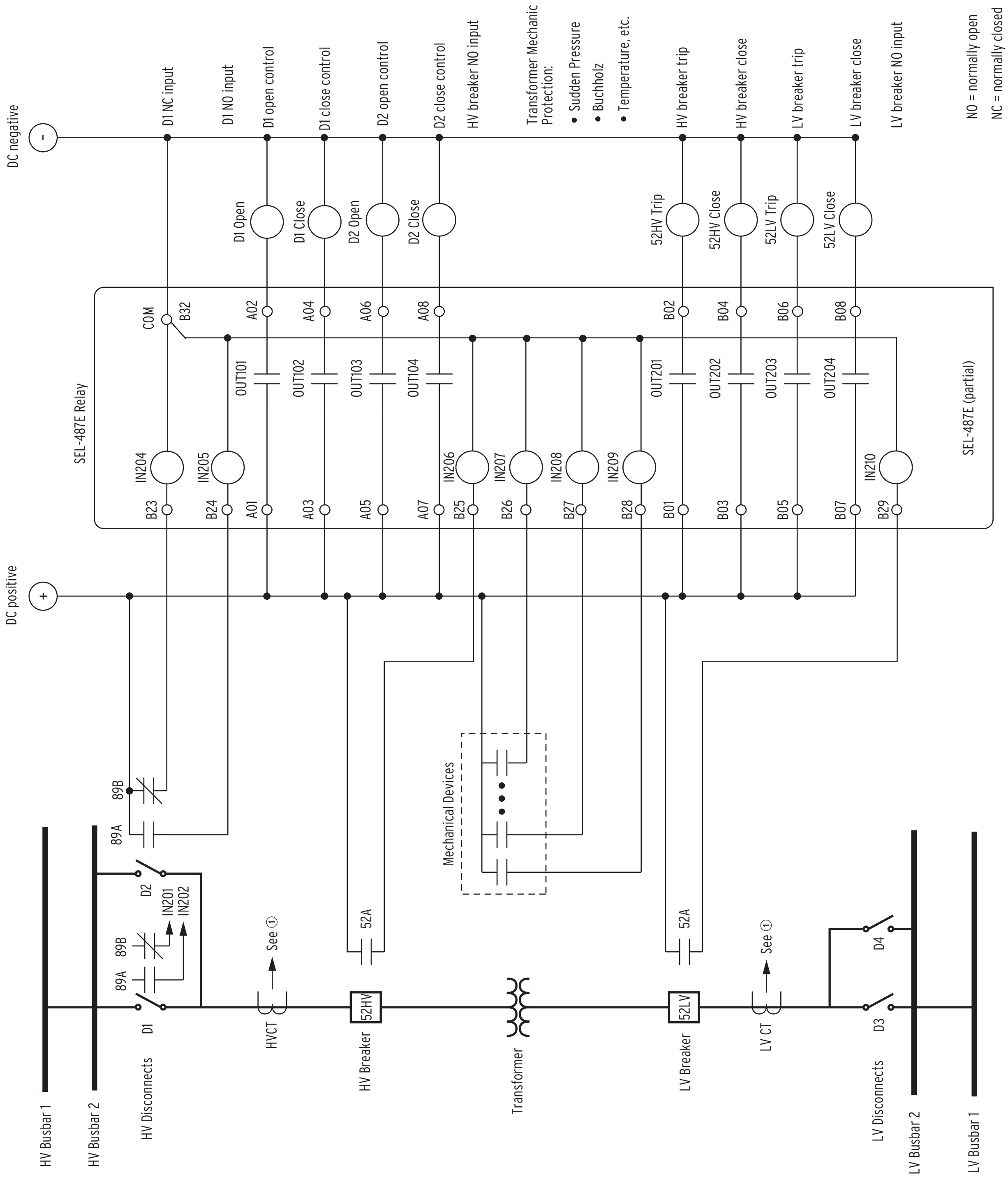


Figure 2.26 Autotransformer Application



① See Figure 2.26.

Figure 2.27 Typical External DC Connections

Figure 2.28 shows the connections for an open-delta connected PT when wired to the V-PT inputs. Connect the A-phase and C-phase polarity wires from the PT secondary to the SEL-487E A- phase (**Y19**) and C-phase (**Y23**) terminals with polarity marks. Connect the common point from the PT to the SEL-487E B-phase (**Y21**) terminal with polarity mark. Connect jumpers between terminals **Y20**, **Y22** and **Y24**, and also connect this wire to **Y21**.

Figure 2.28 shows the ground connection on the common point; be sure to follow the wiring standards of you company when grounding the PTs. However, be sure to apply only one ground to the PTs.

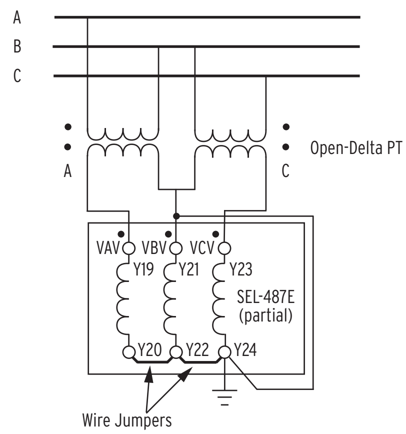


Figure 2.28 Wiring Connections for Open-Delta Connected PTs

Section 3
PC Software

Overview

This section provides information on the following topics:

The SEL-487E Relay includes ACSELERATOR QuickSet® SEL-5030 software, a powerful relay settings, analysis, and measurement tool to aid you in applying and using the relay. ACSELERATOR QuickSet reduces engineering costs for relay settings, logic programming, and system analysis. ACSELERATOR QuickSet also makes it easier for you to do the following:

- Create and manage relay settings
  - Create settings for one or more SEL-487E relays
  - Store and retrieve settings with an IBM-compatible personal computer (PC)
  - Upload and download relay settings files to and from SEL-487E relays
- Analyze events
  - Use the integrated waveform and harmonic analysis tools
- Monitor real-time and relay-stored power system data
  - Use the human machine interface (HMI) to view metering, Relay Word bits, and circuit breaker monitor data
- Control the relay
  - Command relay operation through use of a graphical user interface (GUI) environment
  - Execute relay serial port commands in terminal mode
- Configure the serial port and passwords

SEL provides ACSELERATOR QuickSet for easier, more efficient configuration of relay settings, metering, and control. ACSELERATOR QuickSet gives you the advantages of rules-based settings checks, SELOGIC® control equation Expression Builder, operator control and metering HMI, and event analysis.

However, you do not have to use ACSELERATOR QuickSet to configure the SEL-487E; you can continue to use an ASCII terminal or a computer running terminal emulation software to access all relay settings and metering.

Installing the Computer Software

Load ACSELERATOR QuickSet on an IBM-compatible PC. If you encounter any difficulties installing ACSELERATOR QuickSet, contact your Technical Service Center or the SEL factory for assistance.

System Requirements

To successfully install and use ACSELERATOR QuickSet, your PC must have the minimum resources listed in *Table 3.1*.

Table 3.1 System Requirements for ACSELERATOR QuickSet

Item	Description
Processor	Pentium® class, ≥ 90 MHz
Operating System/RAM	Microsoft® Windows® 98/ME/XP—64 MB RAM Microsoft Windows 2000—64 MB RAM Microsoft Windows NT®—32 MB RAM (64 MB recommended)
Hard drive	At least 100 MB available storage space
Communications Port	One EIA-232 serial port or one Ethernet port
Drives	CD-ROM for software installation
Monitor	SVGA 800 x 600 pixel resolution or greater (1024 x 768 pixel resolution recommended)
Pointing Device	Mouse or other pointing device

Installation

You can load ACSELERATOR QuickSet automatically if your computer autorun feature is enabled; this is Method A.

If autorun is not enabled on your computer, use the Windows **Run** command to load ACSELERATOR QuickSet; this is Method B.

Method A

Load ACSELERATOR QuickSet automatically:

Step 1. Turn on your PC and run the Windows operating environment.

Step 2. Close all other applications on your PC.

Step 3. Place the ACSELERATOR QuickSet CD-ROM in the PC CD-ROM drive.

The setup software runs automatically and the SEL **Software License Agreement** appears, as in *Figure 3.1*.

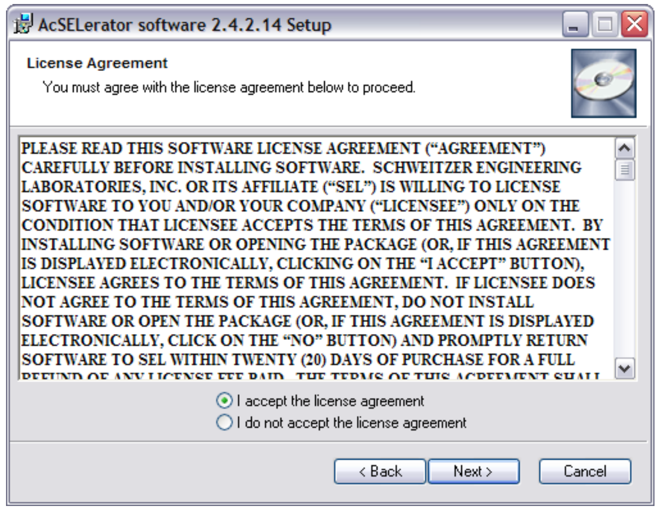


Figure 3.1 SEL Software License Agreement (Sample)

Method B

Load ACSELERATOR QuickSet with the Windows **Run** Command:

Step 1. If the **Setup** program does not start automatically, click **Start > Run** to load ACSELERATOR QuickSet.

Step 2. Type the command shown in *Figure 3.2*, being certain to use the correct drive letter for the CD-ROM drive in your PC (the CD-ROM drive in the *Figure 3.2* example is drive **D:**).

Step 3. The SEL **Software License Agreement** appears (*Figure 3.1*).

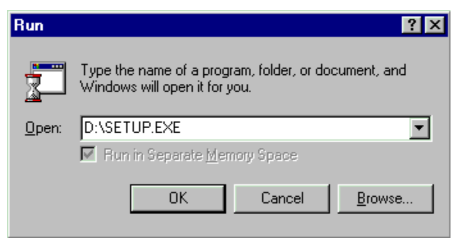


Figure 3.2 Windows Run Command Line to Load ACSELERATOR QuickSet

Step 4. Complete the software loading process.

Step 5. Read the **Software License Agreement** and follow the loading instructions as these instructions appear on the PC screen.

Starting ACSELERATOR QuickSet

You can use the Windows **Start** menu to open ACSELERATOR QuickSet:

Step 1. If you installed ACSELERATOR QuickSet to the **Program Manager** group, click **Start > Programs**.

Step 2. Click SEL **Applications >** ACSELERATOR QuickSet.

Step 3. If you used a custom program group, click **Start** and click ACSELERATOR QuickSet in the custom group.

You can also create a shortcut on the Windows Desktop (see your Windows documentation for instructions on creating a shortcut). Double-click the shortcut icon to start ACSELERATOR QuickSet from the shortcut.

Communications Setup

ACSELERATOR QuickSet uses the relay communications ports to communicate with the SEL-487E. Configure the ACSELERATOR QuickSet **Communication Parameters** menu settings to communicate effectively with the relay.

You can also use a basic terminal emulation window any time you run ACSELERATOR QuickSet. Use the **Communication** menu to view and clear a **Connection Log**.

Communication Parameters

Use the **Communication Parameters** dialog box to configure relay communications settings. Select the **Communication > Parameters** from the top ACSELERATOR QuickSet toolbar to open this dialog box.

Figure 3.3 shows the ACSELERATOR QuickSet **Communication Parameters** dialog box.

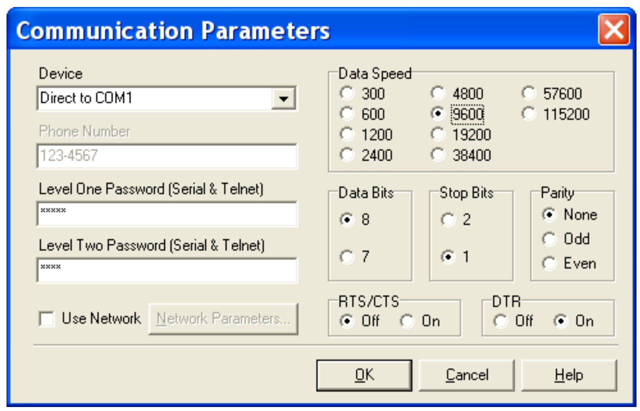


Figure 3.3 ACSELERATOR QuickSet Communication Parameters Dialog Box

Serial Setup

You can use serial communication via PORT 1, PORT 2, PORT 3, and PORT F (front panel). *Figure 3.3* shows the default serial port parameters (**9600**, **8**, **N**, **1**). Enter your relay **Level One** and **Level Two** passwords in the respective text boxes.

If you choose a device from the **Device** text box that is a telephone modem, enter the dial-up telephone number in the **Phone Number** text box.

FTP Setup

Click the **Use Network** check box to access the **Network Parameters**. *Figure 3.4* shows the **Network Parameters** dialog box. For **FTP** (File Transfer Protocol) use **Telnet Port number 23**.

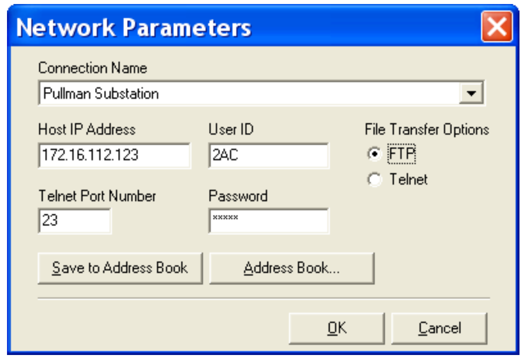


Figure 3.4 ACSELERATOR QuickSet Network Parameters Dialog Box: FTP

When you connect to a relay to use FTP, you must specify the access level and password.

Enter the access level command (**ACC**, **2AC**, for example) in the **User ID** text box and the corresponding access level password in the **Password** text box to control the relay at a specific access level.

Telnet Setup

Click the **Telnet** option button in the **Network Parameters** dialog box (see *Figure 3.5*) to connect to a relay for a **Telnet** session. The **Telnet** session uses the relay passwords in the **Communication Parameters** dialog box (*Figure 3.3*).

The default **Telnet Port Number** for accessing the relay is **T1PNUM := 23**. The default **Telnet Port Number** for communicating directly with an installed Ethernet card is **T2PNUM := 1024**.

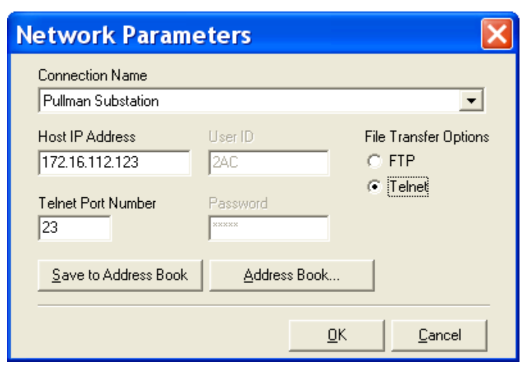


Figure 3.5 ACSELERATOR QuickSet Network Parameters Dialog Box: Telnet

Terminal Mode

The terminal emulation window is an ASCII interface between you and the relay. This is a basic terminal emulation with no file transfer capabilities. Many third-party terminal emulation programs are available with file transfer encoding schemes.

Click **Communication > Terminal** to start the terminal emulation window. Another convenient method to start the terminal is to type **<Ctrl+T>**.

Terminal Logging

When you check the **Terminal Logging** item in the **Communication** menu, ACSELERATOR QuickSet records communications events and errors in a log.

Click **Communication > Connection Log** to view the log.

Clear the log by selecting **Communication > Clear Connection Log**.

Settings Database Management and Drivers

Database Manager

ACSELERATOR QuickSet uses a relay database to save relay settings. ACSELERATOR QuickSet contains sets of all settings files for each relay that you specify in the **Database Manager**. See *Virtual File Interface on page 7.13* for a list of the settings files in the SEL-487E.

Choose appropriate storage backup methods and a secure location for storing your relay database files. Use the **File > Active Database** menu to retrieve a relay database from computer memory.

Relay Database

The default relay database file already configured in ACSELERATOR QuickSet is **Relay.rdb**. This database may contain example settings files for the SEL products with which you can use ACSELERATOR QuickSet.

Perform the following steps to access and/or modify the database:

Step 1. Open the **Database Manager**.

Step 2. Click **File > Database Manager** in the ACSELERATOR QuickSet top toolbar.

A dialog box similar to *Figure 3.6* appears.

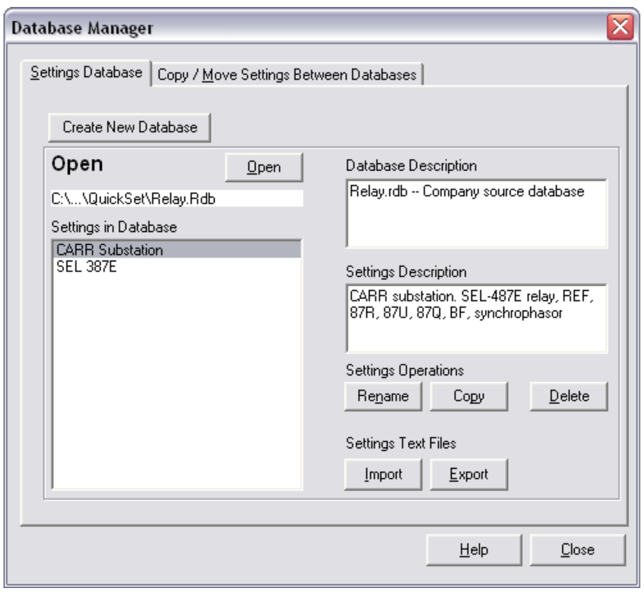


Figure 3.6 Database Manager Relay Database in ACSELERATOR QuickSet

Step 3. Enter descriptions for the database and for each relay in the database in the **Database Description** and **Relay Description** dialog boxes.

Type in the **Relay Description** dialog box special operating characteristics that describe the relay settings. These can include the protection scheme settings and communications settings.

Perform the following steps to create a new collection of relay settings:

Step 1. Highlight one of the relays listed in **Relays in Database** and click **Copy**.

ACSELERATOR QuickSet prompts you to provide a new name.

Step 2. Enter a new description in **Relay Description**.

Copy/Move Relays Between Databases

You can create multiple relay databases with the **Database Manager**; these databases are useful for grouping similar protection schemes or geographic areas.

Perform the following steps to copy or move a relay between databases:

Step 1. Select the **Copy / Move Relays Between Databases** tab to access the dialog box shown in *Figure 3.7*.

Step 2. Click **Open B** to open a relay database.

Step 3. Select or type a filename and click **Open**; for example, **Relay2.rdb** is the B relay database in *Figure 3.7*.

Step 4. Highlight a relay in the **Database A** list, select **Copy** or **Move**, and click the **>** button to create a new relay in **Database B**.

- ➢ **Copy** creates an identical relay that appears in both databases.
- ➢ **Move** removes the relay from one database and places the relay in another database.

Step 5. Reverse this process to copy or move relays from **Database B** to **Database A**.

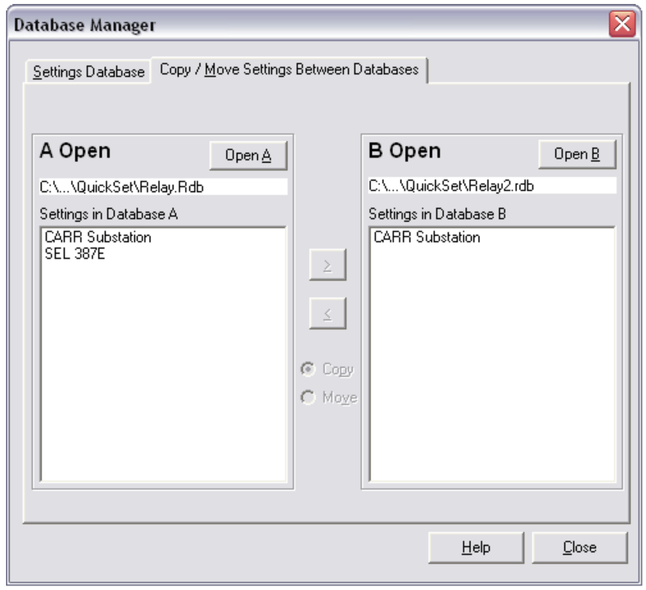


Figure 3.7 Database Manager Copy/Move in ACSELERATOR QuickSet

Create a New Database

Perform the following steps to create and copy an existing database of relays to a new database:

Step 1. Select the **File > Database Manager** to access the **Database Manager** dialog box.

Step 2. Select the **Copy / Move Relays Between Databases** tab in the **Database Manager** dialog box.

ACSELERATOR QuickSet opens the last active database and assigns it as **Database A** (see *Figure 3.7*).

Step 3. Click the **Open B** button.

ACSELERATOR QuickSet prompts you for a file location.

Step 4. Type a new database name, click the **Open** button, and answer **Yes.**

The program creates a new empty database.

Step 5. Load relays into the new database as in *Copy/Move Relays Between Databases on page 3.7*.

Drivers

Relay settings folders in ACSELERATOR QuickSet are closely associated with the ACSELERATOR QuickSet relay driver that you used to create the settings. The relay settings and the ACSELERATOR QuickSet drivers must match.

Perform the following steps to ensure that the relay settings and ACSELERATOR QuickSet drivers match:

Step 1. Use any of the following methods to view the relay FID information:

- ➤ Enter the **STATUS** command.
- ➤ Click the **Status** button in the HMI tree view.
- ➤ At a terminal (**<Ctrl+T>** from ACSELERATOR QuickSet), type **ID <Enter>**.

Step 2. View the ACSELERATOR QuickSet settings driver information at the bottom of the **Relay Editor** window (see *Figure 3.15*).

Step 3. Compare the ACSELERATOR QuickSet driver number and the relay FID number. The ACSELERATOR QuickSet driver Z-number and the corresponding part of the relay FID must match.

The first portion of the Z-number is the ACSELERATOR QuickSet settings driver version number (see *Figure 3.8*).

Relay Settings Version Number

FID = SEL-487E-R100-V0-Z001001-D20020104

HMI Version Number

Figure 3.8 ACSELERATOR QuickSet Driver Information in the FID String

ACSELERATOR QuickSet reads the latter portion of the Z-number (ZXXX001, for example) to determine the correct HMI to display when you select the HMI **Meter and Control** menu. View the bottom of the HMI window to check the HMI driver number (see *Figure 3.9*).

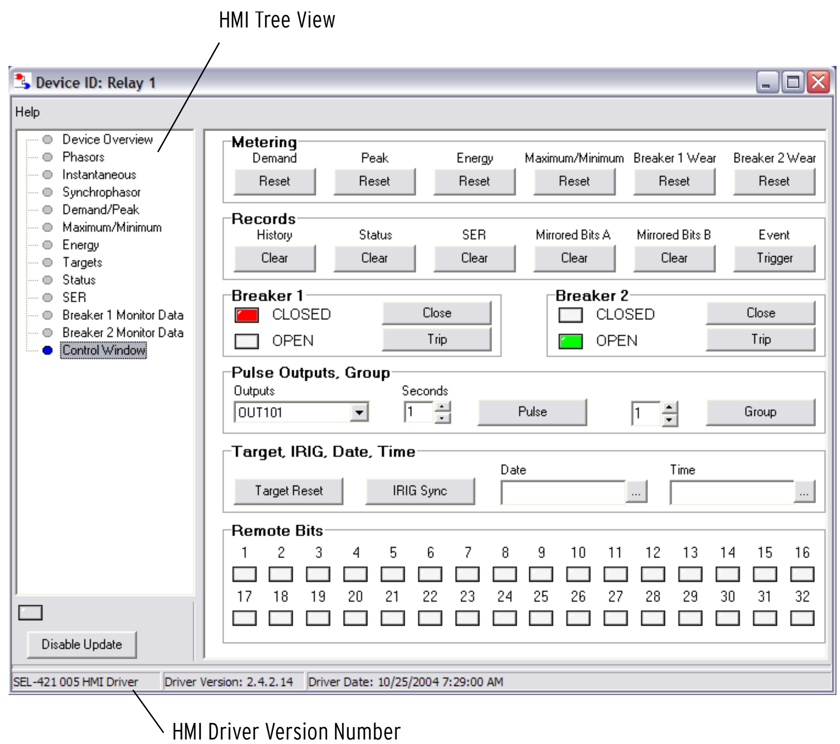


Figure 3.9 HMI Driver Version Number in the HMI Window

As SEL develops new drivers, you can update your existing ACSELERATOR QuickSet software with specific relay drivers for each SEL product that uses ACSELERATOR QuickSet. Contact your local Technical Service Center or the SEL factory for the latest ACSELERATOR QuickSet drivers.

Create and Manage Relay Settings

Setting Tiers

When considering the SEL-487E as a device with 5 sets of three-phase current inputs, 3 single-phase current inputs and 2 sets of three-phase voltage inputs, the application possibilities are considerable. For example, a wye/delta, two-winding transformer requires only two sets of three-phase current inputs for differential protection and one single-phase current input for REF. This leaves 3 three-phase current inputs and 2 single-phase current inputs available for other functions, such as overcurrent protection for a distribution feeder or frame leakage protection for metal-clad switchgear. To simplify the setting process, the settings are arranged in a multitier structure to enable and control the input currents for the appropriate application.

Tier 1

First-tier settings identify which of the 21 analog inputs (CTs and PTs) the relay processes except the 3 REF (IY1, IY2, IY3) channels. Enable the REF channels under the restricted earth-fault settings category. Settings on the first tier include the following settings:

ECTTERM, ECPTERM

Terminals entered here are function independent, i.e., entering a terminal here does not indicate the intended functional use (differential, REF, etc.); it merely instructs the relay to process the analog inputs from these terminals.

Tier 2

After selecting the appropriate analog channels, Tier 2 settings enable the protection functions required for the particular application. Settings on the second tier include the following enable settings:

E87, EREF, E50, E51, E46, E59, E27, E81, E24, EBFL, EPCAL, E32, EDEM

Tier 3

The third tier is usually in the form of a torque control (TC) SELOGIC control equation, and is not available for all protection functions. This tier provides conditional availability of protection elements, i.e., the settings are function dependent. For example, Terminal S is enabled (ECTTERM = S,…), and also assigned to the differential element (E87 = S,…). Third-tier Setting E87T provides a method to dynamically enable/disable current S in the differential element. Settings on the third tier include the following settings:

E87T[S,T,U,W,X], TCREF[1–3], 51TC[1–20], 24TC, 27TC[1–5], 59TC[1–5], EXBF[S,T,U,W,X], BFI[S,T,U,W,X], E32OP[01–10], EDM[01–10]

ACSELERATOR QuickSet gives you the ability to create settings for one or more SEL-487E relays. You can store existing relay settings downloaded from SEL-487E relays with ACSELERATOR QuickSet, creating a library of relay settings (see *Database Manager on page 3.6*). You can then modify and upload these settings from your settings library to an SEL-487E.

ACSELERATOR QuickSet makes setting the relay easy and efficient. For an example of setting the SEL-487E with ACSELERATOR QuickSet.

Collected Settings

ACSELERATOR QuickSet arranges relay settings in easy-to-understand categories (for an explanation of settings organization. These categories of collected settings help you quickly set the relay.

Figure 3.10 is an example of relay settings categories in the **Relay Editor Settings** tree view. (Use the procedures described in *Settings Menu on page 3.12* to view the tree views in *Figure 3.10*.)

ACSELERATOR QuickSet shows all of the settings categories in the settings tree view. When you enable and disable settings categories, the tree view remains constant, but when you click the tree view to access the settings in a disabled category, the disabled settings are dimmed.

For example, select the **Group 1 > Set 1 > Relay Configuration** branch of the **Settings** tree view, and notice that the ECTTERM includes Terminal S and Terminal T, the EPTTERM is set to OFF, and the EREF is set to N. Further notice that E87 is also set to OFF, but that only Terminals S and T are available for selection; Terminal U, W, and X are dimmed out. This is because the ECTTERM only includes Terminals S and T. Because EREF is set to N (no REF elements enabled), all three REF elements are dim.

Figure 3.10 illustrates this feature of ACSELERATOR QuickSet.

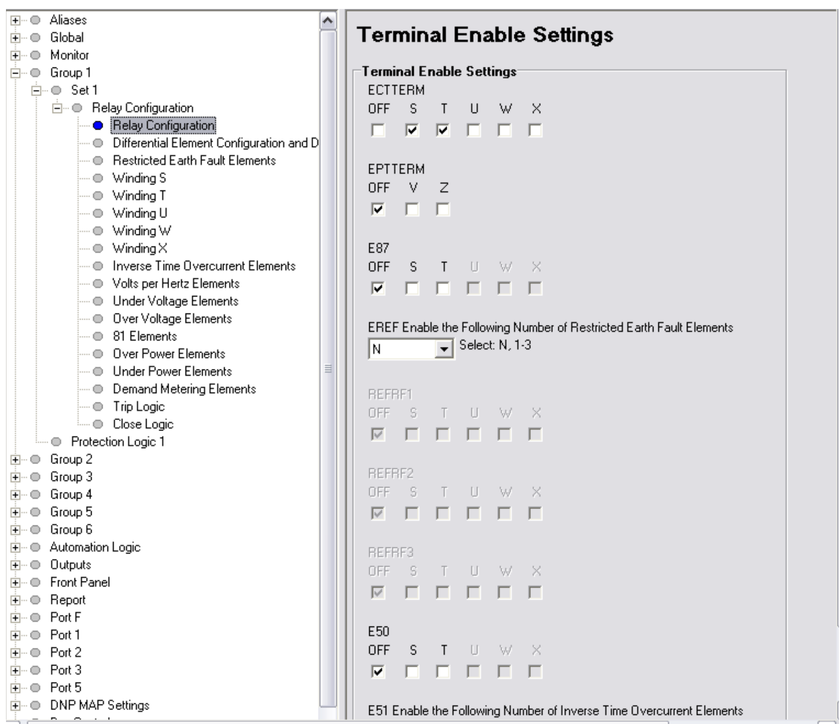


Figure 3.10 Sample Settings in ACSELERATOR QuickSet

If you select 1 for **EREF**, then the first REF element (REFRF1) settings are active and the remainder of the **REF** settings are dim, as shown in *Figure 3.11*. Here again, only Terminals S and T are available for association with the REF elements (Terminals U, W, and X are dim because the ECTTERM setting only includes Terminals S and T).

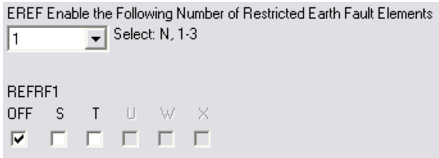


Figure 3.11 One REF Element Selected

Settings Menu

The **Settings** menu on the top ACSELERATOR QuickSet toolbar is the starting point for all settings entries. The menu items on the **Settings** menu are **New**, **Open**, and **Read**. All of these menu items open the **Relay Editor** (see *Relay Editor on page 3.13*).

New

Selecting the **New** menu item creates new relay settings files. ACSELERATOR QuickSet makes the new settings files from the relay drivers that you specify in the **Settings Editor Selection** dialog box (see *Figure 3.12*).

ACSELERATOR QuickSet uses the Z-number in the relay FID string to create a particular version of relay settings (see *Drivers on page 3.8*).

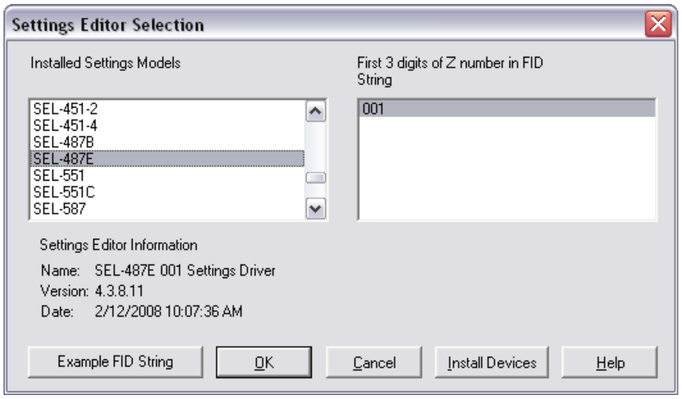


Figure 3.12 Selecting a Settings Driver in ACSELERATOR QuickSet

After selecting the relay model and settings driver, ACSELERATOR QuickSet presents the **Relay Part Number** dialog box. Use this dialog box to configure the **Relay Editor** to produce settings for a relay with options determined by the part number (see *Relay Part Number on page 3.14*).

Open

The **Open** menu item opens an existing relay from the active database folder (see *Figure 3.13*). ACSELERATOR QuickSet prompts you for a folder containing relay settings to load into the **Relay Editor**.

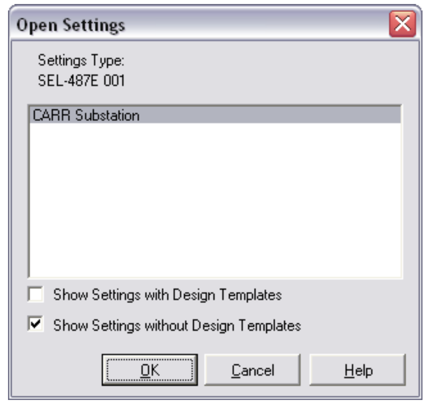


Figure 3.13 Opening Relay Settings in ACSELERATOR QuickSet

Read

When you select the **Read** menu item, ACSELERATOR QuickSet reads the relay settings from a connected relay. As ACSELERATOR QuickSet reads the relay, and a dialog box similar to *Figure 3.14* appears.

ACSELERATOR QuickSet uses serial protocols at a serial port or FTP from an Ethernet port to read settings from SEL devices.

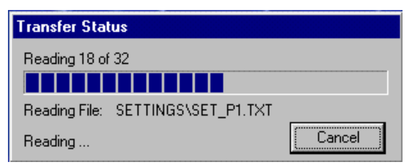


Figure 3.14 Reading Relay Settings in ACSELERATOR QuickSet

Relay Editor

Use the **Relay Editor** to enter relay settings. *Figure 3.15* illustrates the important features of the editor. These features include the ACSELERATOR QuickSet settings driver version number (the first three digits of the Z-number) in the lower left corner of the **Relay Editor**.

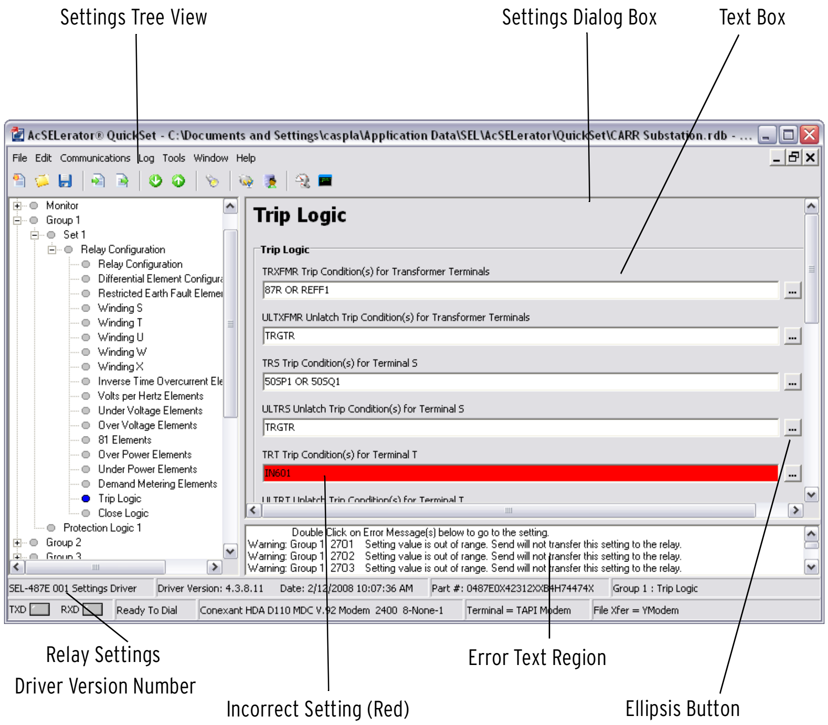


Figure 3.15 ACSELERATOR QuickSet Relay Editor

Entering Settings

Click the + marks and the buttons in the **Settings Tree View** to expand and select the settings class, instance, and category that you want to change.

Use **<Tab>** or click in a dialog box to edit a setting.

The right-click mouse button performs two special functions when you are editing settings: **Previous Value** and **Default Value**. To restore the previous value for a setting, right-click the setting and select **Previous Value**. Right-click the setting dialog box and select **Default Value** if you want to restore the factory default setting value.

If you enter a setting that is out of range or has an error, ACSELERATOR QuickSet shows the error at the bottom of the **Relay Editor**. Double-click the error listing to go to the setting to enter a valid input.

Relay Part Number

The relay part number determines the settings that ACSELERATOR QuickSet displays and the functions that the software controls. When configuring ACSELERATOR QuickSet to control a particular relay, you should confirm that the ACSELERATOR QuickSet part number matches the relay part number so that you can access all of the settings you need for your relay.

Configuring the Part Number

Perform the following steps to configure the part number:

Step 1. Select the **Settings** menu on the ACSELERATOR QuickSet top toolbar and click **New**, **Open**, or **Read** to start the **Relay Editor** (see *Settings Menu on page 3.12*).

Step 2. Once in the **Relay Editor**, click the **Options** menu on the **Relay Editor** toolbar (see *Figure 3.16*).

Step 3. Click **Part Number**.

Figure 3.16 Retrieving the Relay Part Number

The **Relay Part Number** dialog box appears, as shown in *Figure 3.17*.

Step 4. Use the arrows inside the text boxes to match corresponding portions of the **Relay Part Number** dialog box to your relay.

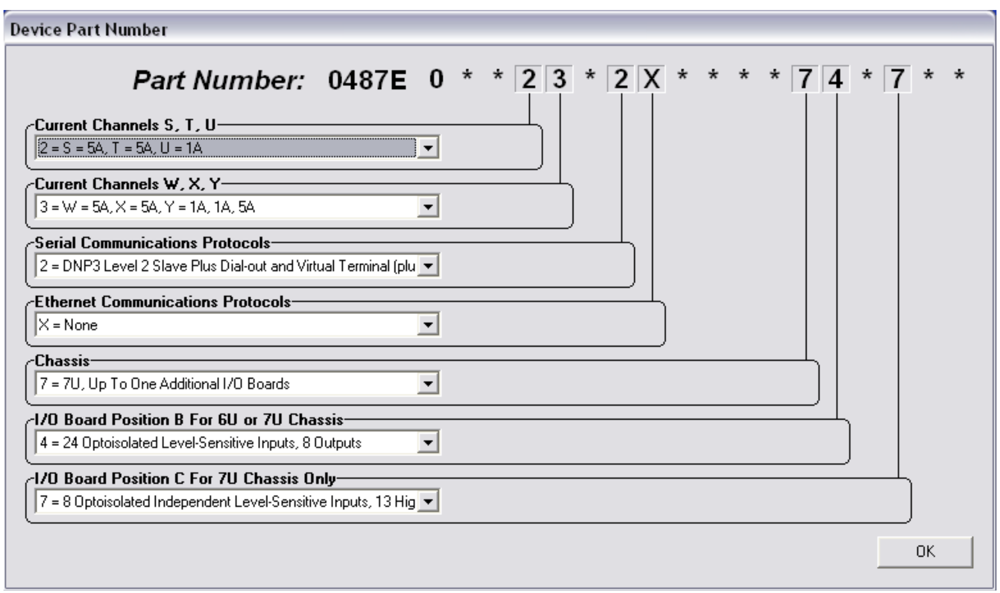


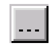
Figure 3.17 Setting the Relay Part Number in ACSELERATOR QuickSet Expression Builder

SELOGIC control equations are a powerful means for customizing relay performance. Creating these equations can be difficult because of the large number of relay elements (Relay Word bits) and analog quantities in the relay.

ACSELERATOR QuickSet simplifies this process with the **Expression Builder**, a rules-based editor for programming SELOGIC control equations. The **Expression Builder** organizes relay elements, analog quantities, and SELOGIC control equation variables and focuses your equation decision-making. The **Expression Builder** checks basic rules and flags mistakes in SELOGIC control equation settings.

Access the Expression Builder

Settings dialog boxes (see *Figure 3.18*) in the **Relay Editor** window show the following (ellipsis) button:



Click this button of a SELOGIC control equation to use the **Expression Builder**.

Expression Builder Organization

The **Expression Builder** dialog box is organized into two main parts representing the left side (LVALUE) and right side (RVALUE) of the SELOGIC control equation. (The LVALUE is fixed for all settings except Protection Free-Form SELOGIC and Automation Free Form SELOGIC settings.

Figure 3.18 shows the two sides of the **Expression Builder**, with the SELOGIC control equation that you are constructing at the top of the dialog box. Note the dark vertical line and the equals sign (**:=**) separating the equation left and right sides.

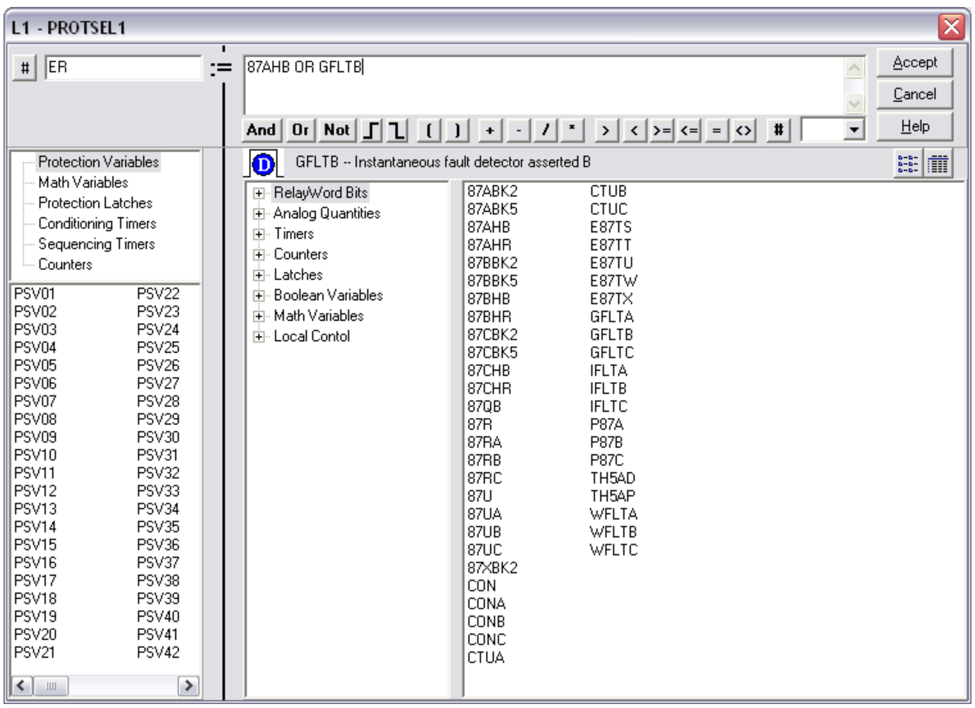


Figure 3.18 The ACSELERATOR QuickSet Expression Builder

Using the Expression Builder

For Protection Free-Form SELOGIC and Automation Free Form SELOGIC, select the type of result (LVALUE) for the SELOGIC control equation to use the **Expression Builder**. ACSELERATOR QuickSet shows these possibilities in the file box directly underneath the left side of the equation. The program shows the relay elements for each type of SELOGIC control equation (Boolean Variables, Math Variables, etc.).

On the right side of the equation (RVALUE), you can select broad categories of relay elements, analog quantities, counters, timers, latches, Boolean variables, and math variables. Select a category in the RVALUE tree view, and the **Expression Builder** displays all elements for that category in the list box at the bottom right side.

Directly underneath the right side of the equation, you can choose operations to include in the RVALUE. These operations include basic logic functions, rising and falling edge triggers, expression compares, and math functions.

See *Section 12: SELOGIC Control Equations* for more information on programming SELOGIC control equations.

Settings

This section provides, at a glance, the setting categories and major headings within each settings category. Each category also includes the ASCII command and a reference to the section in the instruction manual where more information is available.

Figure 3.19 shows Alias (ASCII: SET T) settings (where you can enter alias settings for any Relay Word bit or Analog Quantity) and Global (ASCII SET G) settings, as described in *Section 6: Settings*. Enter the station and relay names, and the CT and PT information, such as the CT/PT ratios, connections (wye or delta) and the metering compensation angle for the PT (if required) in the Global settings category. Be sure to set a VREF*k* value (Voltage Reference Terminal Selection) for each terminal want metering information to be displayed, because the relay calculates metering values only for terminals with a valid VREF*k* value.

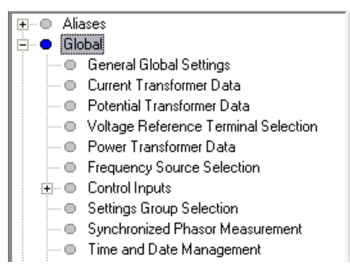


Figure 3.19 Global Settings Category (SET G)

Figure 3.21 shows the Monitor (ASCII: SET M) category, described in *Section 5: Monitoring and Metering*. This category includes all the monitor enable settings:

- Battery monitor (EDCMON)
- Breaker monitor (EBMON and BK_SEL)
  - 52A_k
  - Breaker contact wear
  - Breaker electrical operating time
  - Breaker mechanical operating time
  - Breaker inactivity time
  - Breaker motor running time
  - Breaker current interrupted
  - Breaker monitor reset
- Through-fault monitoring, (ETHFLTM)
- Thermal element monitoring (ETHERM)

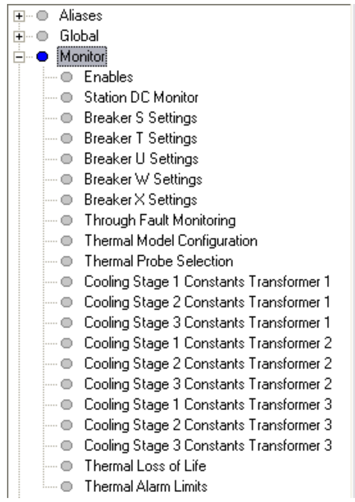


Figure 3.20 Monitor Settings Category

Figure 3.20 shows the Group 1 (ASCII: SET) category, described in *Section 4: Protection and Logic Functions* in the instruction manual. Group settings comprise two sub-categories: Set 1 and Protection Logic 1. Set 1 consists of all the protection settings, and Protection Logic 1 offers 250 lines of programming, processed at the deterministic time interval of 2 milliseconds. Following are some of the more settings in the Set 1 sub-category:

Relay Configuration consist of all the protection enable settings:

- ECTTERM—This is a first tier setting that enables CT inputs from a terminal (winding). This setting applies to all functions that require CT inputs; the relay only processes CT inputs from windings included in the ECTTERM setting.
- EPTTERM—This is a first tier setting that enables PT (VT) inputs from the voltage transformers. This setting applies to all functions that require PT inputs; the relay only processes PT inputs from PTs included in the EPTTERM setting.
- Enable windings to be part of the differential element (E87)
- Enable the REF elements (EREF)
- Composite setting to enable definite-time OC elements as well as directional elements (E50)
- Enable TOC (IDMT) elements (E51)
- Enable current unbalance elements (E46)
- Enable overvoltage elements (E59)
- Enable undervoltage elements (E27)
- Enable over/under frequency elements (E81)
- Enable V/Hz elements (E24)
- Enable breaker fail elements on a per-winding basis (EBFL)
- Enable the active, reactive and apparent power calculations for each winding (EPCAL). The relay calculates power only for those windings included in the EPCAL setting.

- ➤ Enable under/over power elements (E32)
- ➤ Enable the number of demand meter elements (EDEM)

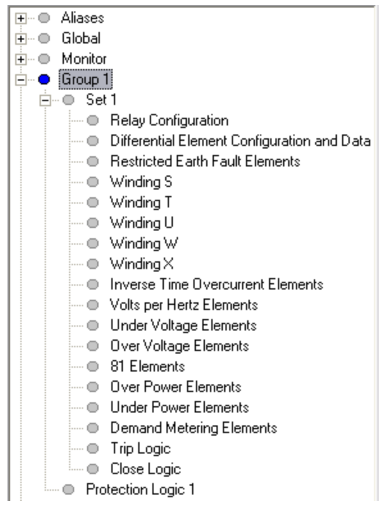


Figure 3.21 Group Settings Category

Refer to *Section 4: Protection and Logic Functions* for a description of the protection elements.

Automation Logic offers 1000 lines of programming, processed at a variable rate, although still deterministic within 1 second.

Figure 3.22 shows the output (ASCII: SET O) category settings for the main board and up to two interface boards, described in *Section 4: Protection and Logic Functions* in the instruction manual, as well as Communication Card outputs (*Appendix I: Communications Card*) and MIRRORED BITS® Transmit Equations (*Section 7: Communications, Interfaces, and Protocols*).

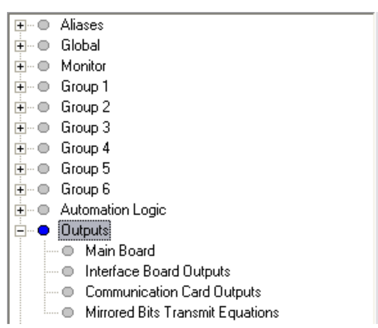


Figure 3.22 Outputs Settings Category

Figure 3.23 shows the Front Panel (ASCII: SET F) category, described in *Section 8: Front-Panel Operations* in the instruction manual. This category includes the following settings:

- ➤ **Pushbuttons**—Select the color of each pushbutton LED
- ➤ **Target LEDs**—Select the conditions, latch preference and the color preference for each target LED
- ➤ **Selectable Screens**—Select the scroll update rate for the front panel
- ➤ **RDD Selection**—Choose up to 70 front-panel screens that rotate on the front panel.

- **Selectable Operate Pushbuttons**—Assigns a direct action to a front-panel pushbutton. Choose from Alarm point, Display Point, Events, SER or Bay Control
- **Event Display**—Auto displays event summaries on the front panel.
- **Display Points and Aliases**—Set the display points
- **Local Control**—Assign control functions to be controlled from the front panel
- **Local Bit** SELOGIC—Provides supervision for the local control

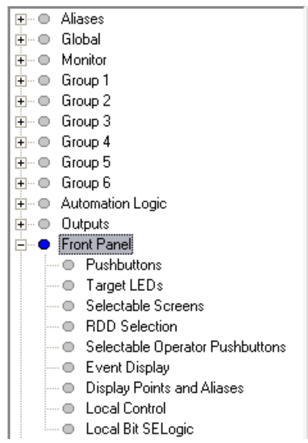


Figure 3.23 Output Settings Category

Figure 3.24 shows the Report (ASCII: SET R) category, described in *Section 10: Event Reports and SER* in the instruction manual.

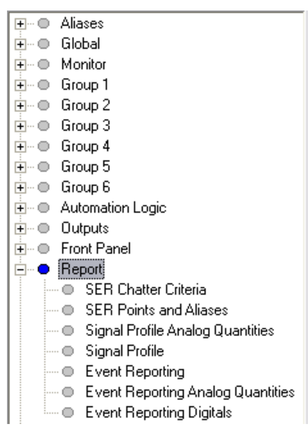


Figure 3.24 Report Settings Category

Figure 3.25 shows the Port (ASCII: SET P *n*, *n* = F, 1-3) category, described in the following sections:

- Port settings—*Section 6: Settings*
- SEL Protocol—*Section 7: Communications, Interfaces, and Protocols*
- DNP Protocol and DNP MAP—*Appendix E: DNP3 Communications Protocol*
- MIRRORED BITS Protocol—*Section 7: Communications, Interfaces, and Protocols*

- RTD Protocol—*Section 7: Communications, Interfaces, and Protocols*
- Port 5 is the optional Ethernet card settings, described in *Appendix I: Communications Card*

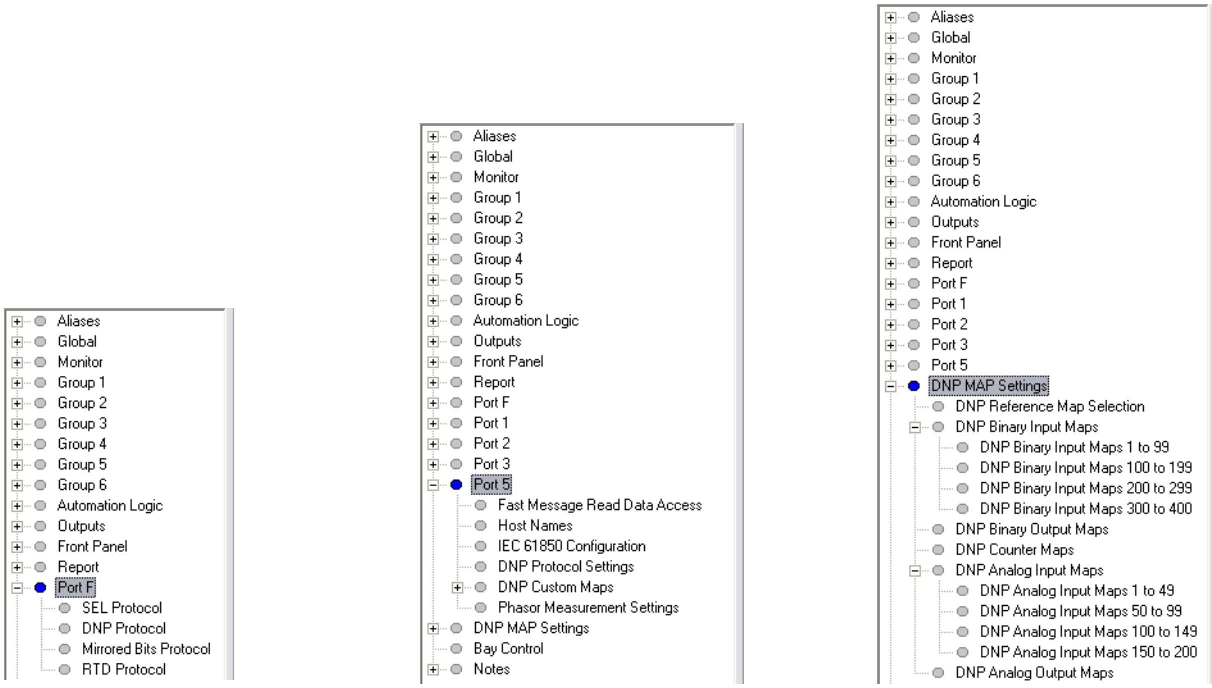


Figure 3.25 Port Settings Category

Figure 3.26 shows the Bay Control (ASCII: SET B) and the Notes (ASCII: SET N) categories. Bay Control settings are described in *Section 9: Bay Control*, and Notes:

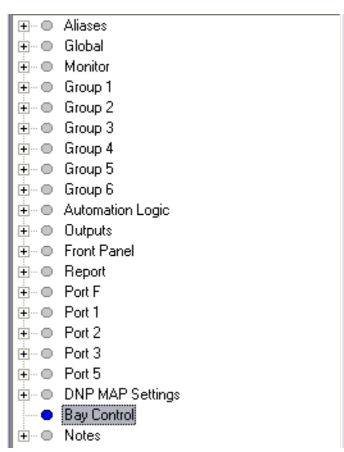


Figure 3.26 Bay Control and Notes Settings Categories

Analyze Events

ACSELERATOR QuickSet has integrated analysis tools that help you retrieve information about protection system operations quickly and easily. Use the protection system event information that the SEL-487E stores to evaluate the performance of a protection system.

Event Waveforms

The SEL-487E records power system events for all trip situations and for other operating conditions that you program with SELOGIC control equations.

The relay provides two types of event data captures: high-resolution oscillography that uses raw sample per second data and event report oscillography that uses filtered sample per cycle data.

Read History

You can retrieve event files stored in the relay and transfer these files to your PC.

To download event files from the relay, open the ACSELERATOR QuickSet **Tools** menu at the top ACSELERATOR QuickSet toolbar and click **Events, and Get Event Files** as shown in *Figure 3.27*.

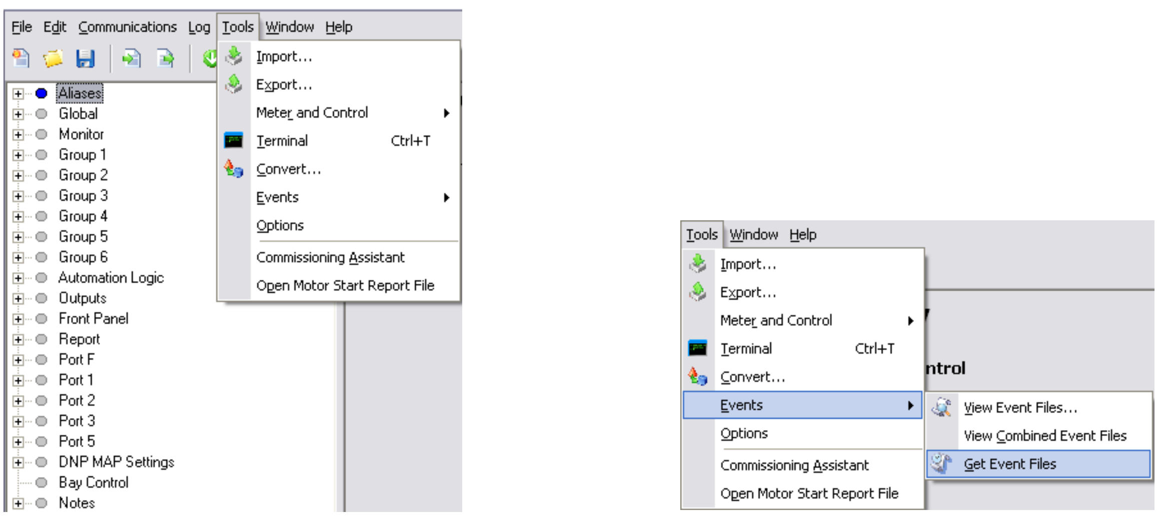


Figure 3.27 Retrieving Relay Event History

Get Event

Perform the following steps to view events:

Step 1. Highlight the event you want to view and click the **Get Selected Event** button.

For post-fault analysis, choose Binary COMTRADE option, (other options are CEV 4 samples/cyc and CEV 8 samples/cyc). Select the file from the list, and click on **Get Selected Event**, as shown in *Figure 3.28*.

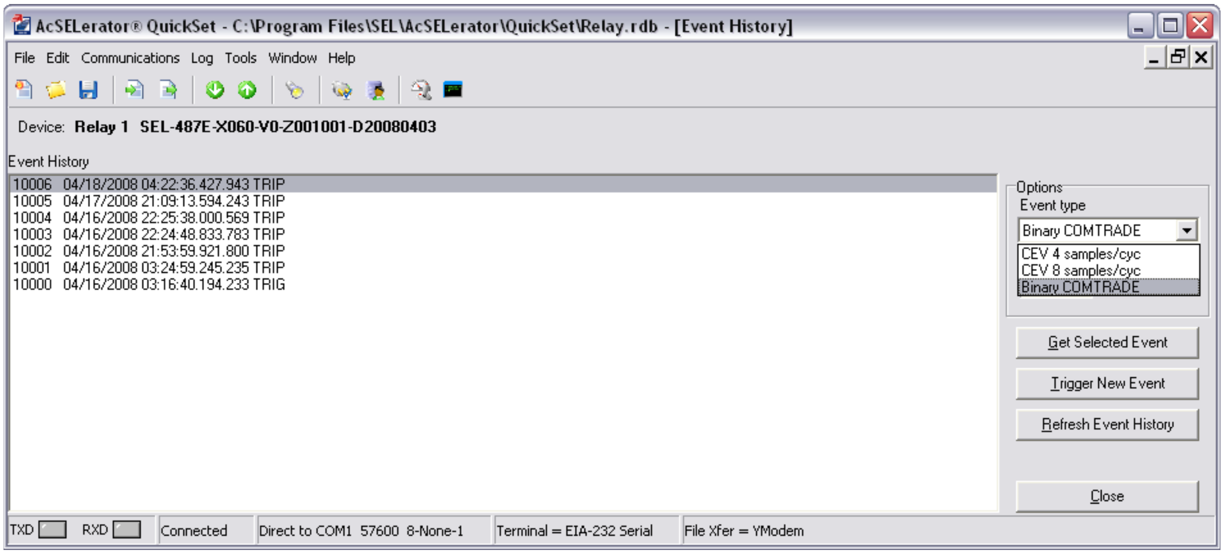


Figure 3.28 Retrieving Events

Step 2. When downloading is complete, ACSELERATOR QuickSet asks you to save the file on your PC.

Step 3. Select a descriptive name such as the substation name (CARR substation in this example) and save the file, as shown in *Figure 3.29*.

Step 4. Once the file is saved, press the **Close** button, and then select the **Events** menu and click **View Event Files**, as shown in *Figure 3.29*.

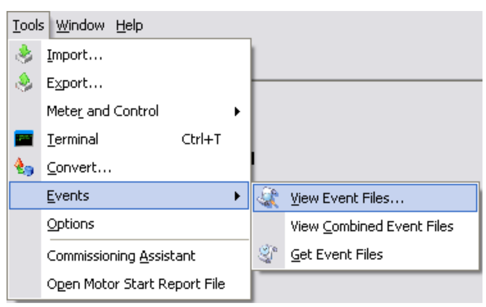


Figure 3.29 Viewing Events

Step 5. Open the oscillography file you just saved. Be sure to change the file format to COMTRADE, as shown in *Figure 3.30*.

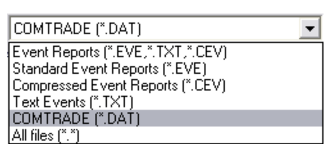


Figure 3.30 Change File Format

Step 6. ACSELERATOR QuickSet displays the **Event Waveform** dialog box and the event oscillogram, as shown in *Figure 3.31*.

NOTE: If your PC is loaded with SEL-5601 Analytic Assistant software (purchased separately), ACSELERATOR QuickSet automatically uses SEL-5601 to provide event analysis functionality. Some of the screen captures and related information may differ from the examples shown in this manual.

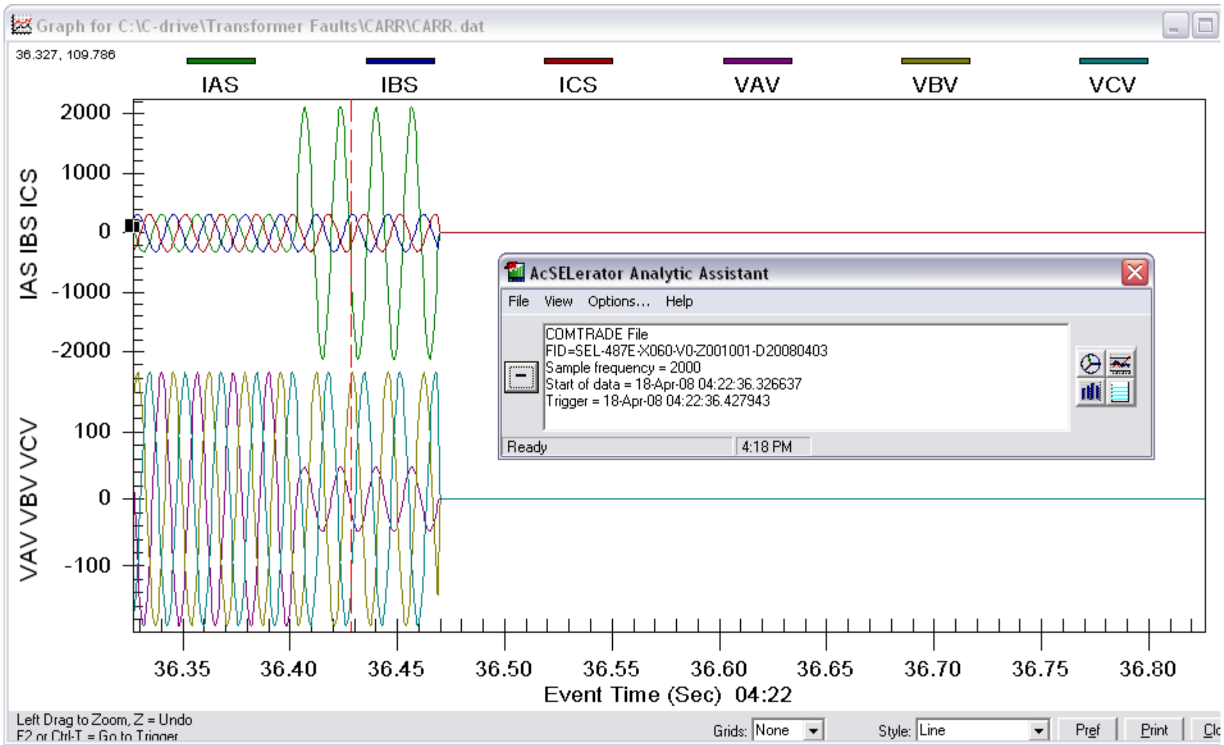


Figure 3.31 Event Waveform Dialog Box and the Event Oscillogram

Step 7. Click on the **Pref** button (bottom right) to remove the voltages (VAV, VBV and VCV) from the display, move the currents IAT, IBT and ICT as well as digital point TRPXFMER, TRXFMR, TRIP and OUT108 into the display, as shown in *Figure 3.32*.

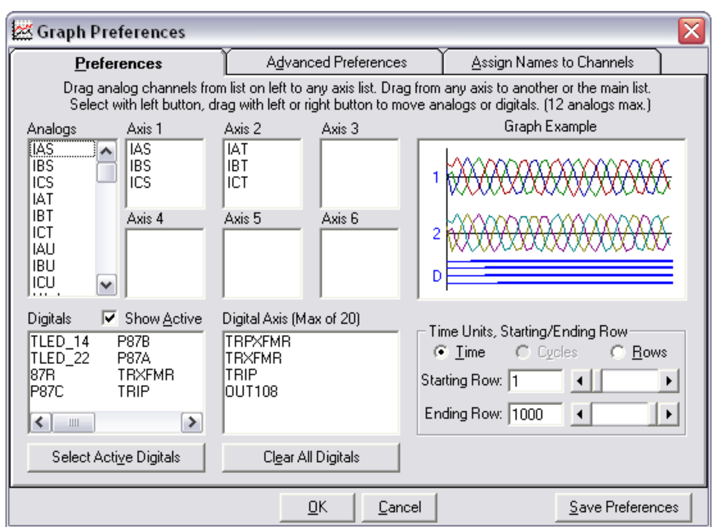


Figure 3.32 Re-arrange Display Quantities

Figure 3.33 shows the event report with the selected quantities.

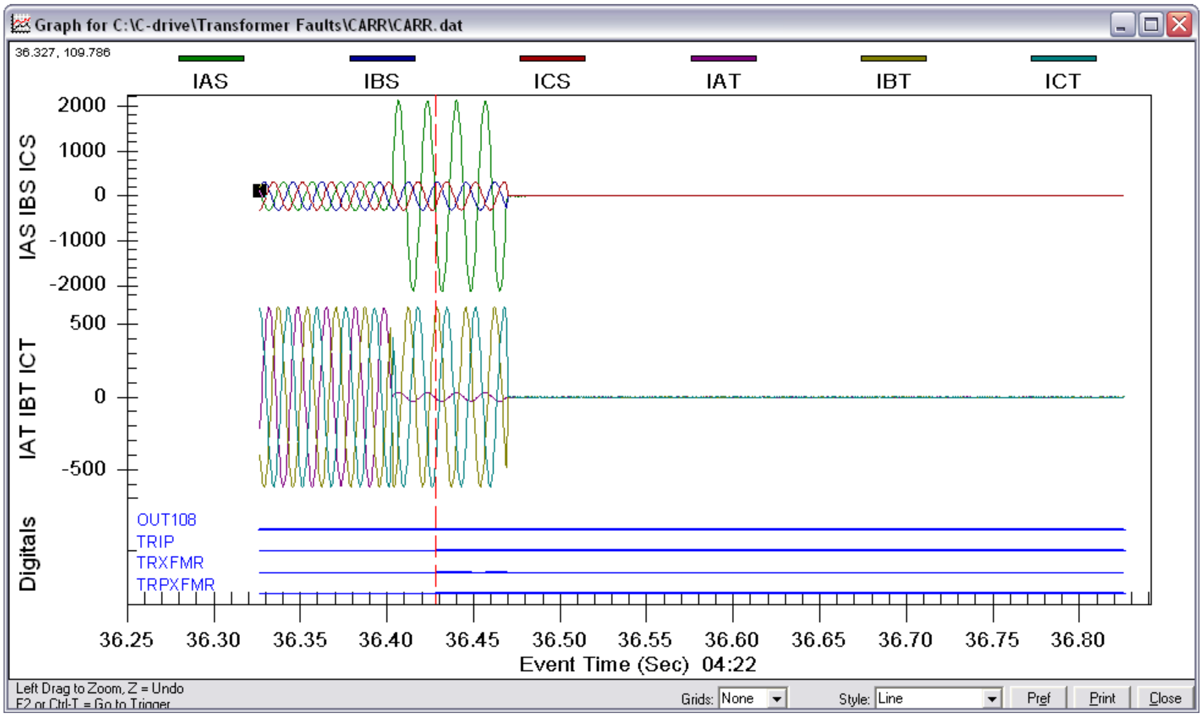


Figure 3.33 Event Report With New Quantities

You can see high-accuracy time-stamp information on the event oscillogram.

When viewing the event oscillogram, use keyboard function keys to measure the time of oscillogram occurrences. These function keys and related functions help in event analysis

<F2>: go to trigger

<F3>: Cursor 1

<F4>: Cursor 2

The display shows the time difference between the **<F3>** and **<F4>** cursors.

Step 8. Click the **Pref** button at the bottom of the oscillogram and select **Time** (under **Time Units, Starting/Ending Row**).

Step 9. Click **OK**.

Step 10. Click on any point in a graph to observe the **Event Time** in microseconds of that data point at the bottom of the oscillogram.

You can also view other event displays:

Step 11. From the **Event Waveform** dialog box, select the **View** menu.

Step 12. Click **Phasors**, as shown in *Figure 3.34*, to view a sample-by-sample phasor display.

NOTE: The Phasors display is designed for 4 or 8-sample per cycle event reports. A warning message is displayed if you are viewing a COMTRADE file that cannot be properly represented in the phasor display.

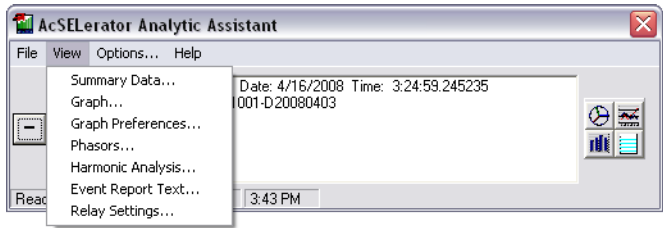


Figure 3.34 View Menu

Figure 3.35 shows the sample-by-sample phasor values.

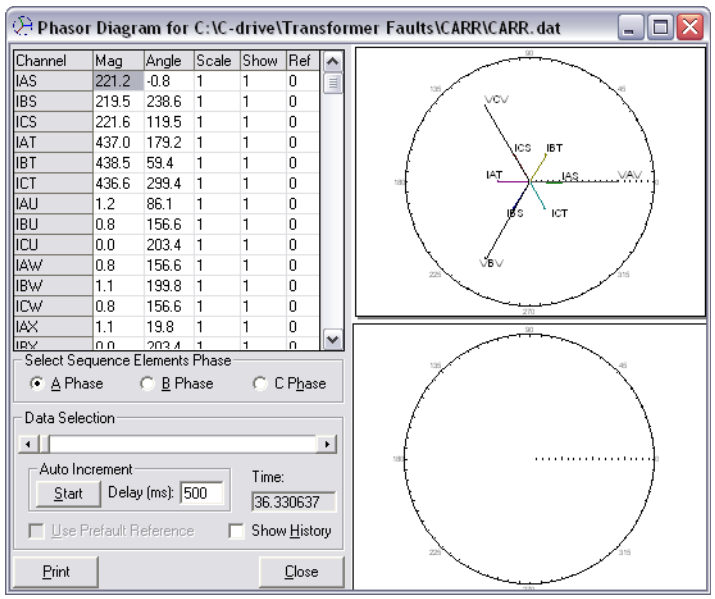


Figure 3.35 Sample Phasors Event Waveform Screen

ACSELERATOR QuickSet also presents a harmonic analysis of power system data for raw data binary COMTRADE event captures.

Step 1. From the **Event Waveform View** menu, click **Harmonic Analysis**.

A window similar to *Figure 3.36* appears.

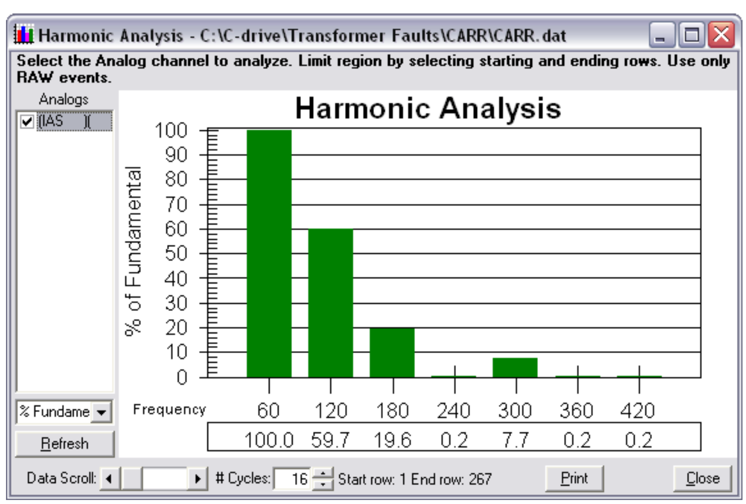


Figure 3.36 Sample Harmonic Analysis Event Waveform Screen

Step 2. On the left side of the **Harmonic Analysis** screen, choose the relay voltage and current channels to monitor for harmonic content.

Step 3. Click the arrows of the **Data Scroll** box or the **# Cycles** box to change the data analysis range.

Step 4. Click **Summary Data** on the **Event Waveform View** menu to see event summary information and to confirm that you are viewing the correct event.

Figure 3.37 shows a sample ACSELERATOR QuickSet **Event Report Summary** screen.

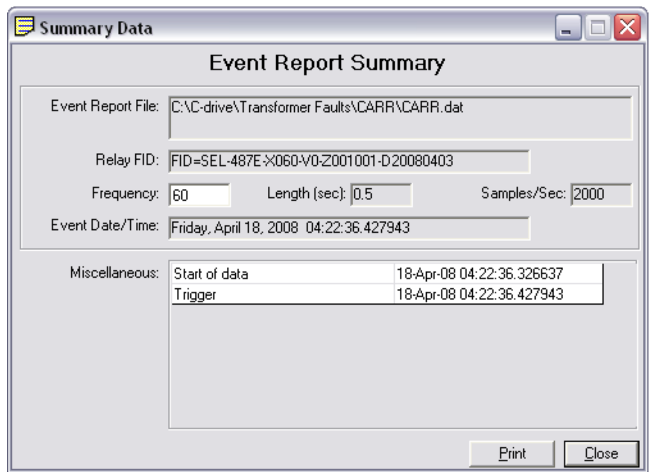
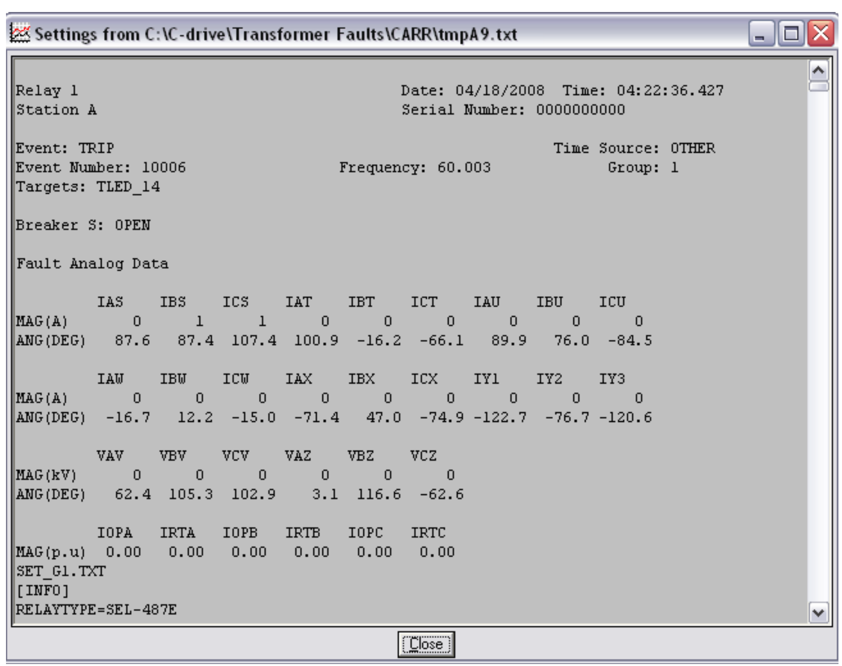


Figure 3.37 Sample Event Report Summary Screen

Step 5. Click **Settings** on the **Event Waveform View** menu to view the relay settings that were active at the time of the event.

Figure 3.38 shows a sample CEV-type event **Settings** screen.




```
Relay 1                                     Date: 04/18/2008  Time: 04:22:36.427
Station A                                   Serial Number: 0000000000

Event: TRIP                                                  Time Source: OTHER
Event Number: 10006                  Frequency: 60.003             Group: 1
Targets: TLED_14

Breaker S: OPEN

Fault Analog Data

         IAS    IBS    ICS    IAT    IBT    ICT    IAU    IBU    ICU
MAG(A)       0      1      1      0      0      0      0      0      0
ANG(DEG)   87.6   87.4  107.4  100.9  -16.2  -66.1   89.9   76.0  -84.5

         IAW    IBW    ICW    IAX    IBX    ICX    IY1    IY2    IY3
MAG(A)       0      0      0      0      0      0      0      0      0
ANG(DEG)  -16.7   12.2  -15.0  -71.4   47.0  -74.9 -122.7  -76.7 -120.6

         VAV    VBV    VCV    VAZ    VBZ    VCZ
MAG(kV)      0      0      0      0      0      0
ANG(DEG)   62.4  105.3  102.9    3.1  116.6  -62.6

         IOPA   IRTA   IOPB   IRTB   IOPC   IRTC
MAG(p.u)  0.00   0.00   0.00   0.00   0.00   0.00
SET_G1.TXT
[INFO]
RELAYTYPE=SEL-487E
```

Figure 3.38 Sample Event Waveform Settings Screen

HMI Meter and Control

Use the ACSELERATOR QuickSet HMI feature to view real-time relay information in a graphical format. Use the virtual relay front panel to read metering and targets and to operate the relay.

Open the ACSELERATOR QuickSet HMI

On the HMI menu, click **Meter and Control**.

ACSELERATOR QuickSet opens the HMI window and downloads the interface data.

ACSELERATOR QuickSet HMI Features

You can use ACSELERATOR QuickSet to access many types of relay information and relay controls.

Step 1. Click the **Tools** on the HMI menu at the top ACSELERATOR QuickSet toolbar and then click **Meter and Control** to access the ACSELERATOR QuickSet HMI, as shown in *Figure 3.39*.

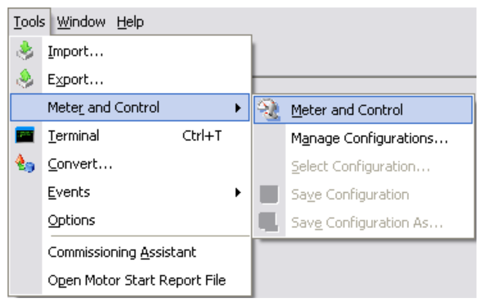


Figure 3.39 Access Meter and Control

Table 3.2 lists the functions in the HMI tree view, a brief explanation of each function, the equivalent ASCII command, and the section where the function is described in more detail the instruction manual. This section details the Device Overview, Phasors, and the Control Window, see the relevant section for m ore information about the other functions.

Table 3.2 ACSELERATOR QuickSet HMI Tree View Functions (Sheet 1 of 2)

Function	Description	ASCII Command
Device Overview	View general metering, selected targets, control input, control outputs, and the virtual front panel.	NA
Phasors	A graphical and textual representation of phase and sequence voltage and current phasors.	**MET <winding>** (*Section 5*)
Targets	View selected Relay Word bits in a row/column format.	**TAR <row number>**
Demand	A table showing demand and peak demand values. Reset buttons are in this display.	**MET D** (*Section 5*)
Synchrophasors	A table showing synchrophasor data, if enabled.	**MET PM** (*Section 5*)
Instantaneous	A table of instantaneous voltages, currents, powers, frequency, and dc monitor voltages.	**MET <winding>** (*Section 5*)
Differential Metering	A table showing differential element metering, if enabled.	**MET DIF** (*Section 5*)
Energy	A table showing energy import/export. A reset button is in this display.	**MET E** (*Section 5*)
Temperature	A table showing temperature values from RTD measurements, if enabled	**MET RTD** (*Section 5*)

Table 3.2 ACSELERATOR QuickSet HMI Tree View Functions (Sheet 2 of 2)

Function	Description	ASCII Command
Protection Math Variables	A table showing the 64 protection math variables	**MET PMV** (*Section 5*)
Automation Math Variables	A table showing the 256 automation math variables	**MET AMV** (*Section 5*)
Remote Analogs	A table showing analog values from MIRRORED BITS	**MET ANA** (*Section 5*)
Through Faults	A table showing through-fault data, if enabled	**TFE** (*Section 5*)
Thermal Monitoring	A table showing data from the transformer thermal model, if enabled.	**THE** (*Section 5*)
Breaker S–Breaker X Monitor Data	A table showing monitoring data for the selected breaker, if enabled.	**BRE <S, T, U, W, X)** (*Section 5*)
Status	A list of relay status conditions.	**STA**
SER	Sequential Events Recorder data listed oldest to newest, top to bottom. Set the range of SER records with the dialog boxes at the bottom of the display	**SER** (*Section 10*)
Control Window	Metering and records reset buttons, trip and close control, output pulsing, target reset, time and date set, group switch, and remote bit control	ASCII commands (*Section 13*)

In the ACSELERATOR QuickSet HMI, an LED representation shows that a color is asserted or "on."

The flashing LED representation in the lower left of each HMI screen indicates an active data update via the communications channel.

Step 2. Click the button marked **Disable Update** to suspend HMI use of the communications channel; again click the Disable Update button to update the HMI.

Step 3. Click on **Device Overview**, causing the screen shown in *Figure 3.40* and *Figure 3.41* to appear.

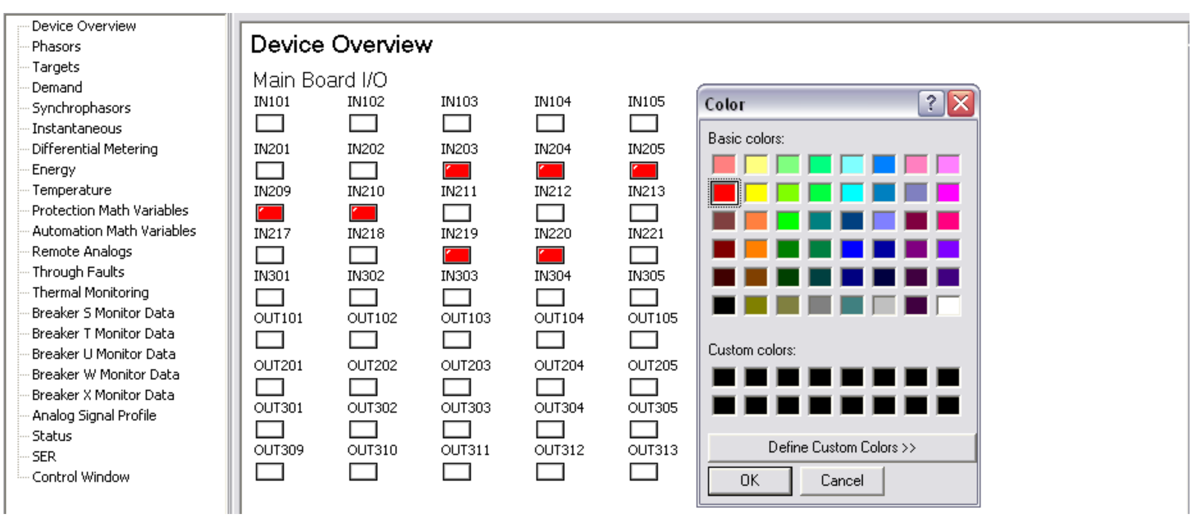


Figure 3.40 Top Half of the Device Overview Screen

Figure 3.40 shows the output contacts of the main board the I/O boards of the relay (two I/O boards in this example). You can choose the color of the LED by clicking on the LED you want to change. The color palette (also shown in *Figure 3.40*) appears. Click on the color you want the LED to show when the contact closes. Changing the color of the LED only affects the HMI; the LED colors on the front panels still show the original colors.

Figure 3.41 shows the bottom half of the Device Overview screen. You can change the LED colors in the same way as in *Figure 3.40*. You have no control over the pushbuttons, except for the **{TARGET RESET}** pushbutton. To reset the **TRIP** LED, click on the **{TARGET RESET}** pushbutton, then click on "Yes."

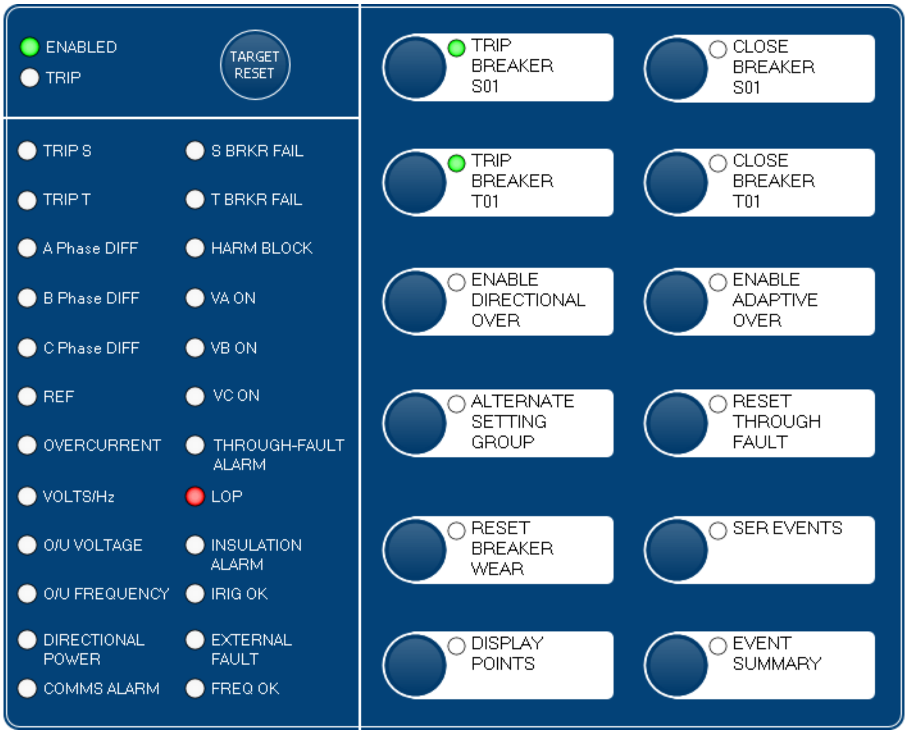


Figure 3.41 Bottom Half of the Device Overview Screen

Step 4. Click on **Phasors** in the tree, causing the screen shown in *Figure 3.42* to appear.

This screen shows the phasor representation of the fundamental current and voltage metering quantities. The phasor quantities do not display the correct magnitude values (see the table at the bottom of the screen for the actual magnitudes), but the angular relationships are correct. Current channels are listed on the left side of the screen, and the voltage channels are listed on the right side of the screen; these channels are always listed, regardless whether the channels are actually in use.

To display analog values do the following:

Step 1. Be sure the channel is included in the ECTTERM (current channels S, T, U, W, X) or the EPTTERM (voltage channels V, Z).

Step 2. Click on each channels you want to display. After you click on the channel, the button appears depressed (IAS, IBS, ICS, IAT, IBT, ICTS, VAZ, VBZ, VCZ) in *Figure 3.42*.

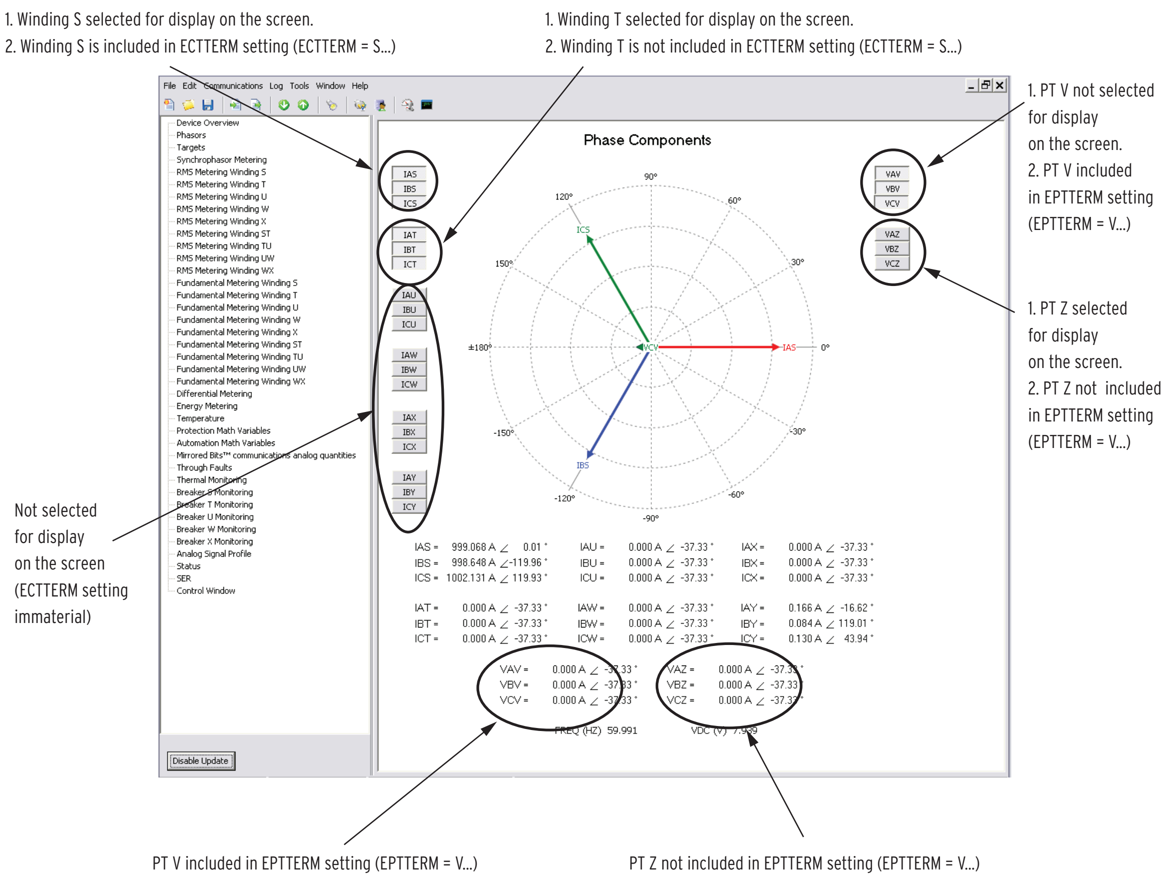
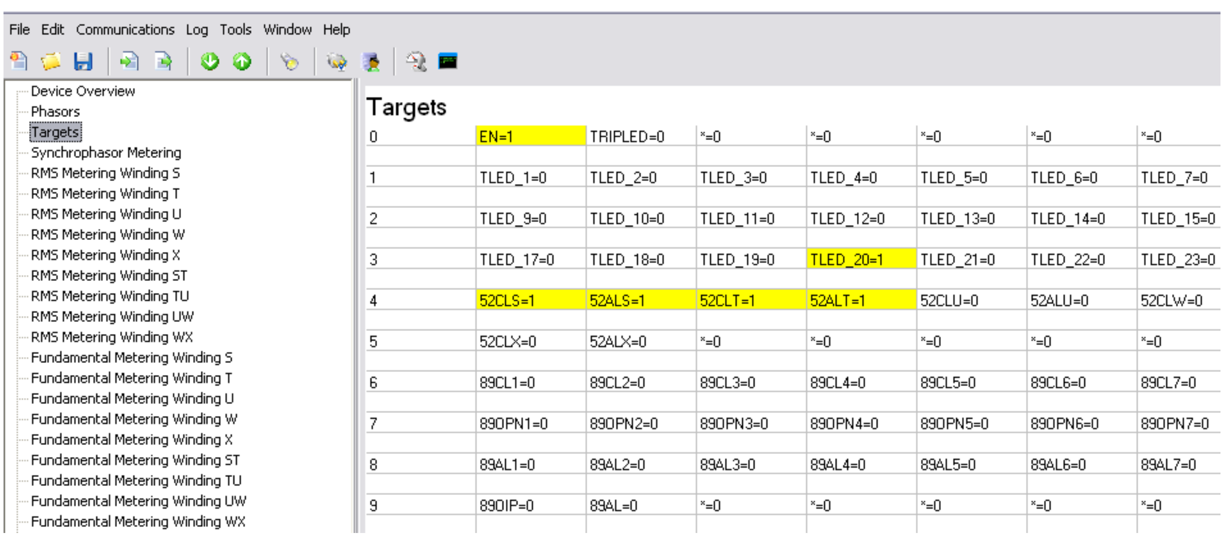


Figure 3.42 Phasor Representation

Step 3. Click on **Targets** in the tree, causing the screen shown in *Figure 3.43* to appear. *Figure 3.43* is a list of selected Relay Word bits. Asserted RWB are highlighted in yellow.



Targets

0	EN=1	TRIPLED=0	*=0	*=0	*=0	*=0	*=0
1	TLED_1=0	TLED_2=0	TLED_3=0	TLED_4=0	TLED_5=0	TLED_6=0	TLED_7=0
2	TLED_9=0	TLED_10=0	TLED_11=0	TLED_12=0	TLED_13=0	TLED_14=0	TLED_15=0
3	TLED_17=0	TLED_18=0	TLED_19=0	TLED_20=1	TLED_21=0	TLED_22=0	TLED_23=0
4	52CLS=1	52ALS=1	52CLT=1	52ALT=1	52CLU=0	52ALU=0	52CLW=0
5	52CLX=0	52ALX=0	*=0	*=0	*=0	*=0	*=0
6	89CL1=0	89CL2=0	89CL3=0	89CL4=0	89CL5=0	89CL6=0	89CL7=0
7	89OPN1=0	89OPN2=0	89OPN3=0	89OPN4=0	89OPN5=0	89OPN6=0	89OPN7=0
8	89AL1=0	89AL2=0	89AL3=0	89AL4=0	89AL5=0	89AL6=0	89AL7=0
9	89OIP=0	89AL=0	*=0	*=0	*=0	*=0	*=0

Figure 3.43 Relay Word Bits

Step 4. Click on **Control Window** in the tree, causing the control screen shown in *Figure 3.44* to appear. You can reset and control a number of functions from this screen.

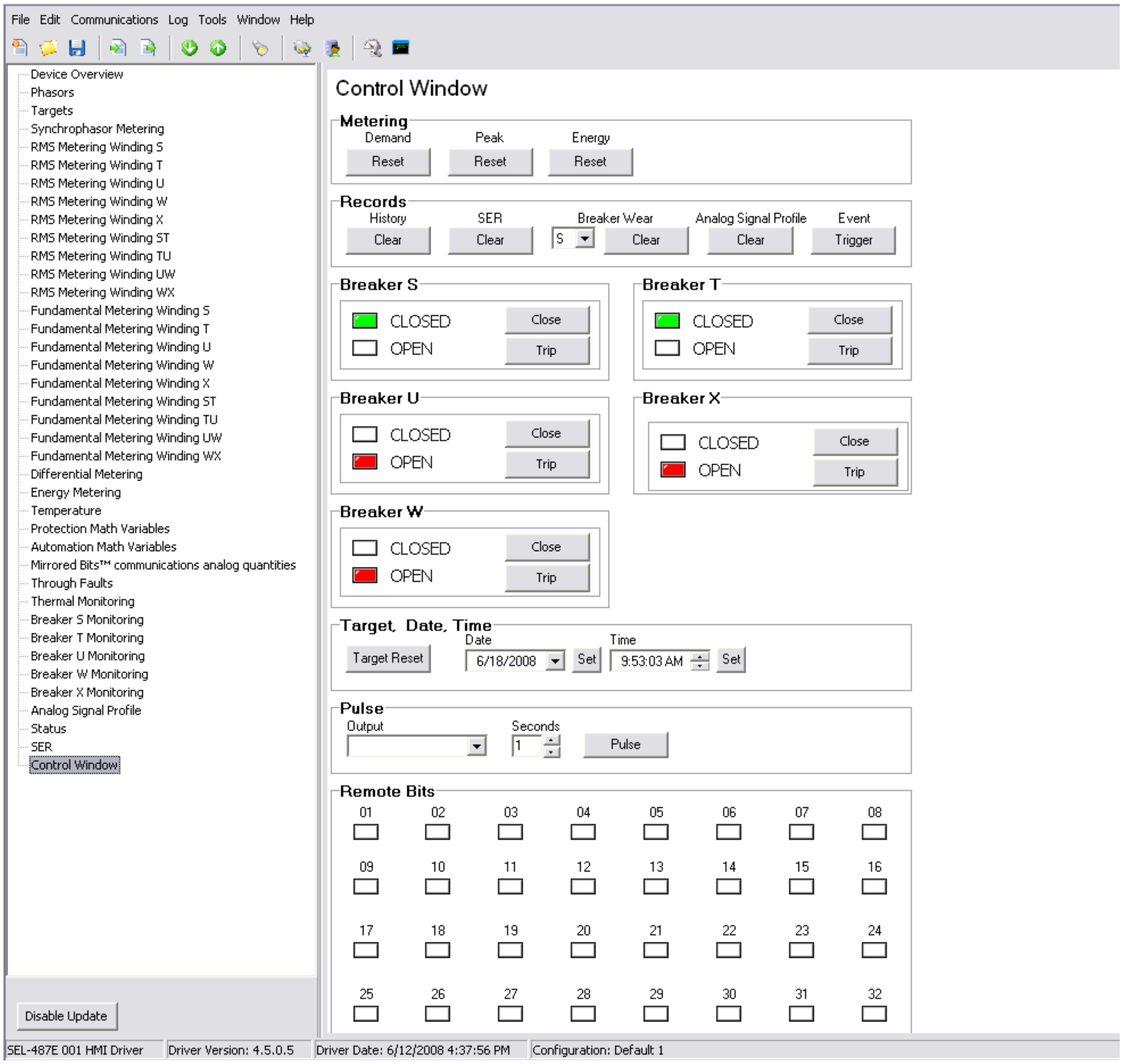


Figure 3.44 Control Screen

At the top, you can reset the Demand and Energy values by clicking on the function you want to reset. Click on the "**Yes**" button to confirm the operation.

Under the Records category, you can trigger an event and clear the following:

- ➤ Event history
- ➤ SER
- ➤ Breaker Wear
- ➤ Analog Signal Profile

If the breaker jumper is in place, you can open and close any of the five breaker by clicking on the **Close** or **Open** buttons.

Reset the front-panel targets, force synchronization to IRIG-B time-coded input and set the date and time from the Target, IRIG, Date and Time control box.

Figure 3.45 shows a pulse operation to pulse an output contact for up to 30 seconds.

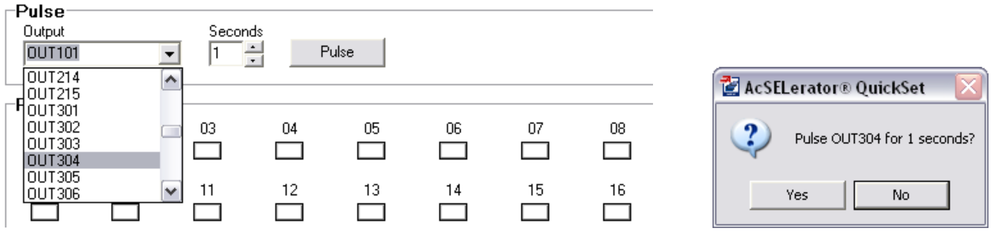


Figure 3.45 Pulse Outputs

Figure 3.46 shows the control screen to set, pulse or clear remote bits.

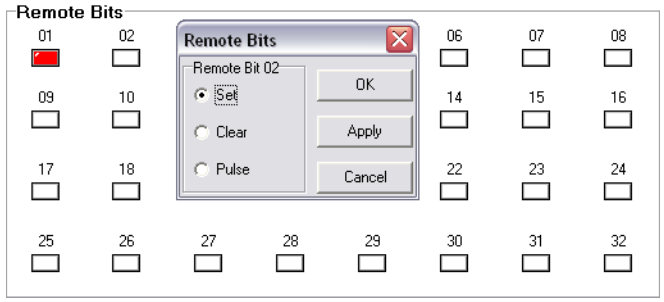


Figure 3.46 Set, Pulse, or Clear Remote Bits

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Section 4

Protection and Logic Functions

Overview

This section provides a detailed explanation of the SEL-487E Relay protection functions. Each subsection provides an explanation of the function, along with a list of the corresponding settings and Relay Word bits. Logic diagrams and other figures are included. *Table 4.15* summarizes the outputs from all protection elements for use in trip equations.

Functions discussed in this section are listed below.

Introduction

In general, three common types of faults occur in power transformers: phase-to-phase faults, phase-to-ground faults, and turn-to-turn faults. Winding configuration, fault location, and load conditions all affect the sensitivity of the traditional phase-percentage differential element. To provide overall transformer protection for all faults, the SEL-487E offers restricted earth-fault protection and negative-sequence differential protection to augment the phase-percentage differential element. Because the phase-percentage differential element has little sensitivity for faults close to neutral, use the restricted earth-fault (REF) element on all grounded wye-connected windings. Restricted earth-fault protection provides protection starting at the first turn from the neutral point. Although load always affects the phase-percentage differential element, turn-to-turn faults are particularly difficult to detect during heavy load conditions. Because negative-sequence current is unaffected by load, use the negative-sequence differential element to detect turn-to-turn faults during heavy load conditions.

Phase-sequence differential elements use an adaptive-slope percentage differential characteristic, as opposed to a dual-slope characteristic. Using an advanced adaptive-slope algorithm that includes filtered differential elements as well as unfiltered differential elements, the SEL-487E operates substantially faster than relays that use the dual-slope percentage differential characteristic. Because the differential element compensates for CT ratio mismatches and any phase angle difference, you can connect all CTs in wye, thus making all metering quantities available. Choose among harmonic blocking, harmonic restraint, or both to obtain relay stability during transformer inrush conditions. Even-numbered harmonics (second and fourth) provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions.

Adaptive Transformer Differential Element

Figure 4.1 shows an overview of the A-phase adaptive differential element of the SEL-487E relay. Because of different harmonic philosophies, the relay includes harmonic blocking and harmonic restraint functions. Although you can select either harmonic blocking or harmonic restraint, selecting both harmonic blocking and harmonic restraint provides a good balance between speed and security.

The internal fault detection supervision adds security during external faults with CT saturation. The harmonic blocking element includes common (cross) second and fourth harmonic blocking and the previously discussed independent fifth harmonic blocking for improved security.

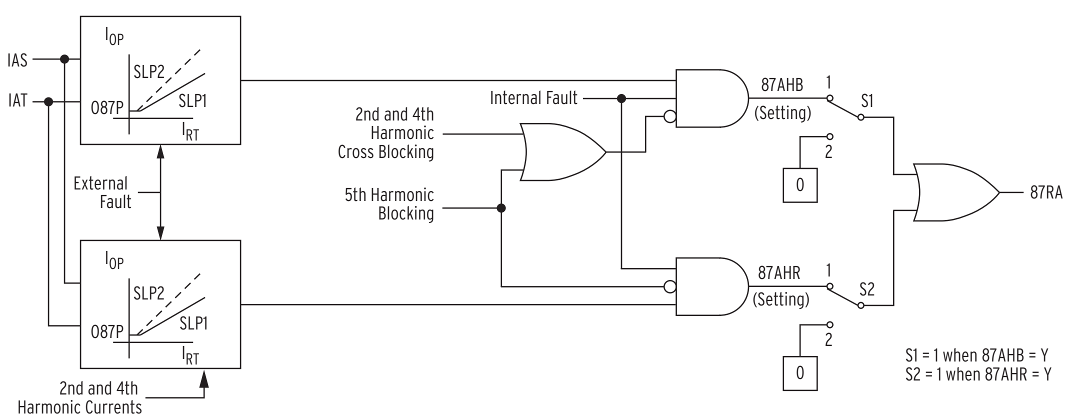


Figure 4.1 Adaptive Differential Element With Harmonic Blocking and Harmonic Restraint in Parallel

Differential Element Operating Characteristic

NOTE: Factor k is 0.5 in the SEL-387 and SEL-587 relays. Take this into consideration when calculating the slope setting. Also see SLP1, SLP2 (Restraint Slope Percentage) on page 4.20.

Although there are a number of differential elements (filtered and unfiltered) in the SEL-487E relay, all differential elements use operate (IOPF*n*, *n* = A, B, C) and restraint (IRTF*n*) quantities that the relay calculates from the winding input currents. *Figure 4.2* shows the characteristic of the filtered differential element as a straight line through the origin of the form

$$\mathrm{IOPFA} = k \bullet \mathrm{SLPc} \bullet \mathrm{IRTFA} \qquad \textbf{Equation 4.1}$$

where:

O87P = minimum IOP level required for operation
IOPFA = operating current
IRTFA = restraint current
c = 1 or 2 (1 if in normal mode, 2 if in high-security mode)
SLP1 = initial slope, beginning at origin
SLP2 = second slope, also starts at the origin
k = 1

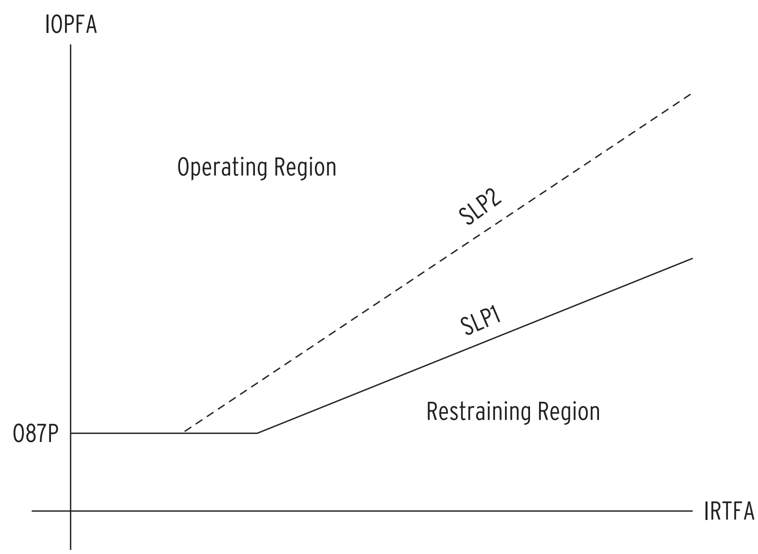


Figure 4.2 Filtered Differential Element Characteristic

NOTE: The relay does not block for external faults, but changes to high security.

For operating quantities (IOPFA) exceeding the threshold level O87P and falling in the operate region of *Figure 4.2*, the filtered differential element issues an output. There are two slope settings: Slope 1 (SLP1) and Slope 2 (SLP2). Slope 1 is effective during normal operating conditions, and Slope 2 is effective when the fault detection logic detects an external fault condition.

In general, the relay uses filtered and unfiltered (instantaneous) analog quantities in two separate algorithms to form the differential element. *Figure 4.3* shows the first stages of the two algorithms for the A-phase current of each terminal. Both algorithms process only the current inputs from those terminals that you select via Group setting E87T. After dividing each input current with the applicable TAP*k* value to form per-unit values, the relay compensates each current channel according to the T*k*CTC Group setting (TAP is a normalization factor that converts current values from ampere to per unit). Group setting T*k*CTC uses 3 x 3 matrix compensation to provide "round the clock" angle compensation for each current input.

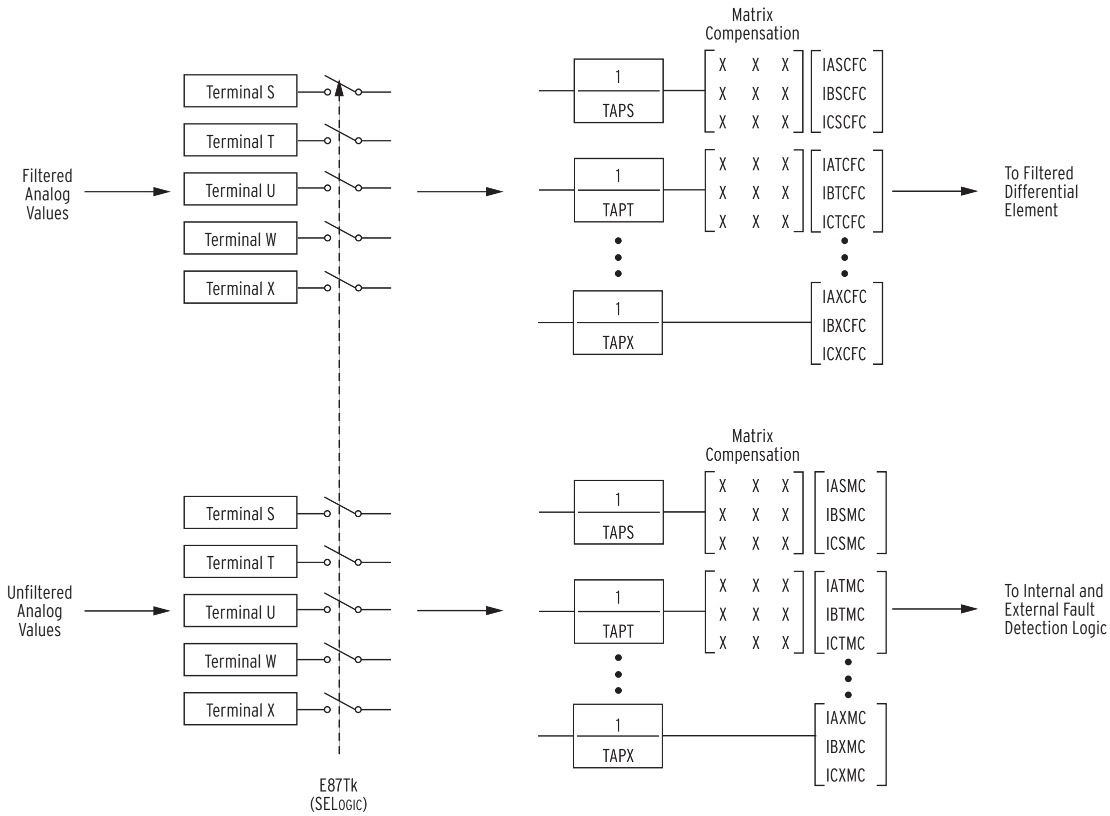


Figure 4.3 Harmonic Filtering and External Fault Detection Logic

Internal and External Fault Detection Logic

Internal Fault Detection Logic

Figure 4.4 shows logic that uses instantaneous quantities to detect an A-phase internal fault (IFTLA) and external fault (CONA). Other phases have similar logic. Elements in the fault detection logic use instantaneous per-unit currents to calculate a restraint quantity, IRTRA, and an operating quantity, IOPRA, according to *Equation 4.2* and *Equation 4.3*.

$$\mathrm{IOPRA} = |\Sigma IAkMC| \qquad \textbf{Equation 4.2}$$

$$\mathrm{IRTRA} = \Sigma|IAkMC| \qquad \textbf{Equation 4.3}$$

where:

IA*k*MC = A-phase instantaneous per-unit current (*k* = S, T, U, W, X)

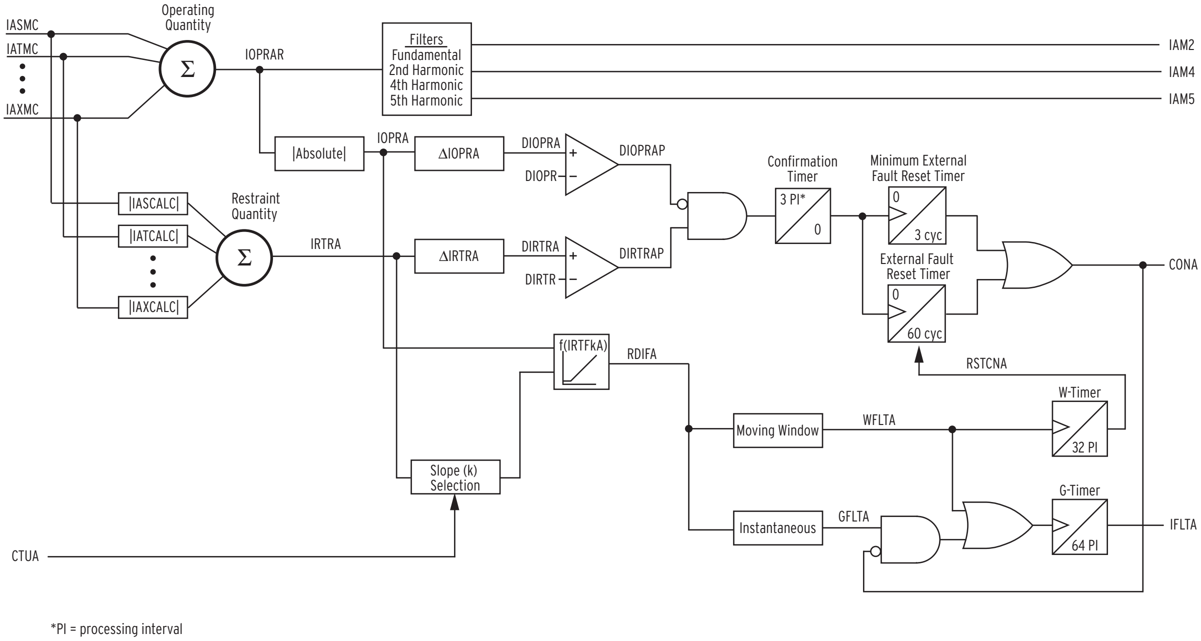


Figure 4.4 A-Phase Internal and External Fault Detection Logic and Harmonic Filtering

Both fault detection logics use the principle that operating and restraint currents increase simultaneously for internal faults, but that only the restraint current increases for external faults (if there is no CT saturation). By comparing the change in operating current (ΔIOPRAP) to the change in restraint current (ΔIRTRAP), the relay distinguishes between external and internal faults. In particular, if DIRTRAP asserts, and DIOPRAP remains de-asserted for 2 ms, then the relay declares the fault as external and asserts Relay Word bit CONA. Conversely, if both DIRTRAP and DIOPRAP assert, then the relay considers the fault to be internal and CONA does not assert.

Two further measurements (instantaneous fault detection and moving window fault detection) ensure that the relay identifies an internal fault correctly. RDIFA, the output from the instantaneous differential element, forms the input into both fault detection modules.

The moving window fault detection logic declares an internal fault when differential current still exists on a consecutive measurement one-half cycle after the instantaneous differential element asserts. Relay Word bit WFLTA asserts when the moving window fault detector logic declares an internal fault.

NOTE: If lightning arrestors within the differential zone at your installation conduct for longer than 1/4 cycle, please contact SEL to adjust the relay to your specification.

If surge (lightning) arrestors are installed within the differential zone, a path to ground exists when these devices conduct, resulting in operating current in the differential elements. The instantaneous fault detection logic qualifies the operating current for a power system quarter cycle to differentiate between operating current resulting from surge arrestor conduction and operating current because of internal faults. Relay Word bit GFLTA asserts when the instantaneous fault detection logic detects an internal fault.

External Fault Detection Logic

Relay Word bit CONA changes the operating mode of the relay to high-security mode, primarily to avoid misoperation resulting from CT saturation for external faults. High security causes the following in the relay:

- Slope 1 changes to Slope 2
- Delay time of the adaptive security timer increases (see *Figure 4.6*)

While the high-security mode provides satisfactory security for through faults, this mode can cause the relay to operate slower for evolving faults (where the fault starts as an external fault and then develops into an internal fault).

To avoid this delayed tripping, the relay uses two timers (minimum external fault reset timer and external fault reset timer) and CT unsaturate logic to switch the relay back to normal operating mode as soon as possible. The minimum external fault reset timer resets after three cycles, ensuring that the relay stays in the high-security mode for at least three cycles after it detects an external fault. The external fault reset timer resets after 60 cycles, or when Relay Word bit RSTCNA asserts. Finally, when there is no danger of CT saturation, Relay Word bit CTUA asserts and resets the fault detector logic to normal mode (the filtered element remains in high-security mode). Resetting the slope latch causes the relay to use the Slope 1 value in the raw differential calculations; the filtered differential element resets only when CONA resets.

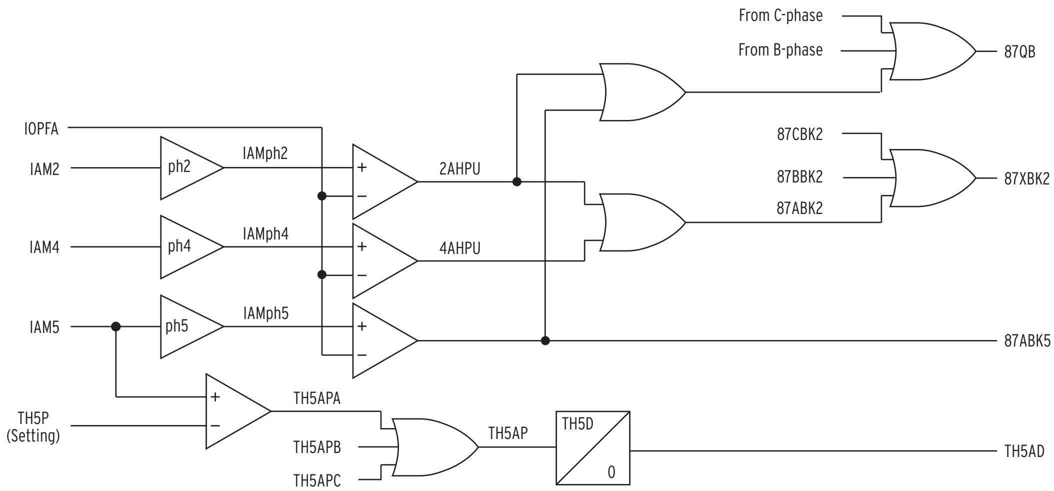
Figure 4.4 also shows the filter function block where the relay calculates the magnitudes of the various harmonics for use in the harmonic blocking, harmonic restraint, and overexcitation elements.

Filtered Differential Element

To avoid relay misoperation during inrush current conditions, the filtered differential element uses harmonics to either block or restrain the differential element. Furthermore, the harmonic blocking functions always operate in cross-blocking mode, whereby the relay blocks all phases when the harmonic magnitude of any phase exceeds the harmonic setting. By contrast, the harmonic restraint functions always operate in independent blocking mode, i.e., no cross blocking between phases.

Harmonic Blocking

Figure 4.5 shows the logic for A-phase harmonic blocking and cross-blocking functions.



where:

ph2 = the second harmonic setting 100/PCT2
ph4 = the fourth harmonic setting 100/PCT4
ph5 = the fifth harmonic setting 100/PCT5

Figure 4.5 Logic for Harmonic Blocking and Cross-Blocking Functions

In *Figure 4.5*, the relay scales the magnitudes of the harmonic quantities (IAM2, IAM4, and IAM5) by the per-unit value of their respective harmonic settings (PCT2, PCT4, and PCT5). After scaling the values, the relay compares each harmonic value against the fundamental quantity IOPFA, and asserts the appropriate Relay Word bits (2AHPU, 4AHPU, 87ABK5) when the calculated values exceed the settings.

When either (or both) second or fourth harmonic exceeds the setting, Relay Word bit 87ABK2 asserts. Output 87XBK2 is the OR combination of the second or fourth harmonic blocking values from the other phases. Output 87XBK2 (cross blocking), together with fifth harmonic blocking, 87ABK5, form the blocking function.

An additional alarm function for the fifth harmonic, to warn of overexcitation, employs a separate threshold (TH5P) and an adjustable timer (TH5D). This threshold and timer may be useful for transformer applications in or near generating stations.

Output 87QB is the OR combination that the relay uses to block the negative-sequence differential element during inrush conditions (see *Figure 4.11*).

Harmonic Restraint, Harmonic Blocking, and the Filtered Differential Elements

NOTE: The SEL-487E restraint quantity IRTFn calculation differs from the SEL-587 and SEL-387 by a factor of 2.

Figure 4.6 shows the A-phase filtered differential element. Using the output quantities from the digital band-pass filter (full-cycle cosine filter), the filtered differential element calculates an operating quantity, IOPFA (*Equation 4.4*), and a restraint quantity, IRTFA, for harmonic blocking (*Equation 4.5*) and IRFHRA for harmonic restraint (*Equation 4.6*).

$$IOPFA = |\Sigma IAkCFC| \quad \textbf{Equation 4.4}$$

$$IRTFA = \Sigma|IAkCFC| \quad \textbf{Equation 4.5}$$

$$IRFHRA = \Sigma|IAkCFC| + IAMph2 + IAMph4 \quad \textbf{Equation 4.6}$$

where:

IA*k*CFC = A-phase filtered per-unit current (*k* = S, T, U, W, X)

IAMph2 = product of the second harmonic current and the second harmonic setting 100/PCT2 (see *Figure 4.5*)

IAMph4 = product of the fourth harmonic current and the fourth harmonic setting 100/PCT4 (see *Figure 4.5*)

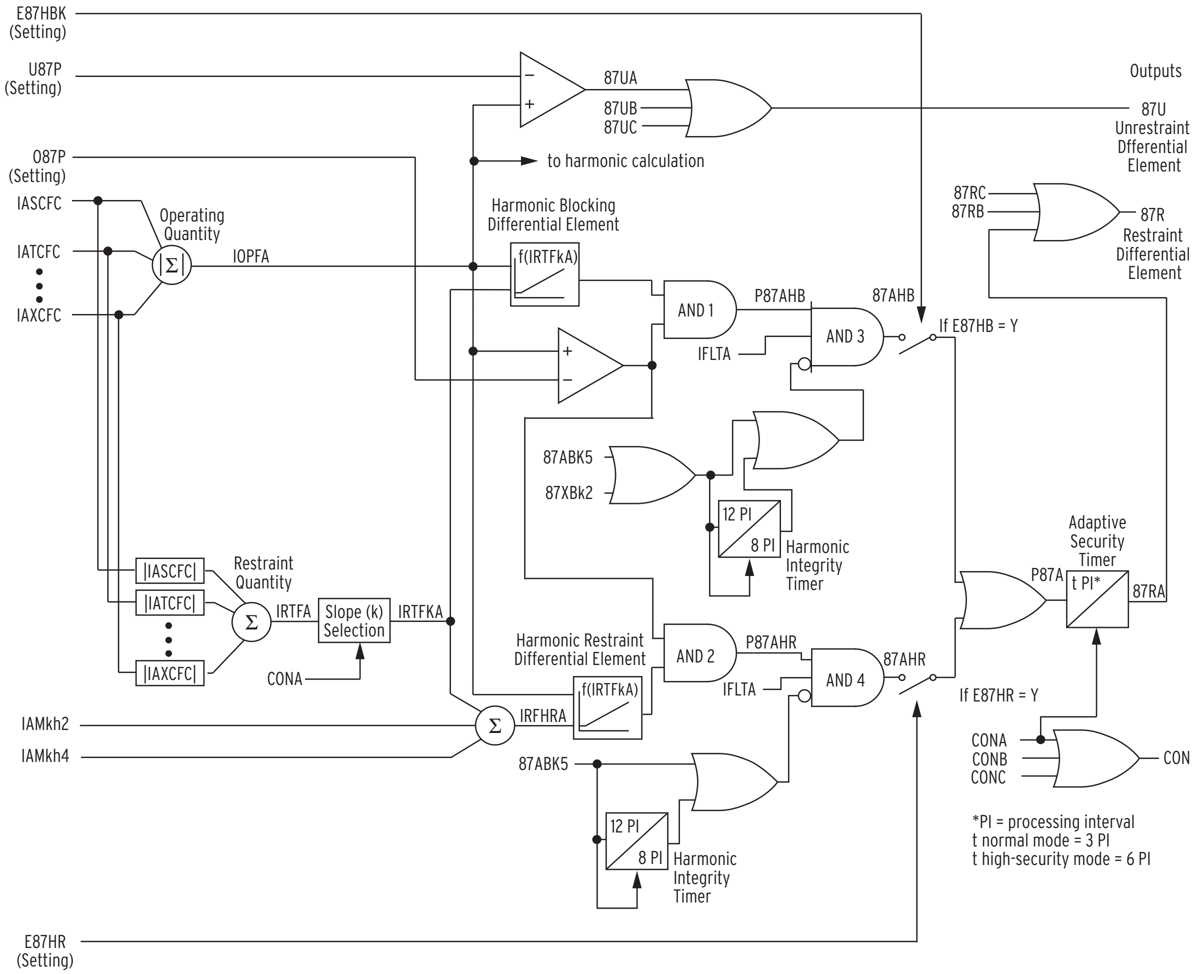


Figure 4.6 Filtered A-Phase Differential Element

Using the filtered, compensated currents (see *Figure 4.3*), the relay calculates the operating (IOPFA) and restraint quantities (IRTFA) used in the filtered differential elements. Both the harmonic blocking and harmonic restraint differential elements are active at all times. Select which element is most suited for your application by setting E87HB = Y (harmonic blocking) or E87HR = Y (harmonic restraint). It is also possible to run both elements in parallel by setting both E87HB = Y and E87HR = Y, which is the setting combination that SEL recommends.

After selecting the correct slope (SLP2 if CONA is asserted or SLP1 if CONA is deasserted), the relay adds the second and fourth harmonic quantities to IRTF*k*A to form IRFHRA. The relay now calculates the differential currents for both the harmonic blocking and the harmonic restraint differential elements.

If the differential current falls in the operate area, and if IOPFA exceeds the O87P value, then AND Gate 1 and AND Gate 2 turn on, and P87AHB and P87AHR assert.

When P87AHB asserts, the top input into AND Gate 3 asserts. AND Gate 3 turns on if the following is also true:

- The fault detection logic detected an internal fault (IFLTA asserted)
- The fifth harmonic block is not asserted (87ABK5 is deasserted)
- Cross blocking is not asserted (87XBK2 is deasserted)

Likewise, when P87AHB asserts, the top input into AND Gate 4 asserts. AND Gate 4 turns on if the following is also true:

- The fault detection logic detected an internal fault (IFLTA asserted)
- The fifth harmonic block is not asserted (87ABK5 is deasserted)

The harmonic integrity timer prevents differential element misoperation when harmonic content momentarily drops below the harmonic threshold setting. Refer to the harmonic blocking part of the logic in *Figure 4.6* for the following discussion (harmonic restraint is similar). When either 87ABK5 or 87XBK2 asserts, 87AHB deasserts. If the OR combination of 87ABK5 or 87XBK2 is asserts continuously for 12 processing intervals (PIs), the harmonic integrity timer activates the 8 PI drop-off timer.

After activation, the dropout timer keeps 87AHB turned off for 8 PIs after the OR combination of 87ABK5 or 87XBK2 deasserts. However, these 8 PIs need not be consecutive. For example, if the OR combination of 87ABK5 or 87XBK2 deasserts for just one PI and then asserts again, the drop-off timer timing value changes from 8 PIs to 7 PIs.

With either harmonic blocking (E87HB) and/or harmonic restraint (E87HR) enabled, the Adaptive Security Timer starts timing when either Gate 3 or Gate 4 turns on. When the Adaptive Security Timer expires, the trip output of the A-phase differential element, Relay Word bit 87RA asserts. Assertion of 87RA asserts Relay Word bit 87R.

Relay Word bit 87R is the OR combination of the outputs from the A-, B-, and C-phase differential elements. Likewise, 87U is the OR combination of 87UA, 87UB, and 87UC.

For your trip equation, use only 87R instead of 87RA, 87RB, and 87RC, and use only 87U instead of 87UA, 87UB, and 87UC.

Setting Descriptions

When one considers the SEL-487E as a device with five sets of three-phase current inputs, three single-phase current inputs, and two sets of three-phase voltage inputs, the application possibilities are considerable. For example, a wye/delta, two-winding transformer requires only two sets of three-phase current inputs for differential protection and one single-phase current input for REF. This leaves three 3-phase current inputs and two single-phase current inputs available for other functions, such as overcurrent protection for a distribution feeder or frame leakage protection for metal-clad switchgear. To simplify the setting process, the settings are arranged in a multitier structure to allow enabling and control of input currents for the appropriate application.

Tier 1

First-tier settings identify which of the 21 analog inputs (CTs and PTs), excluding the three REF (IY1, IY2, IY3) channels, the relay processes. Enable the REF channels under the restricted earth-fault settings category. Settings on the first tier include the following settings:

ECTTERM, EPTTERM

Terminals entered here are function independent. Entering a terminal here does not indicate the intended functional use (differential, REF, etc.); such entry instructs the relay to process the analog inputs from these terminals.

Tier 2

After you select the appropriate analog channels, use Tier 2 settings to enable the protection functions required for your particular application. Settings on the second tier include the following enable settings:

E87, EREF, E50, E51, E46, E59, E27, E81, E24, EBFL, EPCAL, E32, EDEM

Tier 3

The third tier is usually in the form of a torque control (TC) SELOGIC® control equation, and is not available for all protection functions. This tier provides conditional availability of protection elements, because the settings are function dependent. For example, Terminal S is enabled (ECTTERM = S, T,…) and assigned to the differential element (E87 = S, T,…). Third-tier setting E87T provides a method to dynamically enable/disable current S in the differential element. Settings on the third tier include the following settings:

E87T[S,T,U,W,X], TCREF[1–3], 51TC[1–20], 24TC, 27TC[1–5], 59TC[1–5], EXBF[S,T,U,W,X], BFI[S,T,U,W,X], E32OP[01–10], EDM[01–10]

ECTTERM, EPTTERM (CT and PT Terminal Enable)

Identify which of the 21 analog inputs (CTs and PTs), excluding the three REF (IY1, IY2, IY3) channels, the relay processes. Enable the REF channels under the restricted earth-fault settings category.

Setting	Prompt	Range	Default	Category
ECTTERM	Enable Current Terminals	OFF or combo of S, T, U, W, X[a]	S, T	Group
EPTTERM	Enable Voltage Terminals	OFF or combo of V, Z	OFF	Group

[a] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

E87 (Enable Differential Element Protection Terminals)

The SEL-487E has five sets of three-phase current inputs. Depending on the application, you may not need all of these inputs for the differential protection. All terminals not included in the differential element are available for other protection such as stand-alone overcurrent protection. The E87 setting specifies which of the terminals the relay is to include in the differential calculation.

Setting	Prompt	Range	Default	Category
E87	Enable Diff Elem. Prot. Terms	OFF or combo of S, T, U, W, X	S, T	Group

MVA (Maximum Transformer Capacity, Three-Phase MVA)

Use the highest expected transformer rating, such as the forced oil and air cooled (FOA) rating or a higher emergency rating, when setting the maximum transformer capacity.

Setting	Prompt	Range	Default	Category
MVA	Transformer Max. Power Capacity	OFF, 1 to 5000	OFF	Group

E87Tk (Terminals Included in the 87 Element)

Use this SELOGIC control equation to specify operational conditions to include/exclude those terminals specified with the E87 setting in the differential calculations. For example, assume you have a three-winding autotransformer and the 22 kV tertiary delta of the autotransformer is a standby supply for a small 22 kV network. Further assume that the tertiary delta winding connects to the 22 kV busbar through a circuit breaker (CBD) that is normally open, and will only be closed under emergency conditions. You assign Terminal S (HV), Terminal T (LV), and Terminal U (tertiary delta) as the terminals for the differential element. Because the default settings are set to 1, Terminals S and T are already part of the differential element, i.e.:

E87TS = 1

E87TT = 1

Terminal U is only part of the differential element if CBD is closed. Wire a 52A contact to input IN101, and set the SELOGIC control equations for Terminal U as follows:

E87TU = IN101

With this setting, Terminal U is part of the differential element only when CBD is closed.

Setting	Prompt	Range	Default	Category
E87T*k*[a]	SELOGIC Equation	NA	1	Group

[a] k = S, T, U, W, X.

ICOM (Internal CT Connection Compensation)

This Yes/No setting defines whether the input currents need any correction, either to accommodate phase shifts in the transformer or CTs or to remove zero-sequence components from the secondary currents. If this setting is Yes (Y), the relay permits you (see *TkCTC (Internal CT Connection Compensation)*) to define the amount of shift needed to properly align the secondary currents for the differential calculation.

Setting	Prompt	Range	Default	Category
ICOM	Internal CT Conn. Compensation Enabled	Y, N	OFF	Group

TkCTC (Internal CT Connection Compensation)

These settings define the amount of compensation the relay applies to each set of winding currents to properly account for phase shifts in transformer winding connections and CT connections. For example, this correction is needed if both wye and delta power transformer windings are present, but all of the CTs are connected in wye. The effect of the compensation is to create phase shift and to remove zero-sequence current components.

Setting	Prompt	Range	Default	Category
T*k*CTC[a]	Terminal [*n*] CT Conn. Compensation	0 to 12	12	Group

[a] k = S, T, U, W, X.

General Discussion of Connection Compensation

The general expression for current compensation is as follows:

$$\begin{bmatrix} \mathrm{IA}k\mathrm{CFC} \\ \mathrm{IB}k\mathrm{CFC} \\ \mathrm{IC}k\mathrm{CFC} \end{bmatrix} = \begin{bmatrix} X & X & X \\ X & X & X \\ X & X & X \end{bmatrix} \bullet \begin{bmatrix} \mathrm{IA}k\mathrm{CF} \\ \mathrm{IB}k\mathrm{CF} \\ \mathrm{IC}k\mathrm{CF} \end{bmatrix}$$

where:

IA*k*CF, etc. = the three-phase currents entering terminal "*k*" of the relay

IA*k*CFC, etc. = the corresponding phase currents after compensation

$$\begin{bmatrix} X & X & X \\ X & X & X \\ X & X & X \end{bmatrix} = [\mathrm{CTC}(m)]$$

a three-by-three compensation matrix (*m* = 0, 1, 2, …, 11, 12)

Setting T*k*CTC specifies which compensation matrix the differential element is to use. The setting values are 0 through 12. These values physically represent the number of increments of 30 degrees that a *balanced set of currents with ABC phase rotation* will be rotated in a *counterclockwise* direction when multiplied by [CTC(*m*)]. For example, setting TSCTC = 1 rotates the Terminal S set of currents counterclockwise by 30 degrees. If a given set of such currents is multiplied by all 12 of the CTC matrices, the resulting compensated values would seem to move completely around the circle in a counterclockwise direction, returning to the original start position.

If a *balanced set of currents with ACB phase rotation* undergoes the same exercise, the rotations by the [CTC(*m*)] matrices are in the clockwise direction. This is because the compensation matrices, when performing phasor addition or subtraction involving B or C phases, will produce mirror image shifts relative to A-phase, when ACB phase rotation is used instead of ABC.

In ACB phase rotation, the three phases still rotate in a counterclockwise direction, but C-phase is in the 120-degree lagging position and B-phase leads by 120 degrees, relative to A-phase. The discussions below assume ABC phase rotation, unless stated otherwise.

The 0 setting value creates no changes at all in the currents but multiplies them by an identity matrix. Thus, for T*k*CTC = 0, we obtain the following:

$$[CTC(0)] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

that is,

IA*k*CFC = IA*k*CF

IB*k*CFC = IB*k*CF

IC*k*CFC = IC*k*CF

The TKCTC(1) setting performs a 30-degree compensation in the counterclockwise direction, as would a delta CT connection of type DAB (Dy1). The name for this connection comes from the fact that the polarity end of the A-phase CT connects to the nonpolarity end of the B-phase CT, and so on, in forming the delta. Therefore, the DAB (Dy1) connection results from the following relationships:

$$IAkCFC = \frac{(IAkCF - IBkCF)}{\sqrt{3}}$$

$$IBkCFC = \frac{(IBkCF - ICkCF)}{\sqrt{3}}$$

$$ICkCFC = \frac{(ICkCF - IAkCF)}{\sqrt{3}}$$

Setting T*k*CTC = 1 realizes the above mentioned relationships, and the relay uses the following [CTC(*m*)] matrix to compensate the currents:

$$\left[CTC(1)\right] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$$

Similarly, a setting of 11 performs a 330-degree compensation (11 • 30) in the counterclockwise direction, or a 30-degree compensation in the clockwise direction, as would a delta CT connection of type DAC (Dy11). The name for this connection comes from the fact that the polarity end of the A-phase CT connects to the nonpolarity end of the C-phase CT, and so on, in forming the delta. Thus, for T*k*CTC = 11, the relay uses the following [CTC(*m*)] matrix:

$$\left[CTC(11)\right] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$$

that is

$$IAkCFC = \frac{(IAkCF - ICkCF)}{\sqrt{3}}$$

$$IBkCFC = \frac{(IBkCF - IAkCF)}{\sqrt{3}}$$

$$ICkCFC = \frac{(ICkCF - IBkCF)}{\sqrt{3}}$$

The compensation matrix [CTC(12)] is similar to [CTC(0)], in that it produces no phase shift (or, more correctly, 360 degrees of shift) in a balanced set of phasors separated by 120 degrees. However, it removes zero-sequence components from the winding currents, as do all of the matrices having nonzero values of *m*, i.e., all matrices except [CTC(0)].

$$[CTC(12)] = \frac{1}{3} \bullet \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$$

that is

$$IAkCFC = \frac{(2 \bullet IAkCF - IBkCF - ICkCF)}{3}$$

$$IBkCFC = \frac{(-IAkCF + 2 \bullet IBkCF - ICkCF)}{3}$$

$$ICkCFC = \frac{(-IAkCF - IBkCF + 2 \bullet ICkCF)}{3}$$

We could use this type of compensation in applications having wye-connected transformer windings (no phase shift) with wye CT connections for each winding. Using T*k*CTC = 12 for each winding removes zero-sequence components, just as connection of the CTs in delta would do, but without producing a phase shift. (One might also use T*k*CTC = 1 or 11 for this same application, yielding compensation similar to that from connection of the CTs on both sides in DAB or DAC.) The effect of each compensation on balanced three-phase currents is to rotate the currents *m* • 30 degrees without a magnitude change. *Table 4.1* shows the complete list of compensation matrices.

Table 4.1 Complete List of Compensation Matrices (m = 1 to 12) (Sheet 1 of 2)

$[CTC(1)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$	$[CTC(2)] = \frac{1}{3} \bullet \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & 1 \end{bmatrix}$
$[CTC(3)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix}$	$[CTC(4)] = \frac{1}{3} \bullet \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix}$
$[CTC(5)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$	$[CTC(6)] = \frac{1}{3} \bullet \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix}$

Table 4.1 Complete List of Compensation Matrices (m = 1 to 12) (Sheet 2 of 2)

$[CTC(7)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix}$	$[CTC(8)] = \frac{1}{3} \bullet \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix}$
$[CTC(9)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{bmatrix}$	$[CTC(10)] = \frac{1}{3} \bullet \begin{bmatrix} 1 & 1 & -2 \\ -2 & 1 & 1 \\ 1 & -2 & 1 \end{bmatrix}$
$[CTC(11)] = \frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$	$[CTC(12)] = \frac{1}{3} \bullet \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$

Selecting the Correct Values of TkCTC for Each Winding

The process of choosing the correct T*k*CTC setting value for each winding involves a complete knowledge of the transformer winding connections and phase relationships, the CT connections, and the system phase rotation (ABC or ACB). The following brief review discusses the nature of various connections, their phase shifts, and the relative motion for selecting T*k*CTC based on system phase rotation.

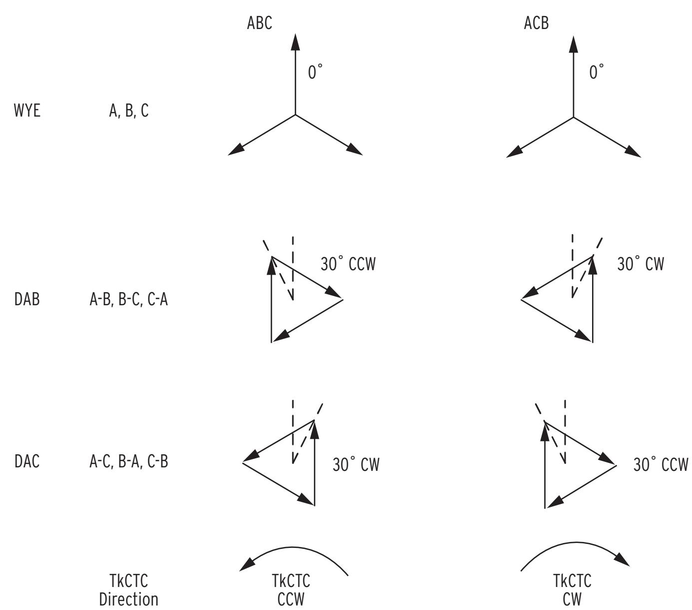


Figure 4.7 Winding Connections, Phase Shifts, and Compensation Direction

Wye (star) connections consist of connecting one end of each winding to a common or neutral point, leaving the other ends of each winding for the line terminals. Because the windings do not interconnect at the line ends, the line current equals the respective winding current (A, B, or C) and no phase shift occurs in the line currents with respect to the winding currents. The neutral point, if it is grounded, permits flow of zero-sequence current components in the windings and line outputs.

There are two possible delta connections. In determining T*k*CTC, it is essential to know not only that the CTs or transformer windings are connected in delta but in which of the two possible delta connections. In this manual, we call these delta connections DAB and DAC. In the DAB connection, the polarity end of the A-phase winding connects to the nonpolarity end of the B-phase winding, and so on, to produce the delta connection. In the DAC connection, the polarity end of the A-phase winding connects to the nonpolarity end of the C-phase winding, and so on, to produce the delta connection. In *Figure 4.7*, an arrowhead indicates the polarity end of each winding.

These arrangements involve a connection point between two windings at each line terminal; the line currents are not the same as the winding currents, but are the phasor difference between the associated winding currents. Therefore, the line currents shift in phase by some amount with respect to the winding currents. In the DAB delta connection, the line currents are the differences between the following phase currents: A-B, B-C, and C-A. In the DAC connection, the line currents are the differences between the following phase currents: A-C, B-A, and C-B.

In a system with ABC phase rotation (A-phase as reference), B lags A by 120 degrees, and C leads A by 120 degrees. The DAB connection line current at Terminal A is A-B, which is a phasor that leads A-phase winding current by 30 degrees. For this reason, DAB is often referred to as the “leading connection.” However, DAB is the leading connection only for ABC phase rotation. In the ACB phase rotation, C lags A by 120 degrees, and B leads A by 120 degrees. Terminal A line current is still A-B, but current now lags A winding current by 30 degrees. The DAC connection produces opposite shifts to DAB. In the ABC phase rotation, line current from Terminal A is A-C, which lags A winding current by 30 degrees. In the ACB phase rotation, line current A is still A-C, but this result leads A winding current by 30 degrees.

Five-Step Compensation Process

The process of determining T*k*CTC for each winding involves the following five basic steps. Two examples illustrate important points about the five steps.

Step 1. Establish the phase direction for the A-phase terminal line voltage for each three-phase winding of the transformer.

(This step requires transformer nameplate drawings and/or internal connection diagrams.)

Step 2. Adjust the A-phase terminal line voltage direction for each set of input currents by the phase shift (if any) of the current transformer connection. (See *Figure 4.7*.)

Step 3. Select any one of the adjusted A-phase terminal directions from *Step 2* to serve as the reference direction.

The relay compensates all other windings to line up with this reference.

Step 4. Choose a T*k*CTC setting for each set of winding input currents.

This setting is the number of 30-degree increments needed to adjust each nonreference winding to line it up with the reference. This number will range from 0 to 12 increments. For ABC phase rotation, begin at the winding direction and proceed in a counterclockwise direction until you reach the reference. For ACB phase rotation, begin at the winding direction and proceed in a clockwise direction until you reach the reference. *Figure 4.7* shows these compensation directions.

Step 5. If any winding needs no phase correction (zero degrees), but is a grounded-wye winding having wye-connected CTs, choose T*k*CTC = 12, rather than T*k*CTC = 0, for that winding.

This setting removes zero-sequence current components from the relay currents to prevent false differential tripping on external ground faults. All non-zero values of T*k*CTC remove zero-sequence current.

Setting TkCTC Selection (DABY Example)

Figure 4.8 illustrates the first example. This is a three-winding transformer with a DAB delta primary and two lower voltage secondaries connected in grounded wye. Both the 24.9 kV and the 14.4 kV windings have wye-connected CTs, but the 115 kV winding has DAB delta-connected CTs. Assuming ABC phase rotation, when we use the "hour of the clock" convention to specify transformer connections, the transformer is a "Dy1y9" connection. This means that the transformer has a high-voltage delta whose reference is "noon," a wye secondary winding whose direction is at "one o'clock," and another whose direction is "9 o'clock" with respect to the direction of the delta. The CT currents go to relay winding inputs S, T, and U, from left to right as *Figure 4.8* illustrates.

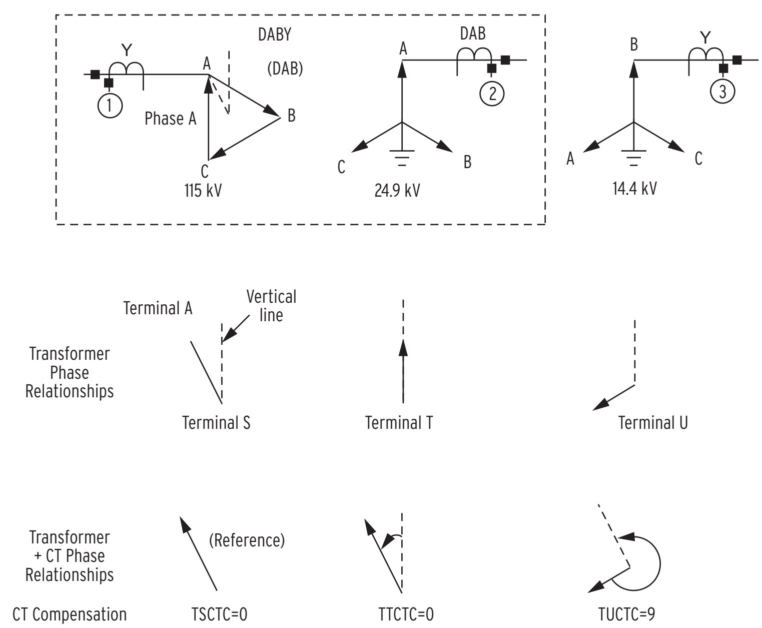


Figure 4.8 TkCTC Selection Example

When we consider only the 115 kV and the 24.9 kV windings, the transformer in the box represents a traditional DABY two-winding application. This application has wye-connected CTs on the delta side and delta-connected CTs on the wye side, using the same CT delta connection as the delta winding of the transformer. Perform the following steps to handle these traditional connections.

Step 1. Select a reference direction for the transformer.

You can use one of the winding directions as the reference, but this need not be the case. You could establish any of the 12 possible directions, separated by 30 degrees around the complete circle of 360 degrees, as the reference. All windings would then receive adjustments to correlate them with this reference. In this example, the 115 kV winding direction serves as reference.

Step 2. Establish the phase relationships resulting from the transformer vector group connections.

Refer to the row below the transformer winding drawings in *Figure 4.8* (labeled "Transformer Phase Relationships") and note that the Terminal A line current of the 115 kV winding is at 30 degrees counterclockwise from the vertical position, as we would expect for a DAB connection with ABC phase rotation. Terminal A of the 24.9 kV winding is in phase with the vertical position. To make the example more interesting, Terminal A of the 14.4 kV winding is at 120 degrees counterclockwise from vertical.

Step 3. Adjust the phase relationships resulting from the CT connections.

Because the secondary currents of wye-connected CTs do not change their phase relationship with respect to the primary currents, the phases of the secondary currents of the 115 kV and 14.4 kV windings remain in the same relationship as the primary currents. This means that the secondary current of Terminal A of the 115 kV winding remains at 30 degrees counterclockwise from the vertical position, and that the secondary current of Terminal A of the 14.4 kV winding remains at 120 degrees counterclockwise from the vertical position. However, the secondary currents of the 24.9 kV winding, with DAB-connected CTs, move through 30 degrees in the counterclockwise direction. *Figure 4.8* shows this adjustment in the bottom line (labeled "Transformer + CT Phase Relationships").

Step 4. Choose T*k*CTC settings for each of the three windings.

Because Terminal S is the reference, we need no adjustment for Terminal S; the setting is TSCTC = 0 (or 12). Because the 115 kV windings are connected in delta (no zero-sequence current can flow in the lines), you can set TSCTC = 0. However, for wye-connected windings (and wye-connected CTs), you must set TSCTC = 12 to remove the zero-sequence current. Note that the adjusted 24.9 kV inputs coincide exactly with the reference direction; we need make no adjustment for the 24.9 kV winding either. Although the windings are wye-connected and grounded, the CTs are connected in delta, and no zero-sequence current flows to the relay. In this case, you can set TSCTC = 0. Had the CTs also been connected in wye, you would have had to set TSCTC = 12 to remove the zero-sequence current.

As discussed previously, these two windings represent a classical DABY application. We can see this from the fact that the TkCTC setting is zero for both windings. In this case, the CT connections themselves perform exactly the right correction without additional compensation from the relay. The final winding inputs still reside at the "8 o'clock" position and need adjustment to the reference at "11 o'clock." Beginning at the Terminal U direction, the compensation direction is counterclockwise until arrival at the reference. This compensation requires nine increments of 30 degrees (or 9 “hours”) in the counterclockwise direction. We therefore set TUCTC = 9.

Step 5. As a final step, ensure that no wye-connected winding having wye-connected CTs is set at T*k*CTC = 0 (uncompensated).

Were this the case, zero-sequence currents could appear in these relay inputs but in no others, and a possible false trip could occur for external ground faults. Any non-zero value of T*k*CTC will eliminate the zero-sequence currents. In this example, the only wye winding with wye CTs is Terminal U, which we have compensated by TUCTC = 9. The selection is complete. The relay receives the three settings as TSCTC = 0, TTCTC = 0, and TUCTC = 9.

VTERMk (Terminal Line-to-Line Voltage)

Enter the nominal line-to-line transformer terminal voltages. If the transformer differential zone includes a load tap-changer, assume that the tap-changer is in the neutral position. The setting units are kilovolts.

Setting	Prompt	Range	Default	Category
VTERM*k*[a]	Terminal [*k*] Line-to-Line Voltage	1.00 to 1000 kV	275	Group

[a] k = S, T, U, W, X.

TAPk (Terminal Line-to-Line Voltage)

Upon your entry of an MVA setting (i.e., MVA is not set to “OFF”), the relay uses the MVA, winding voltage, CT ratio, and CT connection settings you have entered and calculates the TAP*k* values automatically. You can also enter tap values directly. Set MVA = OFF, and enter the TAPS through TAPX values directly, along with the other pertinent settings.

$$TAP = \frac{MVA \bullet 1000}{\sqrt{3} \bullet VTERM \bullet CTR} \bullet C$$

Equation 4.7

where:

MVA = Transformer maximum MVA (MVA)
VTERM = Terminal line-to-line voltage of the winding (kV)
CTR = CT ratio
C = 1 if CTCON = Y (wye- or star-connected CTs)
C = $\sqrt{3}$ if CTCON = D (delta-connected CTs)

The relay calculates TAP with the following limitations:

1. The TAP settings are within the range $0.1 \bullet I_{NOM}$ and $35 \bullet I_{NOM}$ (I_{NOM} = 1 A or 5 A)
2. The ratio $TAP_{MAX} / TAP_{MIN} \le 35$

Setting	Prompt	Range	Default	Category
TAP*k*[a]	Terminal [*n*] Current Tap	0.50 to 175.00	1	Group

[a] k = S, T, U, W, X.

O87P (Restrained Element Operating Current Pickup)

Set the operating current pickup at a minimum for increased sensitivity but high enough to avoid operation because of steady-state CT error and transformer excitation current. To ensure proper relay operation, be sure to select a setting value that satisfies the following equation:

$$O87P \geq \frac{0.1 \bullet I_{NOM}}{TAPk} \qquad \textbf{Equation 4.8}$$

Setting	Prompt	Range	Default	Category
O87P	Differential Element Oper. Current PU	0.10 to 4	0.5	Group

SLP1, SLP2 (Restraint Slope Percentage)

Use restraint slope percentage settings to discriminate between internal and external faults. Set SLP1 and SLP2 to accommodate differential current resulting from power transformer tap-changer, CT saturation, CT errors, and relay error.

We derive the Slope 1 setting (SLP1) as follows:

Assume the CT error, ε, is equal to ±10 percent. In per unit:

$\varepsilon = 0.1$

Assume the voltage ratio variation of the power transformer load tap-changer (LTC), *a*, is from 90 percent to 110 percent. In per unit:

$a = 0.1$

In a through-current situation, the worst-case theoretical differential current occurs when all of the input currents are measured with maximum positive CT error, and all of the output currents are measured with maximum negative CT error while also being offset by maximum LTC variation. Therefore, the greatest differential current one can expect for through-current conditions is as follows:

$$Id\max = \left[(1+\varepsilon) \bullet \sum_{''IN''} ITn\right] - \left[\frac{(1-\varepsilon)}{1+a} \bullet \sum_{''OUT''} ITn\right] \qquad \textbf{Equation 4.9}$$

where the summation terms are the total input and output power transformer secondary currents after tap compensation. Per-unit current entering the transformer equals the per-unit current exiting the transformer, so the summation terms cancel, and we can express the maximum differential current (*Id*max) as a percentage of winding current:

$$\begin{aligned} Id\max &= (1+\varepsilon) - \frac{(1-\varepsilon)}{(1+a)} \\ &= \frac{(2 \bullet \varepsilon) + a + (\varepsilon \bullet a)}{(1+a)} \bullet 100 \\ &= 28.18\% \end{aligned} \qquad \textbf{Equation 4.10}$$

In addition to the error we just calculated, we must consider additional errors from transformer excitation current (≅2 percent) and relay measurement error (<5 percent). The maximum total error is 35 percent. Therefore, if we use only one slope, a conservative slope setting, SLP1, is about 35 percent. This represents a fixed percentage differential application and is a good average setting for covering the entire current range.

In the following text, we briefly discuss the correlation between the percentage error and the relay slope setting (also see *87RA, 87RB and 87RC Restrained Differential Elements on page 14.33*. For this discussion, consider a two-winding transformer, with I1 flowing toward the transformer and I2 flowing away from the transformer (*Figure 4.9*).

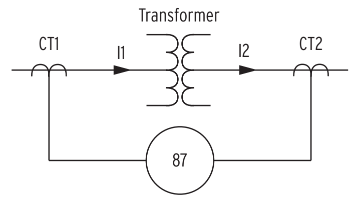


Figure 4.9 Two-Winding Transformer

In general, Slope 1 of the differential element characteristic in SEL percentage differential elements is a straight line through the origin, as *Equation 4.11* represents.

$$\mathrm{IOP(IRT)} = \mathrm{k} \bullet \mathrm{SLP1} \bullet \mathrm{IRT} \qquad \textbf{Equation 4.11}$$

where:

k = design constant (either 0.5 or 1)
SLP1 = Slope 1
IRT = restraint current

The relay uses *Equation 4.12* to calculate the differential current (Idiff), and it uses *Equation 4.13* to calculate the restraint current (IRT).

$$\mathrm{Idiff} = |\overline{\mathrm{I1}} + \overline{\mathrm{I2}}| \qquad \textbf{Equation 4.12}$$

$$\mathrm{IRT} = |\overline{\mathrm{I1}}| + |\overline{\mathrm{I2}}| \qquad \textbf{Equation 4.13}$$

where I1 and I2 are per-unit vector quantities.

To calculate I1 and I2, evaluate the IN (I1) and OUT (I2) values of *Equation 4.9* separately.

$$\mathrm{I1} = (1 + \varepsilon) = 1.1 \text{ pu}$$

and

$$\mathrm{I2} = \frac{(1 - \varepsilon)}{(1 + \mathrm{a})} = 0.818 \text{ pu}$$

Use *Equation 4.12* to calculate Idiff.

$$\mathrm{Idiff} = |\overline{\mathrm{I1}} + \overline{\mathrm{I2}}|$$

$$\mathrm{Idiff} = |1.1 - 0.818| = 0.282 \text{ pu (or 28.18 percent as before)}$$

Use *Equation 4.13* to calculate the restraint current.

$$\mathrm{IRT} = |\overline{\mathrm{I1}}| + |\overline{\mathrm{I2}}|$$

$$\mathrm{IRT} = |1.1| + |0.818| = 1.918 \text{ pu}$$

Evaluate *Equation 4.11* with SLP1 = 0.35 (35%) and k = 0.5.

$$IOP(IRT) = k \bullet SLP1 \bullet IRT \text{ pu}$$
$$IOP(IRT) = 0.5 \bullet 0.35 \bullet 1.918$$
$$IOP(IRT) = 0.34 \text{ pu}$$

This value is slightly less than 0.35 because IRT is 1.918 and not 2. However, 0.34 is still greater than 0.282 by an acceptable margin. Because 0.34 is greater than 0.282, the relay does not operate.

Consider now the case of the SEL-487E with k = 1. The maximum differential error is 0.282 pu as before, and the restraint current is 1.918 pu as before. Evaluate *Equation 4.11* with SLP1 = 0.35 (35%) and k = 1.

$$IOP(IRT) = k \bullet SLP1 \bullet IRT$$
$$IOP(IRT) = 1 \bullet 0.35 \bullet 1.918$$
$$IOP(IRT) = 0.67 \text{ pu}$$

The value of 0.67 pu is much greater than 0.282, and is an extremely conservative setting. In this case, divide 0.35 by 2 and set the relay to 18 percent.

$$IOP(IRT) = 1 \bullet 0.18 \bullet 1.918$$
$$IOP(IRT) = 0.345 \text{ pu}$$

During external faults, the relay changes to high-security mode and switches from Slope 1 to Slope 2 to avoid relay misoperation resulting from CT saturation. In contrast to small CT errors for load current, CT errors during external faults can be quite large. Although CT saturation resulting from high-current magnitude is less likely to occur with low-impedance relays, the dc component of the primary current can still cause severe CT saturation. During CT saturation, current resulting from CT errors appears as differential current and can cause relay misoperation.

To avoid relay misoperation, set Slope 2 as high as possible. Normally, a high Slope 2 setting causes slow tripping for evolving faults (external-to-internal faults). However, because the differential element in the SEL-487E requires less than 1.5 cycles to return to normal mode for an evolving fault, a Slope 2 setting as high as 90 percent is acceptable.

Setting	Prompt	Range	Default	Category
SLP1	Slope 1 Percentage	5.00 to 100%	35	Group
SLP2	Slope 2 Percentage	5.00 to 100%	75	Group

Differential Element Settings in SEL-487E, SEL-387, and SEL-587

The SEL-487E restraint quantity IRT*n* calculation differs from the SEL-587 and SEL-387 by a factor of 2. In order to achieve the same characteristics for the differential elements in the SEL-487E, SEL-387, and SEL-587, this factor of 2 has to be accounted for. The relationships between differential element settings for the three relays are shown below:

Convert SEL-387 and SEL-587 Relay Settings to the SEL-487E Relay.

$$O87P_{487E} = O87P_{387/587}$$

$$SLP1_{487E} = 1/2 \bullet SLP1_{387/587}$$

$SLP2_{487E} = 1/2 \bullet SLP2_{387/587}$

$U87P_{487E} = U87P_{387/587}$

Convert SEL-487E Relay Settings to the SEL-387 and SEL-587 Relays.

$O87P_{387/587} = O87P_{487E}$

$SLP1_{387/587} = 2 \bullet SLP1_{487E}$

$SLP2_{387/587} = 2 \bullet SLP2_{487E}$

$U87P_{387/587} = U87P_{487E}$

U87P (Unrestrained Element Current Pickup)

NOTE: The SEL-487E uses the total value of the restraint current. The SEL-387 and SEL-587 relays use half the restraint current (IRT/2).

The purpose of the instantaneous unrestrained current element is to react quickly to very heavy current levels that clearly indicate an internal fault. Set the pickup level (U87P) to about 8 times tap. The unrestrained differential element only responds to the fundamental frequency component of the differential operating current. It is unaffected by the SLP1, SLP2, PCT2, PCT4, PCT5 settings, so there is no harmonic blocking/restraint for this element during inrush conditions. Thus, you must set the element pickup level high enough that the element does not react to large inrush currents.

Setting	Prompt	Range	Default	Category
U87P	Unrestrained Element Current PU	1.00 to 20	8	Group

DIOPR and DIRTR (Incremental Operate and Restraint Threshold)

The relationship between the change in operating current and the change in restraint current determines the relay mode of operation. A change in restraint current without a change in operating current causes the relay to change to high-security mode, while a change in both restraint current and operating current causes the relay to trip. In setting the incremental quantities (DIOPR and DIRTR), we must consider the effect of load current on relay operation.

For low DIRTR settings, the relay enters the high-security mode for small changes in load current. Although the relay detects evolving faults (external to internal) in a short time, there is a time delay (less than one cycle) when the relay changes to internal fault detection. We should, therefore, select a step value that indicates an external fault rather than an increase in load current.

In general, we want to enter the high-security mode of operation when there is a danger of CT saturation for external faults. DIOPR and DIRTR default settings of 1.2 per unit provide satisfactory results in most applications.

Setting	Prompt	Range	Default	Category
DIOPR	Incr. Operate Current Threshold p.u.	0.10 to 10	1.2	Group
DIRTR	Incr. Restraint Current Threshold p.u.	0.10 to 10	1.2	Group

E87HB (Enable Harmonic Blocking)

Choose among harmonic blocking, harmonic restraint, or both to obtain relay stability during transformer inrush conditions (see *Figure 4.6*). Select E87HB = Y to enable harmonic blocking. Note that the relay always operates in cross blocking (common harmonic blocking) mode.

Setting	Prompt	Range	Default	Category
E87HB	Enable Harmonic Blocking Diff. Element	Y, N	N	Group

E87HR (Enable Harmonic Restraint)

Choose among harmonic blocking, harmonic restraint, or both to obtain relay stability during transformer inrush conditions (see *Figure 4.6*). Select E87HR = Y to enable harmonic restraint.

Setting	Prompt	Range	Default	Category
E87HR	Enable Harmonic Restraint Diff. Element	Y, N	Y	Group

PCT2, PCT4, PCT5 (Second-, Fourth-, and Fifth-Harmonic Percentage of Fundamental)

NOTE: The larger the PCT2, PCT4, or PCT5 setting, the smaller the effect of the setting.

The SEL-487E measures the amount of second-, fourth-, and fifth-harmonic current flowing in the transformer (see *Figure 4.5* and *Figure 4.6*). With older transformers, magnetizing inrush current contains high percentages of second and fourth harmonics. However, some types of newer transformers may require setting the threshold as low as 7 percent.

When the volt/hertz function is unavailable, use the fifth harmonic measurement to assert an alarm output during startup. This alarm indicates current in excess of the rated transformer excitation current. At full load, a TH5P setting of 0.1 corresponds to 10 percent of the fundamental current. Use Timer TH5D to prevent the relay from indicating transient presence of fifth harmonic currents. You might consider triggering an event report if transformer excitation current exceeds the fifth-harmonic threshold.

There are two criteria for setting TH5P:

- $TH5P \cdot TAP_{MIN} \geq 0.05 \cdot I_{NOM}$
- $TH5P \cdot TAP_{MAX} \leq 35 \cdot I_{NOM}$

where TAP_{MIN} and TAP_{MAX} are the least and greatest, respectively, of the tap settings.

To disable a harmonic function, set that setting to OFF.

Setting	Prompt	Range	Default	Category
PCT2	Second-Harmonic Percentage	OFF, 5 to 100%	15	Group
PCT4	Fourth-Harmonic Percentage	OFF, 5 to 100%	15	Group
PCT5	Fifth-Harmonic Percentage	OFF, 5 to 100%	35	Group
TH5D	Fifth-Harmonic Alarm Delay	0.000 to 8000 cycles	30	Group
TH5P	Fifth-Harmonic Alarm Threshold p.u.	OFF, 0.2–3.2	OFF	Group

Negative-Sequence Percentage Differential Element

During heavy load conditions, the resulting increase in restraint current renders the phase-differential element less sensitive, particularly from detecting transformer winding interturn faults. Because negative-sequence currents are unaffected by load in a balanced system, the negative-sequence percentage differential element provides sensitive protection for winding interturn faults.

Figure 4.10 shows the trajectory of a fault that shorts out 2 percent of the A-phase of a three-phase transformer. In the phase-differential operation portion of *Figure 4.10*, the transformer is fully loaded, and the phase-differential relay operates when the operate current reaches around 0.43 per unit. *Figure 4.10* also shows the negative-sequence differential element response for the same fault. Because balanced load does not affect negative-sequence current, the negative-sequence element operates when the operate current reaches 0.1 per unit.

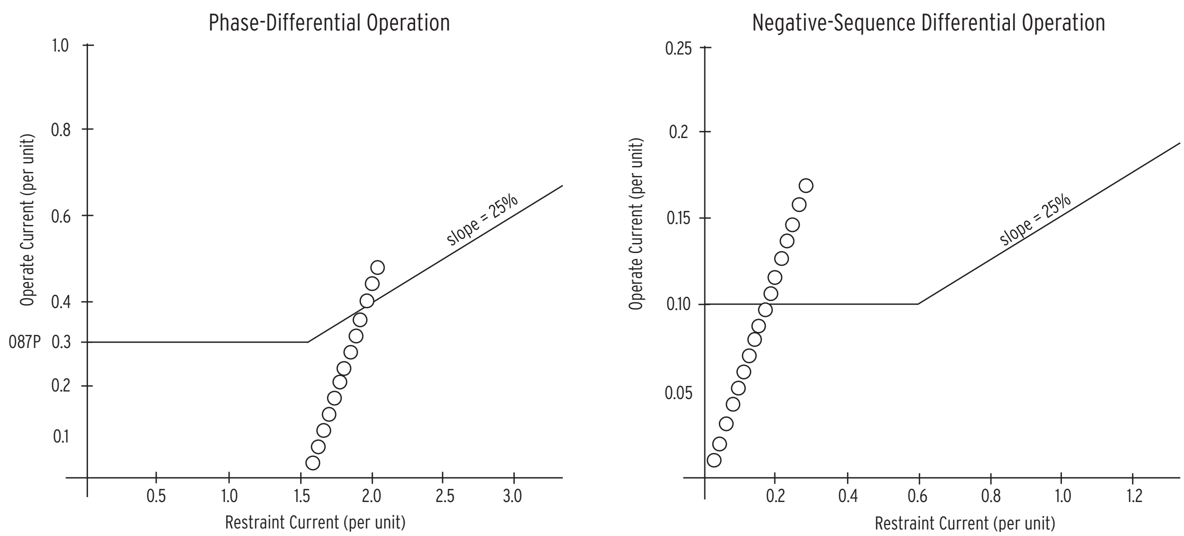


Figure 4.10 Differential Operations

The relay uses compensated currents (see *Figure 4.3*) and *Equation 4.14* to calculate the negative-sequence currents for the differential element (ABC phase rotation).

$$312kC = \begin{bmatrix} 1 & a^2 & a \end{bmatrix} \bullet \begin{bmatrix} IAkCFC \\ IBkCFC \\ ICkCFC \end{bmatrix} \qquad \textbf{Equation 4.14}$$

where:

a = e^{j120}
a^2 = e^{j240}

$$IOP87Q = |\Sigma 312kC| \qquad \textbf{Equation 4.15}$$

$$RST87Q = \max(|312kC|) \qquad \textbf{Equation 4.16}$$

NOTE: CON is the OR combination of CONA, CONB, and CONC.

Figure 4.11 shows the logic that forms the negative-sequence differential relay. In the figure, the relay calculates the operating current in a similar way as the phase-differential relay. However, the restraint current is the maximum of the negative-sequence currents among the windings that are part of the differential calculations. After evaluating the operating and restraint currents in the differential element, the relay verifies that the fault is indeed internal (CON is deasserted) and that harmonic blocking (87QB) is deasserted (no inrush condition). See *Figure 4.5*.

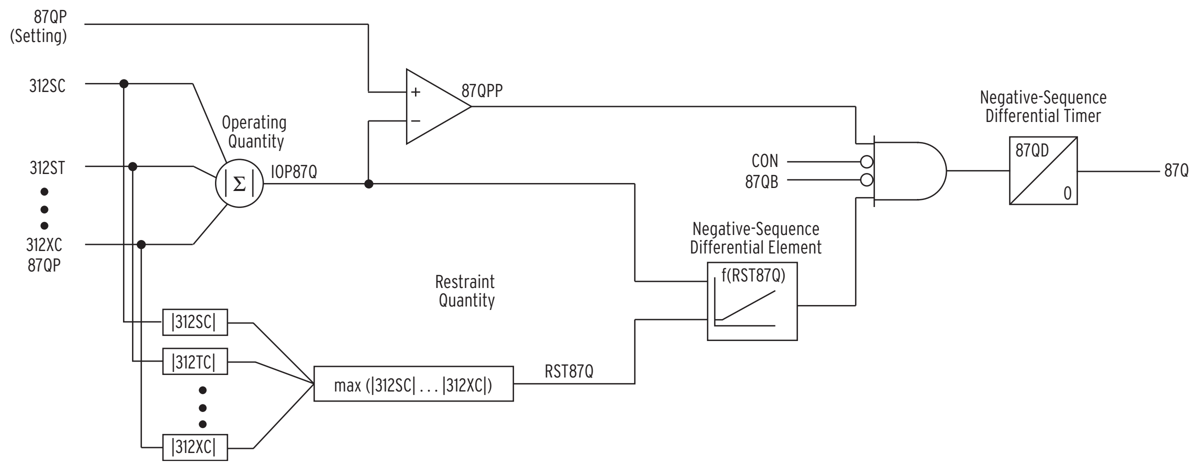


Figure 4.11 Negative-Sequence Differential Relay Logic

For added security, set the negative-sequence differential element delay to the recommended delay of 5 cycles.

Setting	Prompt	Range	Default	Category
87QP	Neg. Seq. Differential Op current	0.05 to 1	0.1	Group
SLPQ1	Neg. Seq. Differential Slope	5 to 100%	25	Group
87QD	Neg. Seq. Differential Element Delay	2.000 to 9999 cycles	10	Group

It is vital that you select adequate current transformers for a transformer differential application. Use the following procedure (based on ANSI/IEEE Standard C37.110-1996) *IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes*.

CT Sizing

Sizing a CT to avoid saturation for the maximum asymmetrical fault current is ideal but not always possible. Such sizing requires CTs with C-voltage ratings greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

CT Ratio Selection for a Multiwinding Transformer

Step 1. Determine the secondary side burdens in ohms for all current transformers connected to the relay.

Step 2. Select the CT ratio for the highest-rated winding (CTRS, for example) by considering the maximum continuous secondary current, I_{HS}, based on the highest MVA rating of the transformer.

For wye-connected CTs, the relay current, I_{REL}, equals I_{HS}. For delta-connected CTs, I_{REL} equals $\sqrt{3} \bullet I_{HS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \bullet I_{NOM}$ and $1.0 \bullet I_{NOM}$ A secondary, where I_{NOM} is the relay nominal secondary current, 1 A or 5 A.

Step 3. Select the remaining CT ratios (CTRT–CTRX) by considering the maximum continuous secondary current, I_{LS}, for each winding.

Typically, the CT ratio is based on the rated maximum MVA of the particular winding. If the MVA rating is much smaller than the rating of the largest winding (typically the case for the tertiary delta winding), you can violate the tap ratio limit for the SEL-487E (see *Step 4* and *Step 5*). As before, for wye-connected CTs, I_{REL} equals I_{LS}. For delta-connected CTs, I_{REL} equals $\sqrt{3} \bullet I_{LS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \bullet I_{NOM}$ and $1.0 \bullet I_{NOM}$ A secondary.

Step 4. The SEL-487E calculates settings TAPS through TAPX if the ratio TAP_{MAX}/TAP_{MIN} is less than or equal to 35.

When the relay calculates the tap settings, it reduces CT mismatch to less than 1 percent. Allowable tap settings are in the range $(0.1–35) \bullet I_{NOM}$.

Step 5. If the ratio TAP_{MAX}/TAP_{MIN} is greater than 35, select a different CT ratio to meet the above conditions.

You can often do this by selecting a higher CT ratio for the smallest rated winding, but you may need to apply auxiliary CTs to achieve the required ratio. Repeat *Step 2* through *Step 5*.

Step 6. Calculate the maximum symmetrical fault current for an external fault, and verify that the CT secondary currents do not exceed your utility standard maximum allowed CT current, typically $20 \bullet I_{NOM}$.

If necessary, reselect the CT ratios and repeat *Step 2* through *Step 6*.

Step 7. For each CT, multiply the burdens you calculated in *Step 1* by the magnitude, in secondary amperes, of the maximum symmetrical fault current you expect for an external fault.

Select a nominal accuracy class voltage for each CT that is greater than twice the calculated voltage. If necessary, select a higher CT ratio to meet this requirement, then repeat *Step 2* through *Step 7*. This selection criterion helps reduce the likelihood of CT saturation for a fully offset fault current signal.

Note that the effective C-voltage rating of a CT is lower than the nameplate rating if you use a tap other than the maximum. Derate the CT C-voltage rating by a factor of ratio used/ratio maximum.

Delta-Connected CTs

Connecting CTs in delta affects different metering and elements in different ways. In general, delta-connected CTs remove zero-sequence quantities and cause a phase shift and a $\sqrt{3}$ increase in magnitude (with respect to the balanced quantities used in the delta connection). Removing the zero-sequence quantities impacts all ground elements, a phase shift impacts all calculations based on quantities from delta-connected CTs, and the increase in magnitude affects all elements that operate on primary values.

Directional Element

Delta-connected CTs remove zero-sequence quantities, so directional elements are not available for those terminals with delta-connected CTs. For example, if the CTs from Terminal S are delta connected, then directional elements are not available for Terminal S. If the CTs of the remaining terminals are wye connected, then directional elements are available for the remaining terminals.

Combined Terminals, Thermal Element, and Through-Fault Element

⚠WARNING
Be sure to connect both sets of CTs in the same delta configuration (AB, BC, CA, for example). When you connect the two sets of CTs in different delta configurations (AB, BC, CA and AC, BA, CB), the phase difference results in incorrect combined current values.

Delta-connected CTs cause a phase shift, so currents from the combined windings (ST, TU, UW, WX) are not available when CTs from one of the two terminals are delta connected. Currents from the combined windings are available if CTs from both terminals are delta-connected. However, be sure to connect both sets of CTs in the same delta configuration because the relay does not check for this condition.

Combined Terminals, Thermal Element, Through-Fault Element, and Event Reporting

Because of the $\sqrt{3}$ increase in magnitude resulting from the delta-connected CTs, elements that operate on primary current values use the incorrect current values. To correct this, the relay divides the secondary currents by $\sqrt{3}$ before multiplying by the CT ratio to convert to primary currents.

For the event report, the relay also divides the secondary currents by $\sqrt{3}$ before multiplying by the CT ratio to convert to primary currents.

In the COMTRADE report, the relay divides the CT ratio in the .cfg file by $\sqrt{3}$ to compensate for the delta connection. This compensation applies to primary values only. Changing the CT ratio instead of the stored data does not change the secondary current values, so you can inject the secondary values into the relay without any change.

In summary, the relay compensates for delta-connected CTs when reporting or using primary values. No secondary currents are compensated; the relay processes secondary currents at the values the relay terminals measure.

Restricted Earth-Fault Element

Restricted earth-fault (REF) protection comes from a zero-sequence directional element that provides sensitive detection of ground faults near the neutral of a grounded wye-connected transformer winding. To provide REF protection, the element compares the direction of a reference current, derived from the line-end CTs, with the operating current, obtained from the neutral CT. *Figure 4.12* shows the characteristic of the REF element, with the shaded area indicating the tripping area.

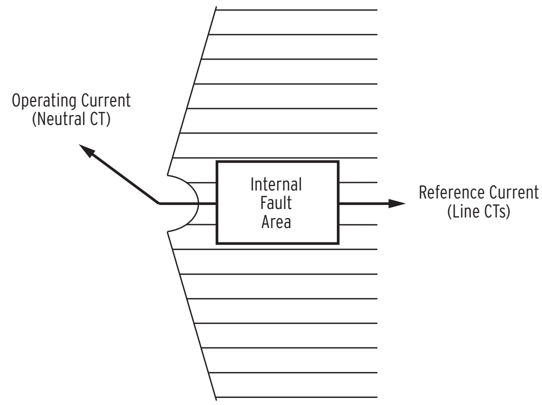


Figure 4.12 REF Directional Element

Because the REF element employs a neutral CT at one end of the winding and a set of three CTs at the line end of the winding, REF protection can detect only ground faults within that particular wye-connected winding. The element is restricted in the sense that protection is limited to ground faults within a zone defined by neutral and line CT placement.

The REF element uses comparison of zero-sequence currents, so the line-end CTs must be connected in wye for the element to function. Delta-connected CTs cancel out all zero-sequence components of the currents, eliminating one of the quantities the REF element needs for comparison.

Figure 4.13 shows the 24 analog inputs of the SEL-487E. Terminal Y consists of three single-phase current inputs that provide three separate inputs for as many as three REF operating quantities.

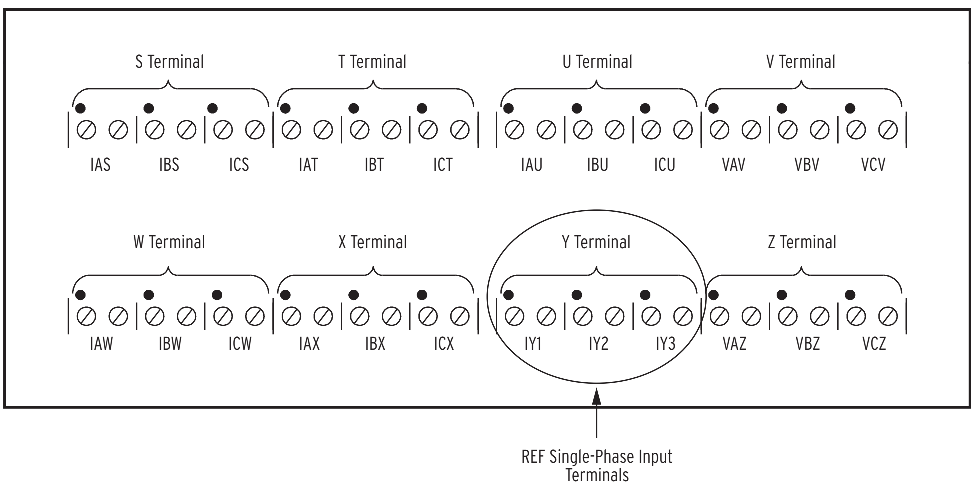


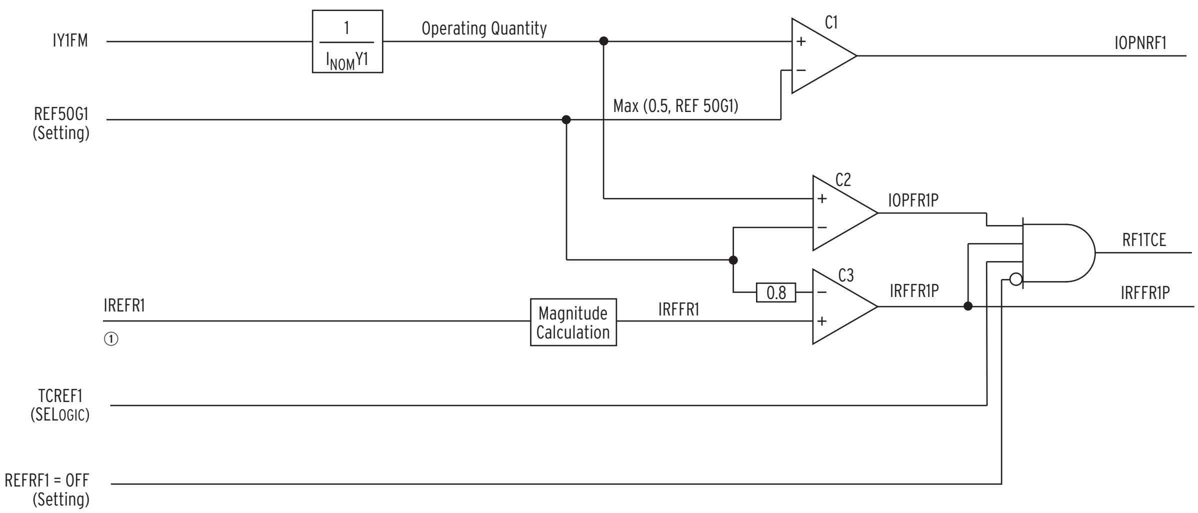
Figure 4.13 REF Terminals

Table 4.2 shows the relationships among the input currents of the Y Terminal and the REF elements. These relationships are not settable; they are fixed and must be observed when you use the REF function. For example, if you select REF 1 for your application, be sure to wire the input current from the neutral CT to IY1.

Table 4.2 Relationships Among Input Currents and REF Elements

Input Current	REF Element
IY1	REF Element 1
IY2	REF Element 2
IY3	REF Element 3

Figure 4.14 shows the REF 1 element logic diagram (REF 2 and REF 3 have similar diagrams) that produces the REF enable output, RF1TCE, and the two bypass outputs IOPNRF1 and IRFFR1P.



① See Figure 4.15.

Figure 4.14 Logic Diagram

IY1FM is the magnitude of the input current from the neutral CT connected to Terminal IY1. The quantity resulting from normalization of the current to 1 A follows two paths. In the top path, Comparator C1 compares the value against the larger of 0.5 (50 percent of the nominal current) and the REF50G1 Group setting. Relay Word bit IOPNRF1 asserts if the measured quantity exceeds the threshold. The bypass logic (see *Figure 4.16*) uses Relay Word bit IOPNRF1.

In the lower path, Comparator C2 compares the normalized IY1FM value against the REF50G1 Group setting and asserts IOPFR1P if the measured quantity exceeds the threshold. Comparator C3 compares 0.8 of the REF50G1 setting value against IRFFR1, the magnitude of the reference current. The 0.8 multiplier secures the operation of the REFF1element by ensuring that IRFFR1P always asserts before IOPFR1P.

Switch S2(a through e) selects the zero-sequence vector currents from those line CTs that are part of the REF calculations, as determined by Group setting REFRF[*a*], where *a* = 1 though 3. As an example, refer to *Figure 4.17*. For a single-wye winding, the logic requires one neutral CT and one set of line CTs for the REF function. If this set of line CTs is from Terminal S, then Switch

S2a is in position 2, while all other cells of Switch S2 remain in position 1. Current inputs from those terminals in position 1 are not included in any REF element calculations.

After closing the appropriate cells of Switch S2, the relay normalizes the selected input currents to 1 A and sums these currents vectorially to produce the reference current in vector form. In the following step, the relay calculates IRFFR1, the magnitude of the reference current for REF 1.

IOPFR1P and IRFFR1P, together with torque equation TCREF1 and setting REFR1, assert output RF1TCE. When RF1TCE asserts, the relay enables the algorithm that performs the directional calculations (see *Figure 4.15*).

Figure 4.15 shows the logic that performs the directional calculations. Switch S operates according to the previous discussion and the logic in *Figure 4.14*. After closing the appropriate cells of Switch S2, the relay converts the currents to primary values by multiplying each current times the appropriate CT ratio. The relay then sums these currents vectorially to produce the reference current in vector form. To bring this value to the same base as the neutral CT, the algorithm divides the reference current by the product of the CT ratio and the neutral CT nominal current. These calculations produce IREFR1, the reference current in vector form. For the operating current, the algorithm normalizes IY1CF to produce IOPR1, the operating current in vector form.

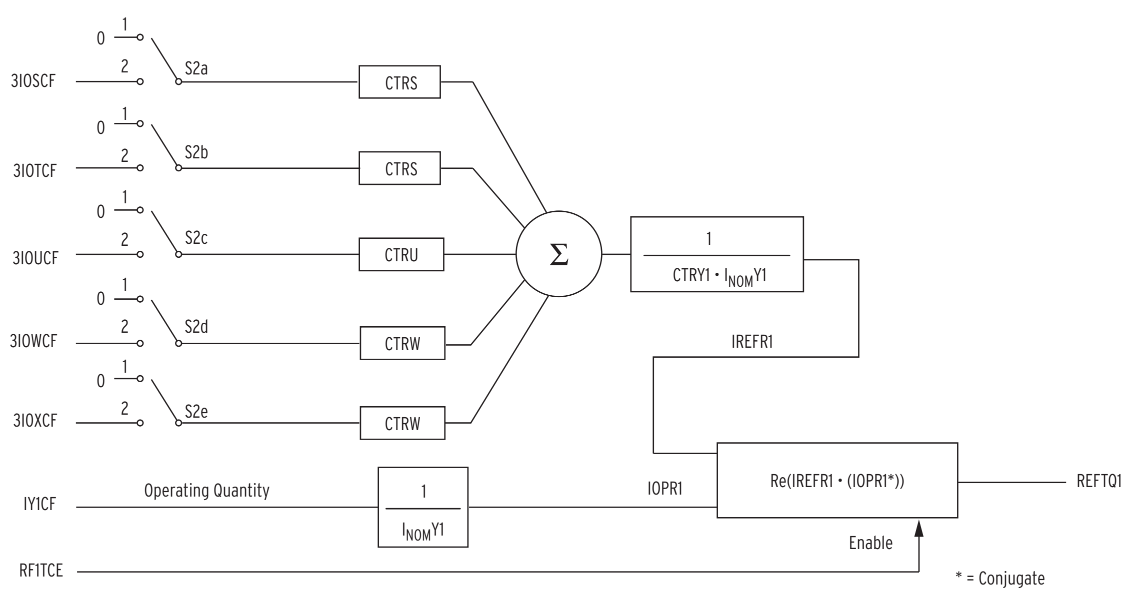


Figure 4.15 Algorithm That Performs the Directional Calculations

When the algorithm meets the conditions in *Figure 4.14*, RF1TCE asserts and enables the calculations of the directional element. To determine the direction, the algorithm calculates the real part of the product of the reference quantity and the conjugate of the operating quantity. This calculation yields the signed torque quantity REFTQ1 (this calculation is equivalent to |IOPR1| times |IREFR1| times the cosine of the angle between them). REFTQ1 is positive if the angle is within ±90 degrees, indicating a forward or internal fault. Conversely, REFTQ1 is negative if the angle is greater than +90 or less than –90 degrees, indicating a reverse or external fault.

Figure 4.16 shows the logic that compares REFTQ1 to positive threshold (THRES1P) and negative threshold (THRES1N), to ensure security for very small currents or for an angle near +90 or –90 degrees.

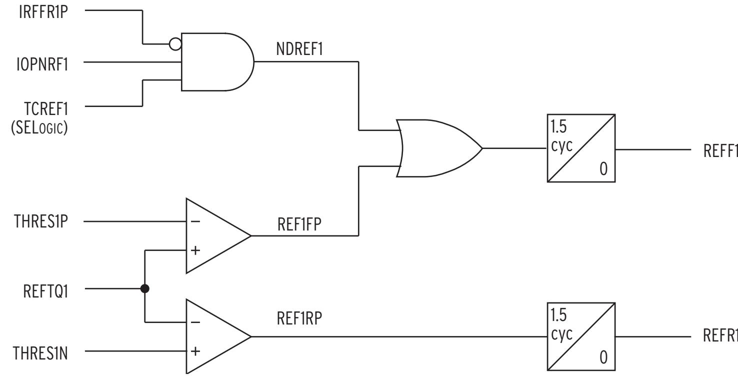


Figure 4.16 REF Element Trip Output

If REFTQ1 exceeds either threshold, it must persist for at least 1.5 cycles before Relay Word bit REFF1 (forward) or REFR1 (reverse) asserts. Assertion of REFF1 constitutes an internal ground fault.

Figure 4.17 shows the need for the bypass logic (C1) in *Figure 4.14*. For the directional element to produce a meaningful result, both operating and restraint quantities must be present. If Fault F1 occurs with the LV breaker open, no current flows through the LV CT, and there is no reference quantity present.

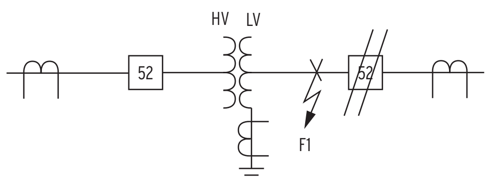


Figure 4.17 Internal Fault With LV Breaker Open

In *Figure 4.16*, the top AND gate has three inputs, namely IOPNRF1 and IRFFR1P (see *Figure 4.14*), and a SELOGIC control equation TCREF1. IOPNRF1 and negated IRFFR1P identify the condition in *Figure 4.17* in which current flows in the neutral but no current flows in the line. Use TCREF1 to further qualify the bypass condition by checking, for example, the status of the LV breaker. Therefore, when Fault F1 occurs, NDREF1 asserts and clears the fault.

For fast tripping, include REFF1, the output of the REF element, into one or more of the trip equations (group settings TR*k*) as appropriate. If you want additional security, use the programmable 51 element in *Figure 4.18* to delay tripping. In *Figure 4.18*, the overcurrent element uses the neutral current (IY1FM) as an input quantity. To avoid inadvertent tripping for external faults, use REFF1 (see *Figure 4.16*) in the torque control equation (RF51TC1) of the overcurrent element.

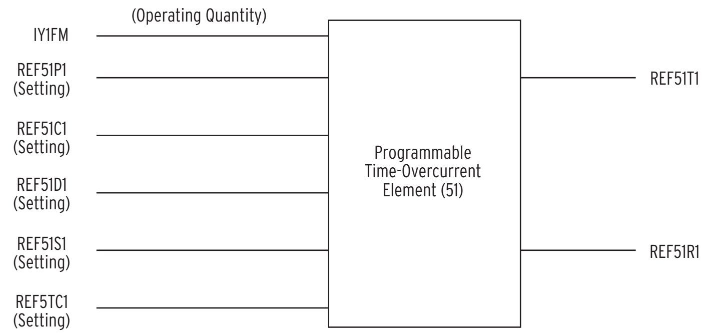


Figure 4.18 Programmable 51 REF Element

Neutral Element

For applications such as frame leakage protection or sustained ground fault protection, the REF element includes a definite-time overcurrent (50) element. *Figure 4.19* shows the REF 50 element, with neutral current IY1FM as an input quantity. If IY1FM exceeds the REF50P1 setting, REF501 asserts and starts the REF Definite Time Timer. If IY1FM exceeds the REF50P1 setting for a period exceeding the REF50D1 timer setting, REF50T1 asserts. Disable this element by setting REF50P1 = OFF.

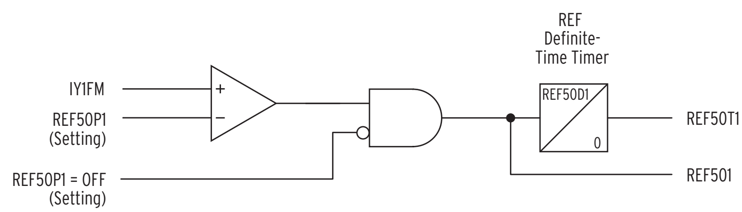


Figure 4.19 REF Neutral Element

Applications and Setting Descriptions

ECTTERM (CT Terminal Enable)

Identify which of the current inputs the relay processes, excluding the three REF (IY1, IY2, IY3) channels. Although you may have already set ECTTERM while establishing differential protection, the setting appears here as a reminder that the relay only accepts enabled terminals as reference quantities for the REF element.

Setting	Prompt	Range	Default	Category
ECTTERM	Enable Current Terminals	OFF or combo of S, T, U, W, X[a]	S,T	Group

[a] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

REF Directional Element Enable (EREF)

Use the EREF setting to enable the number of REF elements appropriate for the application. Setting EREF = N disables all REF elements, but not the neutral element. There are no neutral input current/REF element assignment settings: the relationships are fixed as in *Table 4.2*.

Therefore, when you set EREF = 1, the REF element evaluates only an input connected to Terminal IY1; the element ignores inputs connected to IY2 and IY3.

Setting	Prompt	Range	Default	Category
EREF	Enable Restricted Earth Fault Element	(N, 1 to 3)	N	Group

Restraint (Reference) Quantity from Terminals Enabled With ECTTERM

Setting REFRF[*a*] (*a* = 1–3) identifies the terminal or combination of terminals the REF element must include when it calculates the reference current (closing the cells of Switch S in *Figure 4.14* and *Figure 4.15*).

Setting	Prompt	Range	Default	Category
REFRF[*a*][a]	Restraint Qty REF Elem. [*a*]	OFF or combo of S, T, U, W, X	OFF	Group

[a] a = 1–3, as determined by the EREF setting.

Residual Current Sensitivity Threshold (REF50G[a])

You can set the residual current sensitivity threshold to as low as 0.05 times nominal current (0.25 A for 5 A nominal CT current), the minimum residual current sensitivity of the relay. However, the minimum acceptable value of REF50G[*a*] must be greater than any natural 3I0 unbalance resulting from load conditions.

Setting	Prompt	Range	Default	Category
REF50G[*a*][a]	Residual Current Sensitivity pickup	0.05 to 3.00	0.25	Group

[a] a = 1–3, as determined by the EREF setting.

REF Torque Control Setting (TCREF[a])

SELOGIC control equation TCREF[*a*] provides a method to externally control the enabling of the directional calculations (see *Figure 4.14*).

Setting	Prompt	Range	Default	Category
TCREF[*a*][a]	Torque Control REF Element [*a*]	SELOGIC Equation	1	Group

[a] a = 1–3, as determined by the EREF setting.

REF Neutral Element Instantaneous Overcurrent Pickup (REF50P[a])

REF50P[*a*] is the instantaneous overcurrent pickup setting for the neutral element (see *Figure 4.19*).

Setting	Prompt	Range	Default	Category
REF50P[*a*][a]	REF Op. Current Inst O/C [*a*] pickup	OFF, 0.25 to 5	OFF	Group

[a] a = 1–3, as determined by the EREF setting.

REF Neutral Element Overcurrent Time Delay (REF50D[a])

REF50D[*a*] is the time delay setting for the instantaneous overcurrent element of the neutral element (see *Figure 4.19*).

Setting	Prompt	Range	Default	Category
REF50D[*a*][a]	REF Inst O/C [*a*] Delay	0.000 to 16000 cycles	10	Group

[a] a = 1–3, as determined by the EREF setting.

REF TOC (51) Pickup (REF51P[a])

REF51P[*a*] is the time-overcurrent pickup setting for the programmable 51 element (see *Figure 4.18*).

Setting	Prompt	Range	Default	Category
REF51P[*a*][a]	REF Inv. Time O/C [*a*] P/U	OFF, 0.25 to 5	OFF	Group

[a] a = 1–3, as determined by the EREF setting.

REF TOC (51) Curve (REF51C[a])

REF51P[*a*] is the time-overcurrent pickup (plug) setting for the programmable 51 element (see *Figure 4.18*).

Setting	Prompt	Range	Default	Category
REF51C[*a*][a]	REF Inv. Time O/C [*a*] Curve	U1 to U5, C1 to C5	U1	Group

[a] a = 1–3, as determined by the EREF setting.

REF TOC (51) Time Dial (RF51TD[a])

RF51TD[*a*] is the time-dial (time multiplier) setting for the programmable 51 element (see *Figure 4.18*).

Setting	Prompt	Range	Default	Category
RF51TD[*a*][a]	REF Inv. Time O/C [*a*] Time Dial	0.50 to 15	0.5	Group

[a] a = 1–3, as determined by the EREF setting.

REF TOC (51) Electromechanical Reset (RF51RS[a])

RF51RS[*a*] is the time-dial (time multiplier) setting for the programmable 51 element (see *Figure 4.18*).

Setting	Prompt	Range	Default	Category
RF51RS[*a*][a]	REF Inv. Time O/C [*a*] EM Reset	Y, N	N	Group

[a] a = 1–3, as determined by the EREF setting.

REF TOC (51) Torque Control (RF51TC[a])

RF51TC[*a*] is the torque control setting for the programmable 51 element (see *Figure 4.18*).

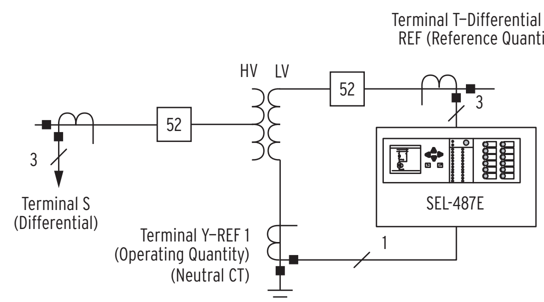
Setting	Prompt	Range	Default	Category
RF51TC[*a*][a]	REF Inv. Time O/C [*a*] Torque Cont	SELOGIC Equation	1	Group

[a] a = 1–3, as determined by the EREF setting.

Selection of the Restraint Quantity

The operating quantity/reference quantity relationship is according to software assignment (instead of a fixed relationship), so you can apply the REF elements to any primary plant configuration with the correct CT arrangement. In general, identify all lines that are electrically connected to the grounded winding that you want to protect with the REF element. Then enter those terminals at the REFRF[*a*] setting. Following are examples of a few applications, assuming that both differential and REF elements protect the transformer in each example.

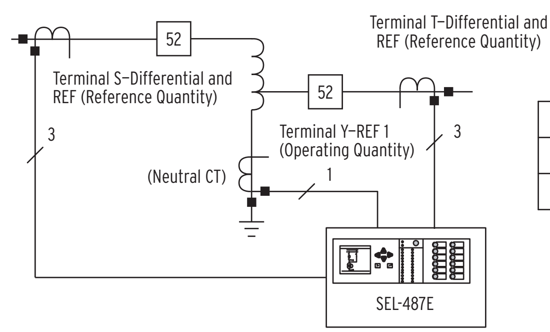
Figure 4.20 shows an ungrounded HV winding and a grounded-wye LV winding. Because we need two terminals for the differential protection, set ECTTERM = S, T, and assign Terminal S to the HV side and Terminal T to the LV side. Set EREF = 1 to enable one REF element (this setting dictates that we connect the neutral CT to Terminal IY1). Although Terminals S and T are enabled, only Terminal T electrically connects to the winding earmarked for REF protection. Therefore, set REFRF1 = T.



ECTTERM	S, T
EREF	1
REFRF1	T

Figure 4.20 Single-Wye Winding REF Application

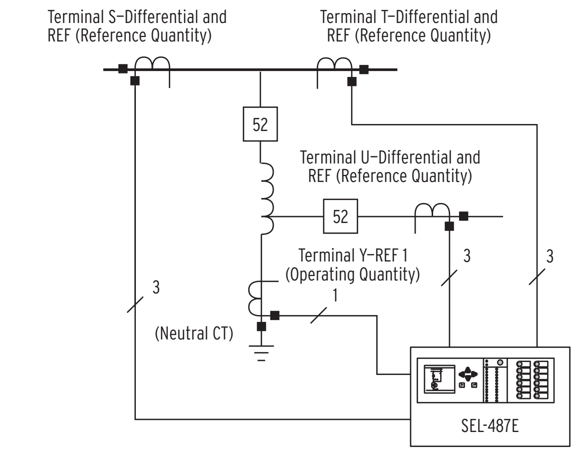
Figure 4.21 shows an autotransformer. Because we need two terminals for the differential protection, set ECTTERM = S, T, and assign Terminal S to the HV side and Terminal T to the LV side. Set EREF = 1 to enable one REF element (this setting dictates that we use IY1). In this case, both Terminal S and Terminal T connect electrically to the winding earmarked for REF protection. Therefore, set REFRF1 = S, T.



ECTTERM	S, T
EREF	1
REFRF1	S, T

Figure 4.21 Autotransformer REF Application

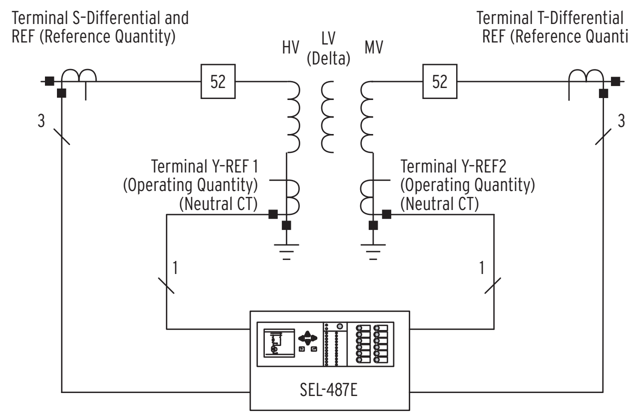
Figure 4.22 also shows an autotransformer, but in this application, the HV side has two CTs (breaker-and-a-half application). Because we need three terminals for the differential protection, set ECTTERM = S, T, U, and assign Terminals S and T to the HV side and Terminal U to the LV side. Set EREF = 1 to enable one REF element (this setting dictates that we use IY1). In this case, Terminal S, Terminal T, and Terminal U connect electrically to the winding earmarked for REF protection. Therefore, set REFRF1 = S, T, U.



ECTTERM	S, T, U
EREF	1
REFRF1	S, T, U

Figure 4.22 Autotransformer With Two-HV Current Transformer REF Application

Figure 4.23 shows a three-winding wye-wye transformer with tertiary delta. Assume that no load connects to the delta, so that the differential calculations exclude the delta. Because we need two terminals for the differential protection, set ECTTERM = S, T, and assign Terminals S to the HV side and Terminal T to the MV side. In contrast to an autotransformer, the HV and MV windings of this transformer are *not connected electrically*, and we need a separate REF for each winding. Set EREF = 2 to enable two REF elements (this setting dictates that we use IY1 and IY2). On the assumption that we assign REF 1 to the HV side, set REFRF1 = S, and set REFRF2 = T for the MV side.



ECTTERM	S, T
EREF	2
REFRF1	S
REFRF2	T

Figure 4.23 Three-Winding Transformer With Two REF Elements

Overcurrent Elements

The SEL 487E provides three levels of instantaneous overcurrent elements (50) for phase, negative-sequence, and zero-sequence currents for each of the five terminals (S, T, U, W, X), and 10 configurable time-overcurrent (51) elements. These overcurrent elements are nondirectional, but you can make any of the 50 or 51 elements directional with a choice of phase- and sequence-directional elements (see the directional element section).

Phase Instantaneous Overcurrent Elements

Figure 4.24 shows the logic for the phase instantaneous overcurrent element. At the top of the logic are four settings that enable the overcurrent element. All four settings must evaluate to a logical 1 to enable the overcurrent element. To enable the Level 1 instantaneous overcurrent element for Terminal S, apply the following settings: ECTTERM = S, … , E50 = S, … , E50S = P, and 50SP1P = 4 (any setting within the range other than OFF).

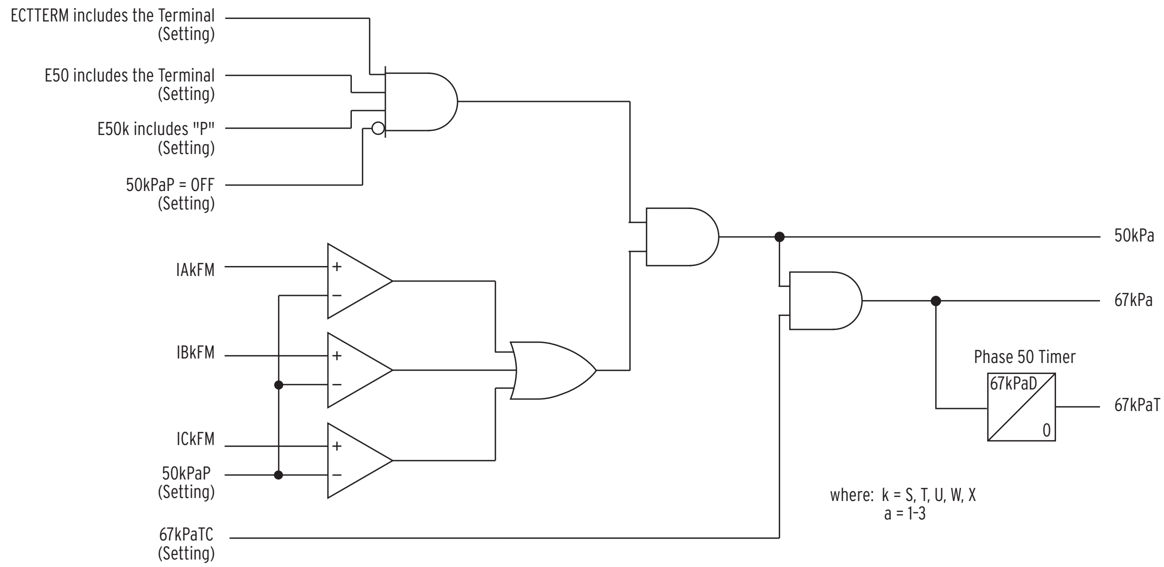


Figure 4.24 Phase Instantaneous Overcurrent Element

Setting 50SP1P also provides the reference value against which three comparators test the three phase currents (IA*k*FM, IB*k*FM, IC*k*FM). If the element is enabled, and any phase current exceeds the 50SP1P setting value, then Relay Word bit 50SP1 asserts.

Use the torque-control setting 67*k*P*a*TC to combine the 50 element with other functions such as the directional element, or to add a time delay. For a time delay (Terminal S, Level 1), set 67SP1TC = 1 (or any other appropriate condition such as the directional element or a breaker auxiliary contact status), and set 67SP1D to the desired time delay. If the element is enabled, and any phase current exceeds the 50SP1P setting value, then Relay Word bits 50SP1 and 67SP1 assert instantaneously, and Relay Word bit 67SP1T asserts when the Phase 50 timer times out.

Negative-Sequence Instantaneous Overcurrent Elements

Figure 4.25 shows the logic for the negative-sequence instantaneous overcurrent element. This element operates similarly to the phase instantaneous overcurrent element, except that the element uses negative-sequence values instead of phase values.

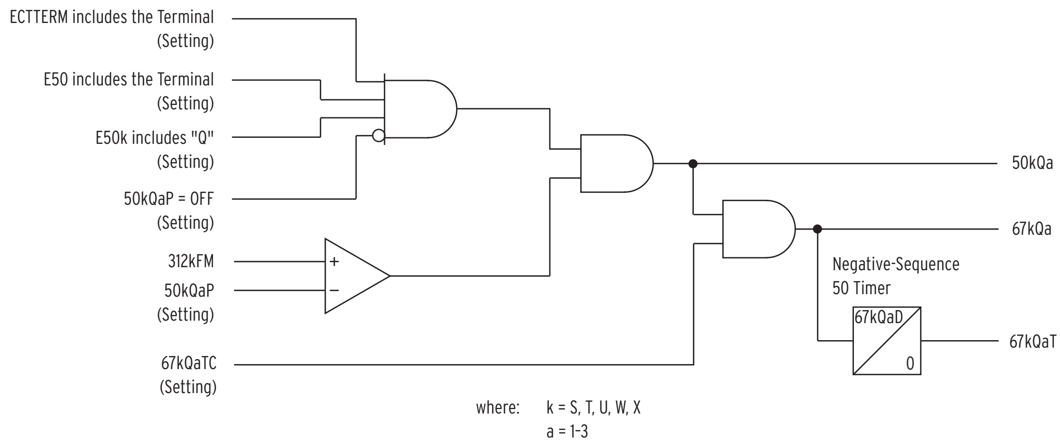


Figure 4.25 Negative-Sequence Instantaneous Overcurrent Element

Zero-Sequence Instantaneous Overcurrent Elements

Figure 4.26 shows the logic for the zero-sequence instantaneous overcurrent element. This element operates similarly to the phase instantaneous overcurrent element, except that the element uses zero-sequence values instead of phase values.

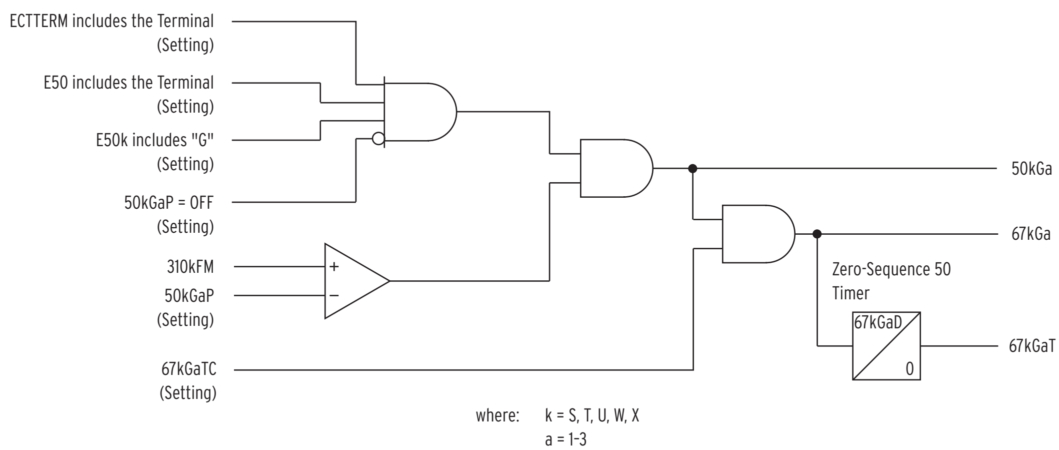


Figure 4.26 Zero-Sequence Instantaneous Overcurrent Element

Setting Descriptions

ECTTERM (CT Terminal Enable)

This setting identifies which of the current inputs, excluding the three REF (IY1, IY2, IY3) channels, the relay processes. You may have already determined this setting. It appears here as a reminder that the relay only accepts enabled terminals for the overcurrent elements.

Setting	Prompt	Range	Default	Category
ECTTERM	Enable Current Terminals	OFF or combo of S, T, U, W, X[a]	S, T	Group

[a] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

E50 (Definite-Time O/C and Directional Element Enable)

Setting E50 is a composite setting that identifies the following three protection options for each winding:

- Windings that require only definite-time overcurrent elements
- Windings that require only directional elements
- Windings that require both definite-time overcurrent elements and directional elements

For example, at a particular substation you want the following protection:

- Winding S: negative-sequence definite-time OC only
- Winding T: only directional control (directional elements for TOC (51) protection)
- Winding U: both definite-time overcurrent protection (Level 1) and directional control
- Windings W and X: not used

Figure 4.27 shows the flow diagram for setting the three protection options (grey blocks are not used).

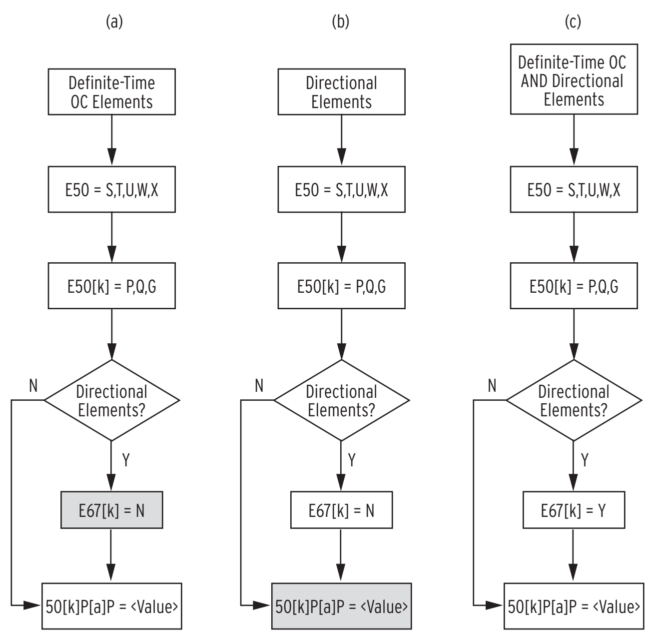


Figure 4.27 Three Setting Possibilities

In general, regardless of the function you want (OC or directional), always enter the E50 and E50[*k*] settings. In this example, include Windings S, T and U in the Group setting ECTTERM to enable these windings for processing, as shown in *Figure 4.28*. Also select the PT for the directional element polarizing (EPTTERM setting).

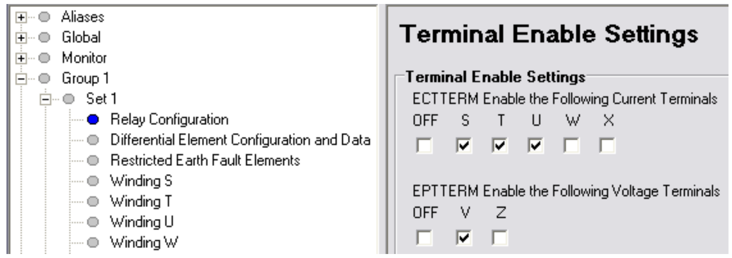


Figure 4.28 ECTTERM and EPTTERM Settings

After enabling the CTs for processing, enter Windings S, T, and U in the Group setting E50 (*Figure 4.29*). *Figure 4.29* also shows the selection of the 51 element that must have directional control. The 51 elements are not winding specific, so setting the winding CT/51 elements correlation occurs later.

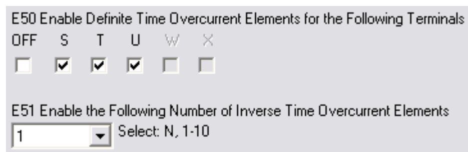


Figure 4.29 E50 and E51 Enables

Use the E50[*k*] setting to specify the type of overcurrent elements you want to use, both for overcurrent elements and for directional elements. Because Winding S requires negative-sequence definite-time OC only, set E50S = Q, and E67S = N, as shown in *Figure 4.30*. Selecting E50S = Q makes the negative-sequence definite-time OC elements available and hides (grays-out) the directional element settings.

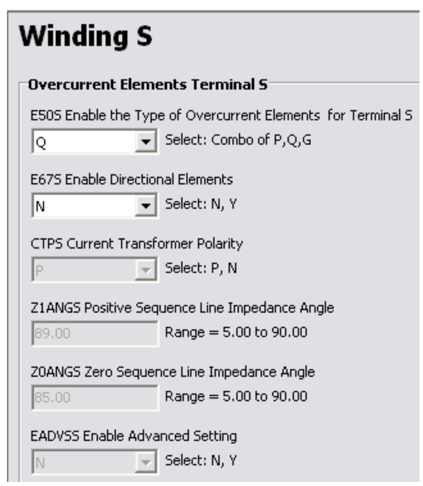


Figure 4.30 Enable Negative-Sequence Definite-Time OC for Winding S; Disable Directional Elements for Winding S

Figure 4.31 shows the negative-sequence definite-time OC settings. The setting 50SQ1P is the Level 1 negative-sequence OC element pick-up value (arbitrarily set at 12). The setting 67SQ1TC is the torque-control setting for the negative-sequence OC element (refer to *Figure 4.31* for the logic diagram). In this example, set 67SQ1TC = 1 (permanently enabled) to assert the bottom input of the timer AND gate in *Figure 4.25*. The last setting is 67SQ1D, the negative-sequence OC element time delay, set in *Figure 4.31* to an arbitrary value of 20 cycles.

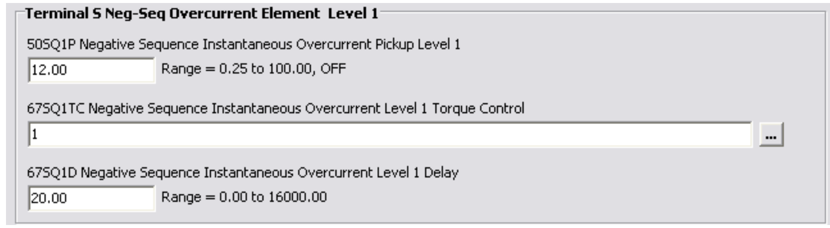


Figure 4.31 Negative-Sequence Definite-Time OC Settings

This concludes the negative-sequence definite-time OC settings for Winding S.

Winding T protection calls for a directional element 51. *Figure 4.32* shows the settings to enable the directional element (E50T = GPQ), and *Figure 4.33* shows the settings to disable the definite-time OC Level 1 elements (50TP1P = OFF) for Winding T. Level 2 is also disabled (50TP2P = OFF).

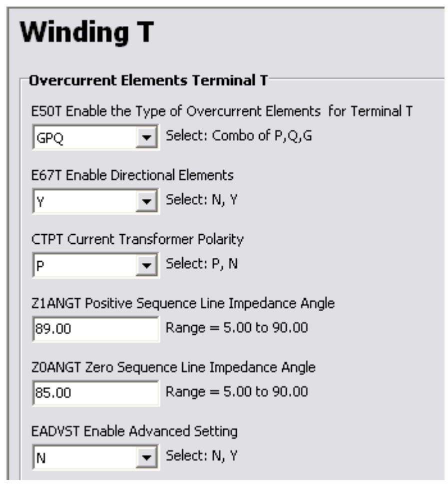


Figure 4.32 Enable Directional Elements

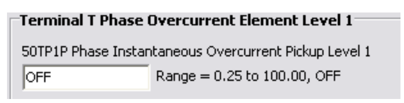


Figure 4.33 Disable Definite-Time OC Elements

Enable the directional elements by setting E67T = Y. This makes the CTPT, Z1ANGT, Z0ANGT (E50T includes both P and G) and EADVST settings available. With 50TP1P = 50TP2P = OFF, the 50 elements are disabled, so that only the directional elements are active for Winding T.

Figure 4.34 shows the settings for the Winding T directional 51 element. For this example, do not use adaptive settings for the pickup and time dial settings. Set the operating quantity (51O01 = IMAXTF), the pickup setting (51P01), Curve type (51C01), time dial (51TD01), and the type of reset (51RS01).

Use setting 51TC01 to add directional control to the 51 element. Setting 51TC01 = TF32G (negative- and zero-sequence direction) OR TF32P (phase direction) causes the 51 element to be active only for forward faults.

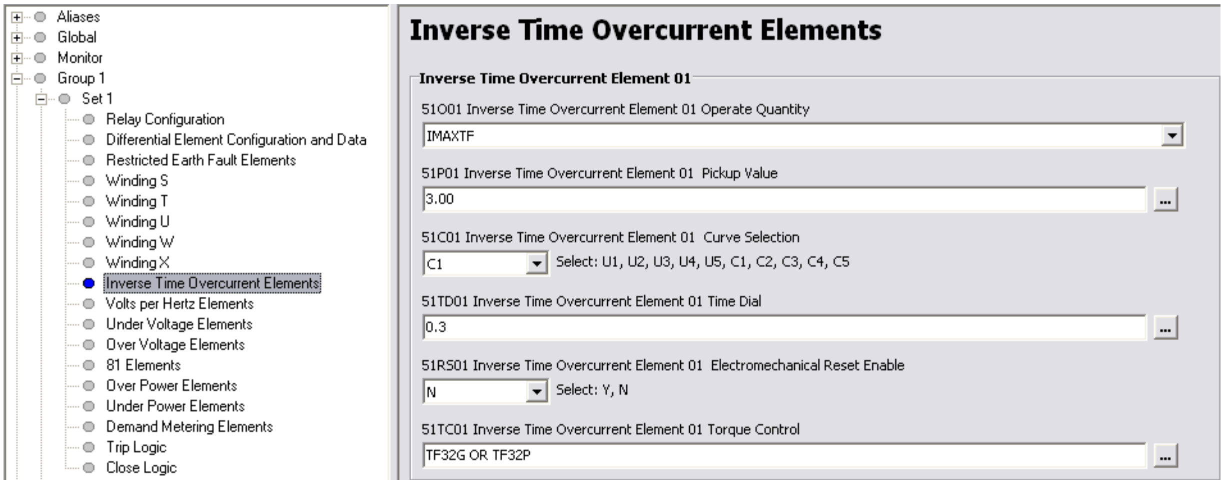


Figure 4.34 Winding T Directional 51 Element Settings

This concludes the directional 51 settings for Winding T.

Winding T protection calls for one level of directional definite-time overcurrent protection. *Figure 4.35* shows the settings to enable the directional element (E50U = GPQ and E67U = Y).

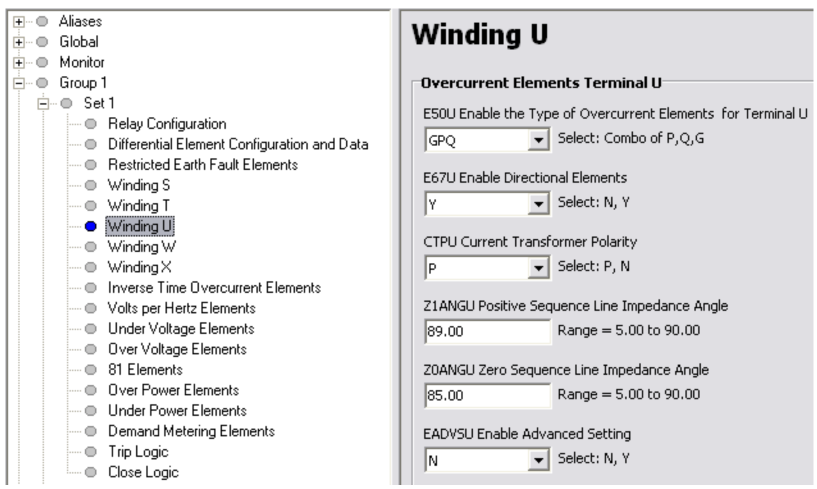


Figure 4.35 Enable Directional Elements for Winding U

With the directional elements enabled, set the 50 elements settings, as shown in *Figure 4.36*. To make the 50 elements directional, enter the forward directional Relay Word bits (UF32P and UF32G) in the 67UP1TC torque equation.

Figure 4.36 Winding U Directional 50 Element Settings

Only one level of OC protection is necessary, so leave 50UP2P = OFF. This concludes the directional 50 settings for Winding U.

Setting	Prompt	Range	Default	Category
E50	Enable Def. Time Dir. O/C Ele.	OFF or combo of S, T, U, W, X[a]	OFF	Group

[a] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

E50[k] (50 Function Enable)

After identifying the terminal(s) that requires definite-time overcurrent/directional protection with the E50 setting, select here the specific instantaneous overcurrent element(s)/directional type for each terminal(s). Choose from among phase (P), negative-sequence (Q), zero-sequence (G), or any combination of P, Q, and G.

Setting	Prompt	Range	Default	Category
E50[*k*][a]	Type of O/C Elements Enabled Term. [*k*]	Combo of P, Q, G[b]	P	Group

[a] k = S, T, U, W, X.
[b] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

50[k]P[a]P (Phase Element Pickup)

Setting 50[*k*]P[*a*]P is the current pickup setting in secondary amps for the phase instantaneous overcurrent element. The following table shows the range for a 5 A relay; the range is 0.05 to 20 for a 1 A relay.

Setting	Prompt	Range	Default	Category
50[*k*]P[*a*]P[a,b]	Phase Inst O/C pickup level [*a*]	OFF, 0.25 to 100.00	OFF	Group

[a] k = S, T, U, W, X.
[b] a = 1–3.

67[k]P[a]TC (Phase Element Torque Control)

NOTE: This setting does not affect the 50kPa outputs (see Figure 4.23).

Use the torque-control setting to specify conditions under which the element must be active. The default setting is [*k*]F32P, so that the 67*k*P*a* and 67*k*P*a*T functions can only assert if the phase directional element declares a fault in the forward direction. With the torque equation set to 1 (67SP1TC = 1, Terminal S, Level 1), the overcurrent element is nondirectional and active constantly.

Setting	Prompt	Range	Default	Category
67[*k*]P[*a*]TC[a,b]	Phase Inst O/C level [*a*] Torque Ctrl	SELOGIC Equation	[*k*]F32P	Group

[a] k = S, T, U, W, X.
[b] a = 1-3.

67[k]P[a]D (Phase Element Time Delay)

NOTE: This setting is active only if 67[n]P[c]TC asserts.

Set the duration of the phase element time delay with this setting.

Setting	Prompt	Range	Default	Category
67[*k*]P[*a*]D[a,b]	Phase Inst O/C level [*a*] Delay	0.00 to 16000 cycles	0	Group

[a] a = 1-3.
[b] k = S, T, U, W, X.

50[k]Q[a]P (Negative-Sequence Element Pickup)

Setting 50[*k*]Q[*a*]P is the current pickup setting in secondary amps for the negative-sequence instantaneous overcurrent element. The following table shows the range for a 5 A relay; the range is 0.05 to 20 for a 1 A relay.

Setting	Prompt	Range	Default	Category
50[*k*]Q[*a*]P[a,b]	Neg-Seq Inst O/C pickup level [*a*]	OFF, 0.25 to 100.00	OFF	Group

[a] a = 1-3.
[b] k = S, T, U, W, X.

67[k]Q[a]TC (Negative-Sequence Element Torque Control)

NOTE: This setting does not affect the 50kQa outputs (see Figure 4.24).

Use the torque-control setting to specify conditions under which the element must be active. The default setting is [*k*]F32Q, so that the 67*k*P*a* and 67*k*P*a*T functions can only assert if the negative-sequence directional element declares a fault in the forward direction. With the torque equation set to 1 (67SQ1TC = 1, Terminal S, Level 1), the overcurrent element is nondirectional and active constantly.

Setting	Prompt	Range	Default	Category
67[*k*]Q[*a*]TC[a,b]	Neg-Seq Inst O/C level [*a*] Torque Ctrl	SELOGIC Equation	[*k*]F32Q	Group

[a] a = 1-3.
[b] k = S, T, U, W, X.

67[k]Q[a]D (Negative-Sequence Element Time Delay)

NOTE: This setting is active only if 67[k]Q[a]TC asserts.

Set the duration of the negative-sequence element time delay with this setting.

Setting	Prompt	Range	Default	Category
67[*k*]Q[*a*]D[a,b]	Neg-Seq Inst O/C level [*a*] Delay	0.00 to 16000 cycles	0	Group

[a] a = 1-3.
[b] k = S, T, U, W, X.

50[k]G[a]P (Zero-Sequence Element Pickup)

50[*k*]G[*a*]P is the current pickup setting in secondary amps for the zero-sequence instantaneous overcurrent element (shown is the range for a 5 A relay; the range is 0.05 to 20 for a 1 A relay).

Setting	Prompt	Range	Default	Category
50[*k*]G[*a*]P[a,b]	Zero-Seq Inst O/C Pickup Level [*a*]	OFF, 0.25 to 100.00	OFF	Group

[a] a = 1-3.
[b] k = S, T, U, W, X.

67[k]G[a]TC (Zero-Sequence Element Torque Control)

NOTE: This setting does not affect the 50kGa outputs (see Figure 4.54).

Use the torque-control setting to specify conditions under which the element must be active. The default setting is [*k*]F32G, so that the 67*k*Pa and 67*k*PaT functions can only assert if the zero-sequence directional element declares a fault in the forward direction. With the torque equation set to 1 (67SG1TC = 1, Terminal S, Level 1), the overcurrent element is nondirectional and active constantly.

Setting	Prompt	Range	Default	Category
67[*k*]G[*a*]TC[a,b]	Zero-Seq Inst O/C Lvl [*a*] Torque Ctrl	SELogic Equation	[*k*]F32G	Group

[a] a = 1-3.
[b] k = S, T, U, W, X.

67[k]G[a]D (Zero-Sequence Element Time Delay)

NOTE: This setting is active only if 67[k]G[a]TC asserts.

Set the duration of the zero-sequence element time delay with this setting.

Setting	Prompt	Range	Default	Category
67[*k*]G[*a*]D[a,b]	Zero-Seq Inst O/C Lvl [a] Delay	0.00 to 16000 cycles	0	Group

[a] a = 1-3.
[b] k = S, T, U, W, X.

Combined Overcurrent Values (51 Elements Only)

Figure 4.37 shows a breaker-and-a-half layout on the transformer HV side and a single busbar on the LV side. On the HV side, the HV current flows through both CTS and CTT, but the total current flows through CTU and the LV side. Current distribution through CTS and CTT is a function of system conditions, so the proper coordination with CTU involves using the sum of CTS and CTT. *Figure 4.38* shows the result of the combined current values in the SEL-487E. The relay adds the currents from CTS and CTT to form the equivalent of a single CT.

Be aware that the relay combines the current values only if the two CTs have the same CTCON[*k*] setting. For example, if CTCONS = Y and CTCONT = D, then the relay does not calculate combined currents.

Furthermore, when both CTs are delta connected, be sure to connect both sets of CTs in the same delta configuration, because the relay does not check for this condition. See *Delta-Connected CTs on page 4.28*.

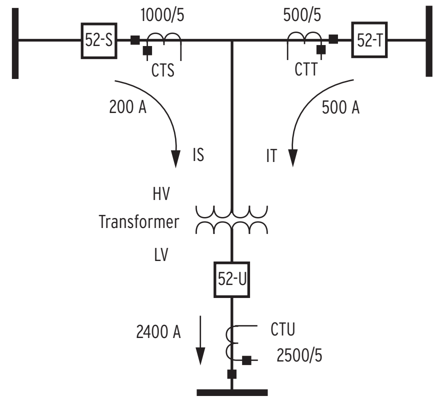


Figure 4.37 Two CTs on HV Side

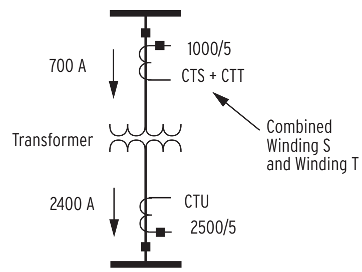


Figure 4.38 Equivalent Single CT on HV Side

When the two CTs have different ratios, the relay adjusts the current from the CT with the lower ratio by the following factor:

$$\text{Factor} = \frac{\text{CTratio}_{\text{LOWER}}}{\text{CTratio}_{\text{HIGHER}}}$$ **Equation 4.17**

For example, the CT ratio of CTS is 1000/5 (200/1) and the CT ratio of CTT is 500/5 (100/1). Therefore, the adjustment factor is:

$$\text{Factor} = \frac{100}{200} = 0.5$$ **Equation 4.18**

For the current flow in *Figure 4.37*, the relay calculates the combined secondary current as follows (notice that the relay only adjusts the current from the CT with the lower ratio):

$$I_{\text{COMBINED}} = \frac{IS_{\text{primary}}}{\text{CTS}} + \left[\text{Factor} \bullet \frac{IT_{\text{primary}}}{\text{CTT}}\right]$$ **Equation 4.19**

$$I_{\text{COMBINED}} = \frac{200}{200} + \left[\frac{100}{200} \bullet \frac{500}{100}\right]$$ **Equation 4.20**

$$I_{\text{COMBINED}} = 1.0\text{A} + 2.5\text{A} = 3.5\text{A}$$ **Equation 4.21**

Selectable Time-Overcurrent Element (51)

Instead of having dedicated inverse-time overcurrent elements (also known as Inverse Definite Minimum Time or IDMT) for each winding, the SEL-487E offers the flexibility of 10 unassigned time-overcurrent elements, each with the choice of five US and five IEC operating curves. Unassigned means that the 51 elements are not assigned to a specific transformer winding, but they are available for assignment, as the application requires (see *Table 4.5*).

Be sure to include the windings selected as 51 element input quantities in the ECTTERM setting. For example, if IMAXSF (see *Table 4.5*) is the input for element 51O01 and if IMAXTF is the input for element 51O02, then set ECTTERM = S, T.

Inverse-time overcurrent elements are not enabled in the default settings. Enable the inverse-time overcurrent elements by setting E51 = *xx* (*xx* = 01 through 10). After you enable these elements, the inverse-time overcurrent elements up to and including the number *xx* you entered at the E51 = prompt are active. For example, if you want to use six inverse-time overcurrent elements for your application, set E51 = 6. Inverse-time overcurrent elements 01 through 06 become active.

Table 4.3 shows the five US characteristics, and *Table 4.4* shows the 5 IEC characteristics. Each table shows the five operating time equations, together with the five electromechanical reset characteristic equations.

Table 4.3 US Operate and Reset Curve Equations

Curve Type	Operating Time	Reset Time
U1 (Moderately Inverse)	$T_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$
U2 (Inverse)	$T_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$
U3 (Very Inverse)	$T_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$
U4 (Extremely Inverse)	$T_p = TD \bullet \left(0.02434 + \frac{5.64}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{5.64}{1 - M^2}\right)$
U5 (Short-Time Inverse)	$T_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$

Table 4.4 IEC Operate and Reset Curve Equations (Sheet 1 of 2)

Curve Type	Operating Time	Reset Time
C1 (Standard Inverse)	$T_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$T_R = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$
C2 (Very Inverse)	$T_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$T_R = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$

Table 4.4 IEC Operate and Reset Curve Equations (Sheet 2 of 2)

Curve Type	Operating Time	Reset Time
C3 (Extremely Inverse)	$Tp = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$T_R = TD \bullet \left(\frac{80}{1 - M^2}\right)$
C4 (Long-Time Inverse)	$Tp = TD \bullet \left(\frac{120}{M - 1}\right)$	$T_R = TD \bullet \left(\frac{120}{1 - M}\right)$
C5 (Short-Time Inverse)	$Tp = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$T_R = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$

where:

T_P = Operate time
T_R = Reset time
TD = Time dial (multiplier)
M = Multiple of pickup current ($I_{measured}/I_{pickup}$)

Figure 4.39 through *Figure 4.41* show the five US curves and the five IEC curves.

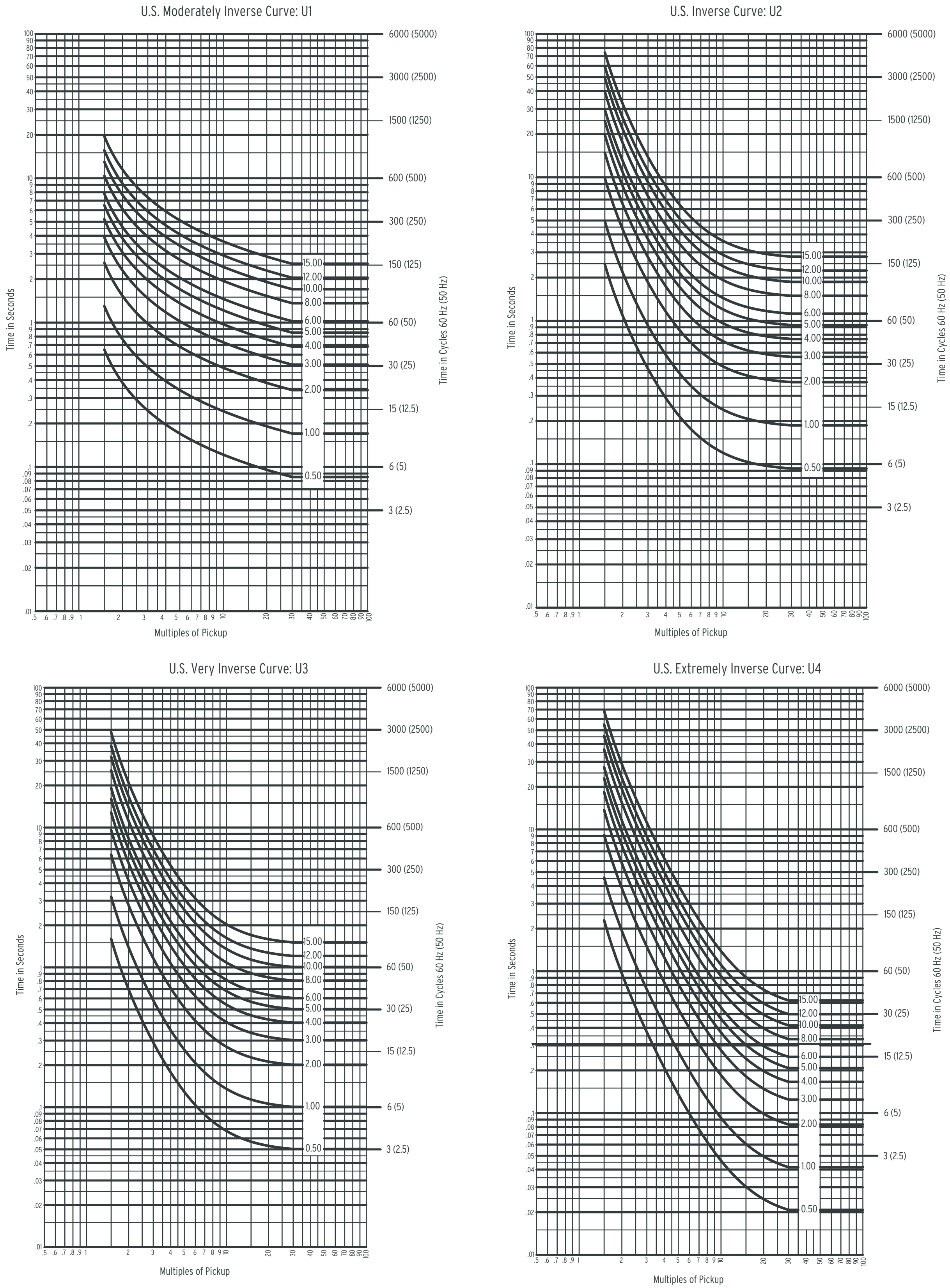


Figure 4.39 US Curves: U1, U2, U3, and U4

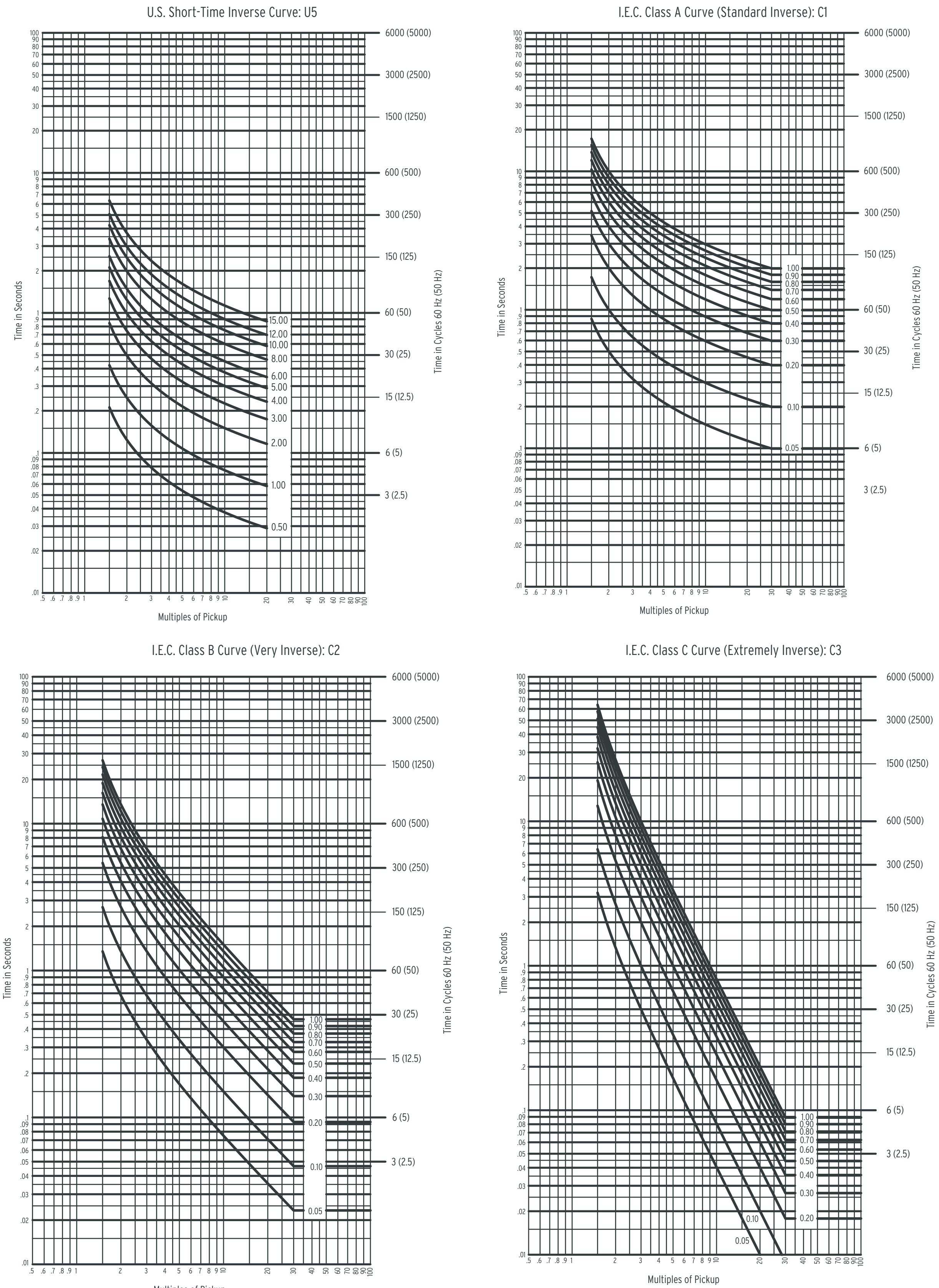


Figure 4.40 US Curve U5 and IEC Curves C1, C2, and C3

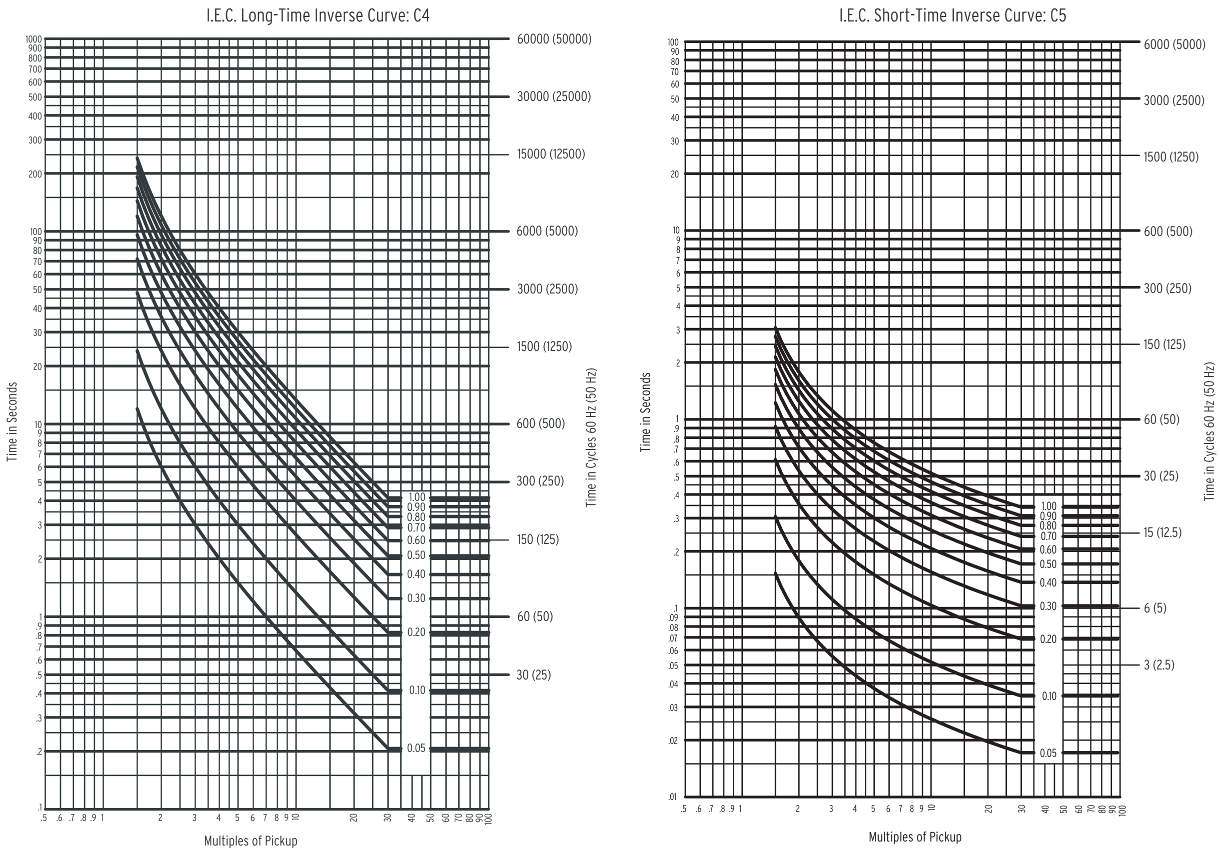


Figure 4.41 IEC Curves C4 and C5

Figure 4.42 uses Element 01 as an example to show the logic for the 51 element. All five inputs are Group settings. Essentially, the logic compares the magnitude of an operating quantity (51O01) to pickup setting 51P01.

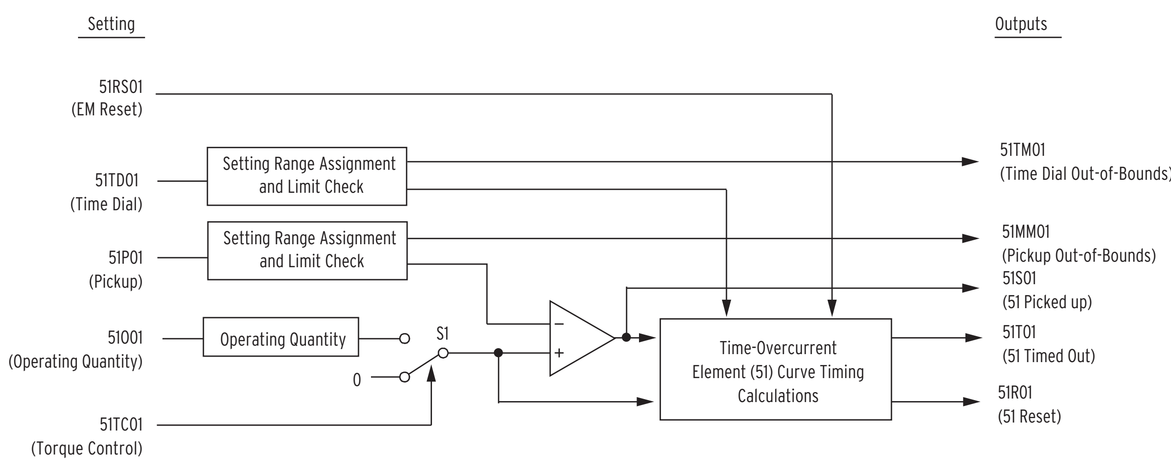


Figure 4.42 Time-Overcurrent Element

Operating Quantity

The 51 elements are unassigned, so you can select the operating quantity from many phase and sequence quantities, either fundamental or root mean square (rms), as Table 4.5 shows.

Table 4.5 Fundamental or RMS Operating Quantities

	Fundamental Quantities	RMS Quantities
Phase	IA*n*FM, IB*n*FM, IC*n*FM, IMAX*m*F	IA*m*RMS, IB*m*RMS, IC*m*RMS, IMAX*m*R
Combined	IA*qp*FM, IB*qp*FM, IC*qp*FM, IMAX*qp*F	IA*qp*RMS, IB*qp*RMS, IC*qp*RMS, IMAX*qp*R
Sequence	I1*n*M, 3I2*m*M, 3I0*m*M	

where:

n = S, T, U, W, X
m = S, T, U, W, X
qp = ST, TU, UW, WX

Pickup and Time Dial Settings

Pickup setting 51P01, operating on the ratio of the measured current to the pickup setting (multiple of pickup setting), moves the characteristic horizontally to vary the pickup current; time-dial (multiplier) setting 51TD01 moves the curve vertically to vary the operating time for a given multiple of pickup.

Both pickup (51P01) and time-dial (51TD01) settings are math variables instead of fixed settings. SEL math variables, unlike fixed settings that cannot be dynamically changed, allow for the adaptive changing of pickup and time-dial settings without the need for changing relay setting groups.

However, if your installation does not require adaptive pickup and/or time-dial settings changes, use the time-overcurrent element as a conventional 51 element. For a conventional element, simply enter the pickup and time-dial settings as numbers, such as:

51P01 = 1.5
51TD01 = 1

Setting Range Assignment and Limit Checks

Because the relay accepts both 1 A and 5 A secondary CTs, the relay assigns the element pickup setting range only after you select the operating quantity. For example, if the relay determines (from the part number) that Winding S is a 5 A CT, then the relay assigns the range 0.25 to 16.00 as the pickup range of all 51 elements that use any of the Winding S quantities.

In the case of combined terminals, the two CTs can have different secondary ratings. For example, Terminal S can be 5 A secondary, and Terminal T can be 1 A secondary. For this case, the relay assigns the range to the first enabled terminal in the S, T, U, W, X sequence. Following are three examples to illustrate the result of the current assignment.

EXAMPLE 4.1

Single Terminal S – 5 A CT secondary

Terminal S has a 5 A nominal CT input, so the range is 0.25 (lower limit) to 16.0 (upper limit)

EXAMPLE 4.2

Single Terminal T – 1 A CT secondary

Terminal T has a 1 A nominal CT input, so the range is 0.05 (lower limit) to 3.2 (upper limit)

EXAMPLE 4.3

Combined Terminal ST; S – 5 A, and T – 1 A CT secondary

Terminal S has a 5 A nominal CT input, and Terminal T has a 1 A nominal CT input. Because S is before T in the S, T, U, W, X sequence, the assignment is for a 5 A CT, which has a range of 0.25 (lower limit) to 16 (upper limit).

Upper and Lower Range Limits

When you use SEL math variables, the selected analog value can exceed the upper value of the pickup range, or it can fall below the lower value of the pickup range. When this happens, the relay assigns the appropriate threshold value (upper threshold if the analog quantity exceeds the upper threshold [3.2 or 16], or the lower threshold value [0.05 or 0.25] if the analog quantity falls below the lower threshold) to the element and continues to calculate the trip time. In addition, the relay also asserts the appropriate Relay Word bits: 51MM01 (pickup value out of bounds) and/or 51TM01 (time dial value out of bounds).

EXAMPLE 4.4

For example, you want a 1 A relay to pick up at 1.5 A when IN101 asserts and to pick up at 2 A when IN102 asserts (IN101 deasserted). Program the following:

51P01:= IN101 • 1.5 + IN102 • 2

With IN101 asserted (logical 1), and IN102 deasserted (logical 0), the 51P01 setting is:

(1 • 1.5) + (0 • 2) = 1.5 + 0 = 1.5

When IN102 asserts (IN101 deasserted), the 51P01 setting is:

(0 • 1.5) + (1 • 2) = 0 + 2 = 2

If, however, IN102 asserts while IN101 is still asserted, the 51P01 setting is:

(1 • 1.5) + (1 • 2) = 1.5 + 2 = 3.5.

Because 3.5 exceeds the upper range value of 3.2, the relay clamps the setting at 3.2 and asserts Relay Word bit 51MM01.

Torque Control

SELOGIC control equation 51TC01 allows you to state the conditions when the element must run. When 51TC01 asserts (logical 1), Switch S1 in *Figure 4.42* closes and the relay evaluates input 51O01. For example, if the element should only measure when the HV circuit breaker (Winding S, for example) is closed, enter the following:

51TC01 := **52CLS**

With this setting, Switch S1 closes only when 52CLS is a logical 1. If the element must measure all the time, enter the following:

51TC01 := **1**

To prevent the inadvertent omission of the inverse-time overcurrent protection, the relay does not permit a torque control SELOGIC control equation (51TC*xx*) setting of 0 or NA.

EM Reset

Setting 51RS01 defines whether the curve resets slowly like an electromechanical disk or after one power system cycle when current drops below pickup. If you set 51RS01 = Y, then the relay resets according to the Reset Timer equations for that particular curve (see *Table 4.3* or *Table 4.4*). If you set 51RS01 = N, then the relay resets after one power system cycle when current drops below pickup.

All 20 time-overcurrent elements have the same setting format, as *Table 4.6* shows.

Table 4.6 Settings for the Time-Overcurrent Settings

Setting	Setting Description	Range	Default Value
51O*xx*[a]	Operating Quantity	See *Table 4.5*	IMAXSF
51P*xx*	Pickup (SEL Math Equation)	SMV[b]	1.00
51C*xx*	Curve Selection	U1 to U5, C1 to C5	U1
51TD*xx*	Time Dial (SEL Math Equation)	SMV[c]	1.00
51RS*xx*	EM Reset	Y or N	N
51TC*xx*	Torque Control (SELOGIC Equation)	SELOGIC Variable	PLT09

[a] Where xx = 01–10.
[b] Relay operating range: 5 A Relay = 0.5 to 16.0 amps secondary, 1 A Relay = 0.1 to 3.2 amps secondary.
[c] U1 to U5 = 0.5 to 15, 1 A C1 to C5 = 0.05 to 1.

Directional Control for Ground-Overcurrent Elements

For each terminal, the SEL-487E offers a choice of two independent voltage-polarized directional elements (negative-sequence and zero-sequence) to supervise the ground-overcurrent elements. In addition, you can also use the REF elements if you prefer current polarization instead of voltage polarization. You can use either negative-sequence (Q) or zero-sequence polarization (V), or a combination of the two (QV or VQ). When using the combination setting, select your polarization preference with the ORDER setting. *Table 4.7* shows the two directional elements, their availability as a function of the potential transformer (PT) connections, and the effect of the ORDER setting in terms of the preferred directional element. Be aware that directional elements are not available for PTs or CTs connected in delta (PTCON[*k*] = D or CTCON[*m*] = D, see *Delta-Connected CTs*). For PTs connected in delta and with an ORDER setting that includes the zero-sequence polarization (QV or VQ), only the negative-sequence element is operational.

Table 4.7 Availability of Directional Elements

ORDER Settings	Corresponding Ground Directional Element	CT Connection PTCON[k] =[a]	PT Connection PTCON[k] =	Polarization Preference	
				First Choice	Second Choice
Q	Negative-sequence	Y or D	Y or D	—	—
QV	Negative- and zero-sequence	Y	Y	Q (k32QGE)	V (k32VE)
V	Zero-sequence	Y	Y	V (k32VE)	—
VQ	Negative- and zero-sequence	Y	Y	V (k32VE)	Q (k32QGE)

[a] k = S, T, U, W, X.

Figure 4.43 shows a block diagram of the directional elements. Note that the order in which the ORDER setting lists directional elements (Q and V) determines the priority in which these elements operate, as selected by the Best Choice Ground Directional Element™ logic. See the discussion on setting ORDER under *Directional Control Settings*.

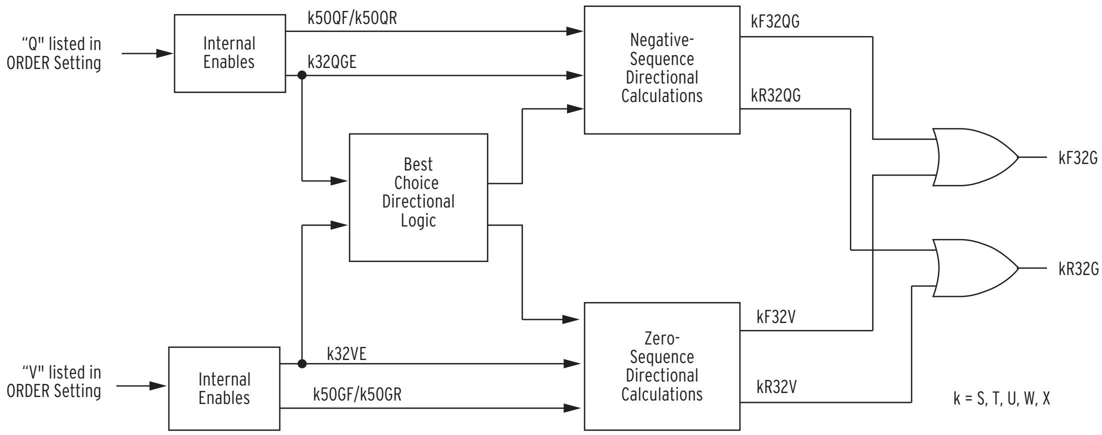


Figure 4.43 Block Diagram of the Directional Elements

Following is a discussion of each of the function blocks in *Figure 4.43*.

Negative-Sequence Internal Enable Function Block

NOTE: Figure 4.44 has internal enables 32QE and 32QGE, which the directional element logic uses to control negative-sequence and zero-sequence overcurrent elements.

Figure 4.44 shows the enable logic for the negative-sequence directional element. This logic checks the validity of the settings in *Table 4.8*, checks for a loss-of-potential condition, and compares the negative-sequence current (3I2*k*FM) against the following four values:

- 50FP*k*—the forward current threshold
- 50RP*k*—the reverse current threshold
- a2*k* • 3I1*k*FM—the positive-sequence current (adjusted by a2, the positive-sequence restraint factor)
- *k*2*k* • 3I0*k*FM—the zero-sequence current (adjusted by *k*2, the zero-sequence restraint factor)

Table 4.8 Enable Logic Checks for Negative-Sequence Element

Setting	Value Required for Valid Setting
E50*k*	Q (enable negative-sequence overcurrent element)
VREF*k*	V or Z (voltage terminals)
ORDER*k*	Includes Q (negative sequence)
E50	Terminal Name (S, T, U, W, or X)
E67*k*	Y
E50*k*	Includes G (enable zero-sequence overcurrent element)

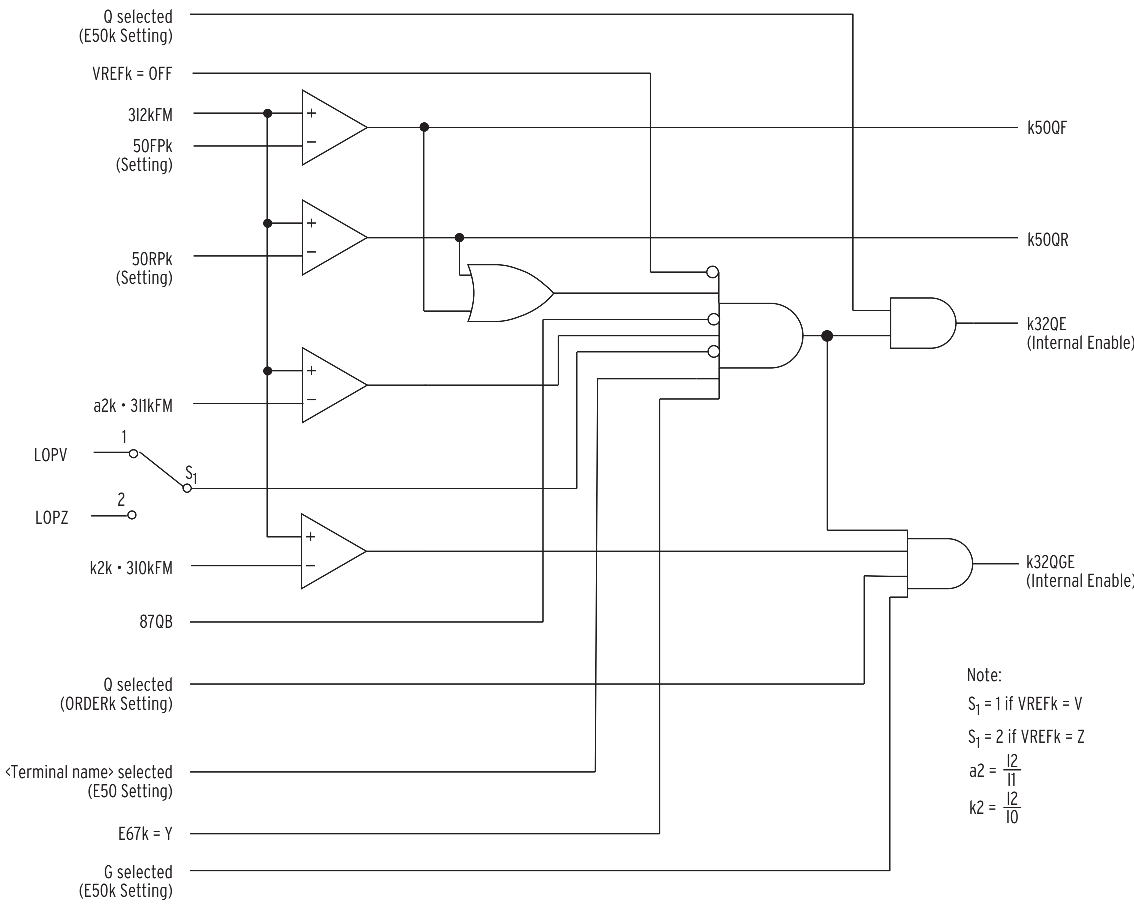


Figure 4.44 Internal Enables for Negative-Sequence (k32QE) and Zero-Sequence (k32QGE) Directional Elements

When a loss-of-potential condition occurs (Relay Word bit LOPV or LOPZ asserts), all the internal enables are disabled. Also, the 87QB input blocks the element when the second-harmonic and fifth-harmonic elements pick up, avoiding relay misoperations during transformer inrush conditions (see the *Directional Control Settings* for the restraint factors).

Zero-Sequence Internal Enable Functional Block

Figure 4.45 shows the enable logic for the zero-sequence directional element. This logic checks the validity of the settings in *Table 4.9*, selects the appropriate voltage source, checks for a loss-of-potential condition, and compares the zero-sequence current (3I0*k*FM) against the following three values:

- 50FP*k*—the forward current threshold
- 50RP*k*—the reverse current threshold
- a0*k* • 3I1*k*FM—the positive-sequence current (adjusted by a0, the positive-sequence restraint factor)

The logic also compares the zero-sequence voltage (3V0V*k*FM or 3V0Z*k*FM) against a fixed value of 7.5.

Table 4.9 Enable Logic Checks for Zero-Sequence Element

Setting	Value Required for Valid Setting
E50*k*	G (enable zero-sequence overcurrent element)
VREF*k*	V or Z (voltage terminals)
ORDER*k*	Includes V (zero sequence)
E50	Terminal Name (S, T, U, W, or X)
E67*k*	Y
E50*k*	Includes G (enable zero-sequence overcurrent element)

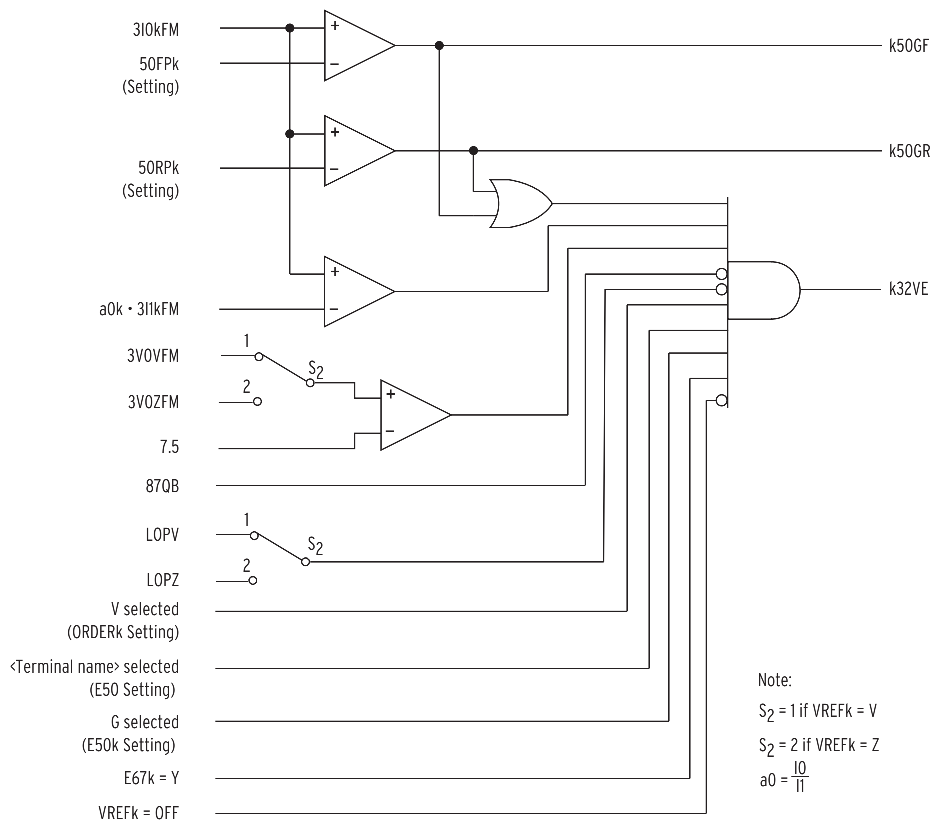


Figure 4.45 Internal Enable (k32VE) for Zero-Sequence Directional Element

Negative-Sequence Directional Calculation Block

Figure 4.46 shows the negative-sequence directional element logic. For each terminal, Group setting VREF[*k*] determines which loss-of-potential (LOPV or LOPZ) value and negative-sequence voltage (3V2VCF or 3V2ZCF) value the algorithm uses in the directional calculations. The directional calculations produce a signed impedance Z2*k* (see *Equation 4.22*) that the logic compares against Z2FTH*k*, the forward threshold, and Z2RTH*k*, the reverse threshold (see *Equation 4.23* through *Equation 4.26* for the threshold calculations). Inputs *k*50QF and *k*50QR are from the internal enable logic (*Figure 4.44*). At the bottom, inputs ORDER and *k*32VE form the Best Choice Ground Directional Element logic selection.

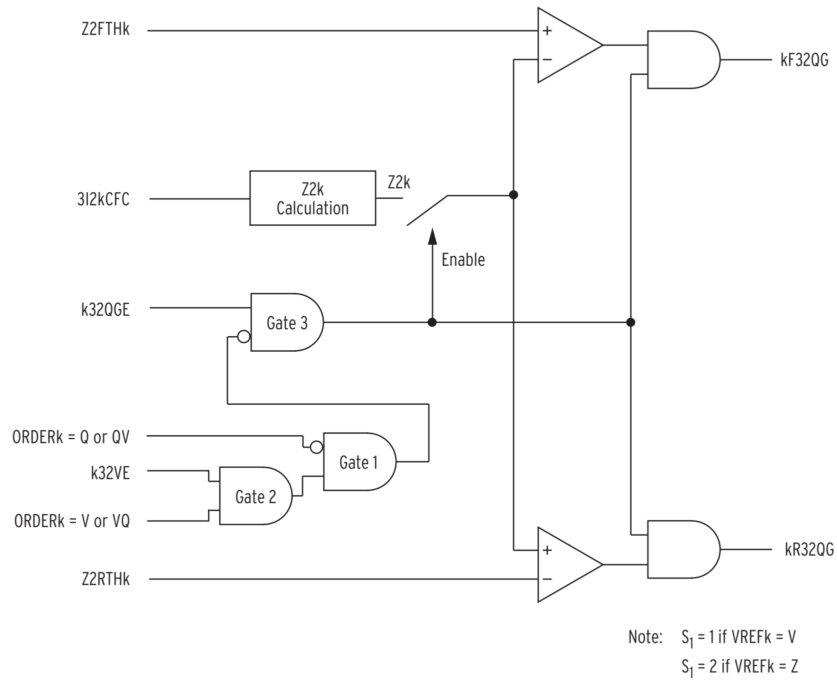


Figure 4.46 Negative-Sequence Directional Calculation Logic (Ground Elements)

Figure 4.47 shows the characteristic of the negative-sequence directional element, consisting of a forward threshold and a reverse threshold.

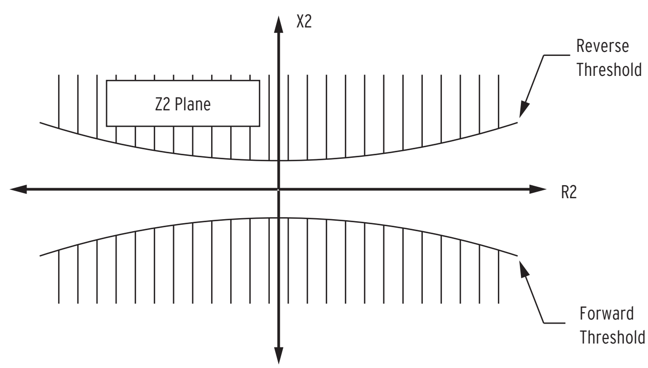


Figure 4.47 Negative-Sequence Directional Element Characteristic

Figure 4.48 shows a system with Fault F1 and Fault F2. These faults are two separate, close-in, A-phase faults. Fault F1 is in the forward direction with respect to Relay R, and Fault F2 is in the reverse direction with respect to Relay R. For the purpose of the following discussion, assume that both faults are at the line angle.

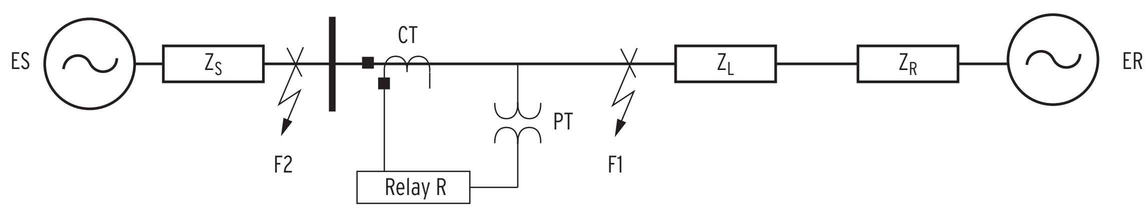


Figure 4.48 Close-In, Single-Phase Fault F1 and Fault F2

Figure 4.49 shows the phasor relationships for Fault F1 at the line angle Z1ANG. Using Phase A as reference, we see that the fault current lags the A-phase voltage by the line angle Z1ANG. All three sequence components of the current are in phase with the A-phase fault current. However, the negative-sequence voltage and the zero-sequence voltages are 180 degrees out of phase with the A-phase voltage.

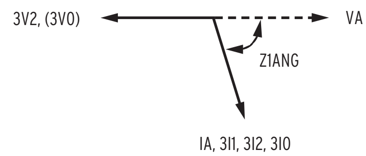


Figure 4.49 Phasor Relationships for an A-Phase-to-Ground Fault

For each phase, the negative-sequence directional element uses *Equation 4.22* to determine the signed quantity Z2*k*.

$$Z2k = \frac{\mathrm{Re}[3V2kCF \bullet (3I2kCFC \bullet 1\angle Z1ANGk)^*]}{3I2kFM^2}$$ **Equation 4.22**

where:

3V2*k*CF = negative-sequence voltage in phasor form
3I2*k*CFC = negative-sequence current in phasor form
1∠Z1ANG = the line angle in degrees
3I2*k*FM = magnitude of the negative-sequence current (scalar)
* = complex conjugate
Re = real part of

If we assume 3V2*k*CF = 100∠180°, 3I2*k*CFC = 10∠–80°, 3I2*k*FM = 10, and Z1ANG =1∠80°, the directional calculation for Terminal S is as follows:

$$Z2S = \frac{\mathrm{Re}[100\angle 180° \bullet (10\angle -80° \bullet 1\angle 80°)^*]}{(10)^2}$$

$$Z2S = \frac{\mathrm{Re}[100\angle 180° \bullet 10\angle 0°]}{100}$$

$$Z2S = \frac{\mathrm{Re}[1000\angle 180°]}{100}$$

$$Z2S = \frac{\mathrm{Re}[-1000 + j0]}{100}$$

$$Z2S = -10\Omega$$

Therefore, for a fault in the forward direction, Z2S has a negative value.

Figure 4.50 shows the phasor relationships for a reverse Fault 2 at the line angle Z1ANG.

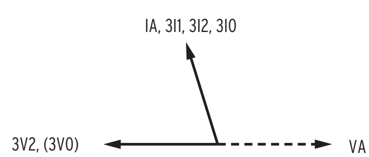


Figure 4.50 Phasor Relationships for a Reverse A-Phase-to-Ground Fault

If we assume 3V2*k*CF = 100∠180°, 3I2*k*CFC = 10∠100°, 3I2*k*FM = 10, and Z1ANG =1∠80°, the calculation for Terminal S is as follows:

$$Z2S = \frac{\mathrm{Re}[100\angle 180° \bullet (10\angle 100 \bullet 1\angle 80°)^*]}{(10)^2}$$

$$Z2S = \frac{\mathrm{Re}[100\angle 180° \bullet 10\angle 180°]}{100}$$

$$Z2S = \frac{\mathrm{Re}[1000\angle 0°]}{100}$$

$$Z2S = (10\Omega)$$

Therefore, for a fault in the reverse direction, ZS2 has a positive value.

To form the distinct shape of the thresholds, the element computes the forward threshold (Z2FTH*k*) and the reverse threshold (Z2RTH*k*) as described below.

Negative-Sequence Directional Element Forward Threshold Calculation

If Z2F*n* Setting ≤ 0, Forward Threshold (Z2FTH*n*) =

$$0.75 \bullet Z2Fn - 0.25 \bullet \left|\frac{3V2kCF}{3I2nCFC}\right| \qquad \text{Equation 4.23}$$

If Z2F*n* Setting > 0, Forward Threshold (Z2FTH*n*) =

$$1.25 \bullet Z2Fn - 0.25 \bullet \left|\frac{3V2kCF}{3I2nCFC}\right| \qquad \text{Equation 4.24}$$

Negative-Sequence Directional Element Reverse Threshold Calculation

If Z2R*n* Setting ≥ 0, Reverse Threshold (Z2RTH*n*) =

$$0.75 \bullet Z2Rn + 0.25 \bullet \left|\frac{3V2kCF}{3I2nCFC}\right| \qquad \text{Equation 4.25}$$

If Z2R*n* Setting < 0, Reverse Threshold (Z2RTH*n*) =

$$1.25 \bullet Z2Rn + 0.25 \bullet \left|\frac{3V2kCF}{3I2nCFC}\right| \qquad \text{Equation 4.26}$$

Zero-Sequence Directional Calculation Block

Figure 4.51 shows the characteristic of the zero-sequence directional element, consisting of a forward threshold and a reverse threshold. When setting the element, be sure to not overlap the two thresholds, because the area between the two thresholds provides security against relay errors.

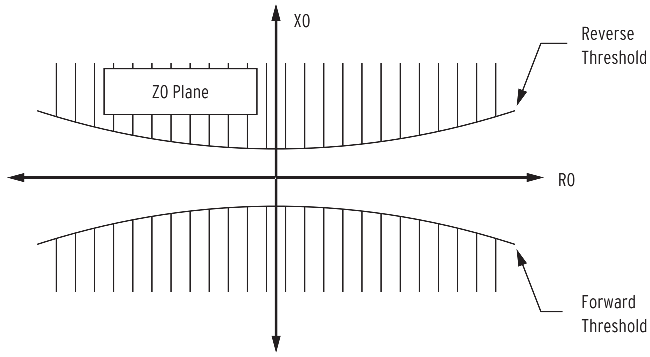


Figure 4.51 Zero-Sequence Directional Element Characteristic

For each phase, the zero-sequence directional element uses *Equation 4.27* to determine the signed quantity Z0*k*.

$$Z0k = \frac{\mathrm{Re}[3V0kCF \bullet (3I0kCF \bullet 1\angle Z0ANGk)]^*}{3I0kFM^2}$$ **Equation 4.27**

where:

3V0*k*CF = negative-sequence voltage in phasor form
3I0*k*CF = negative-sequence current in phasor form
1∠Z0ANG = the line angle in degrees
3I0*k*FM = magnitude of the negative-sequence current (scalar)
* = complex conjugate
Re = real part of

Zero-Sequence Directional Element Forward Threshold Calculation

Calculations for the zero-sequence directional element are identical to those for the negative-sequence directional element, except that the zero-sequence directional element calculations use zero-sequence quantities instead of negative-sequence quantities. The zero-sequence directional element uses *Equation 4.28* through *Equation 4.31*.

If Z0F*k* Setting ≤ 0, Forward Threshold (Z0FTH*k*) =

$$0.75 \bullet Z0Fk - 0.25 \bullet \left|\frac{3V0kCF}{3I0nCFC}\right|$$ **Equation 4.28**

If Z0F*k* Setting > 0, Forward Threshold (Z0FTH*k*) =

$$1.25 \bullet Z0Fk - 0.25 \bullet \left|\frac{3V0kCF}{3I0nCFC}\right|$$ **Equation 4.29**

Zero-Sequence Directional Element Reverse Threshold Calculation

If Z0R*k* Setting ≥ 0, Reverse Threshold (Z0RTH*k*) =

$$0.75 \bullet Z0Rk + 0.25 \bullet \left|\frac{3V0kCF}{3I0nCFC}\right|$$ **Equation 4.30**

If Z0R*k* Setting < 0, Reverse Threshold (Z0RTH*k*) =

$$1.25 \bullet Z0Rk + 0.25 \bullet \left|\frac{3V0kCF}{3I0nCFC}\right|$$ **Equation 4.31**

Figure 4.52 shows the zero-sequence directional element logic. For each terminal, Group setting VREF[*k*] determines which LOP(V/Z) value and 3V0(V/Z)CF value the algorithm uses in the calculations. Inputs ORDER and *k*32QGE form the Best Choice Ground Directional Element logic selection. After calculating the signed impedance Z0*k*, the logic compares Z0*k* against Z0FTH*k*, the forward threshold, and Z0RTH*k*, the reverse threshold (see *Equation 4.28* through *Equation 4.31* for the threshold calculations).

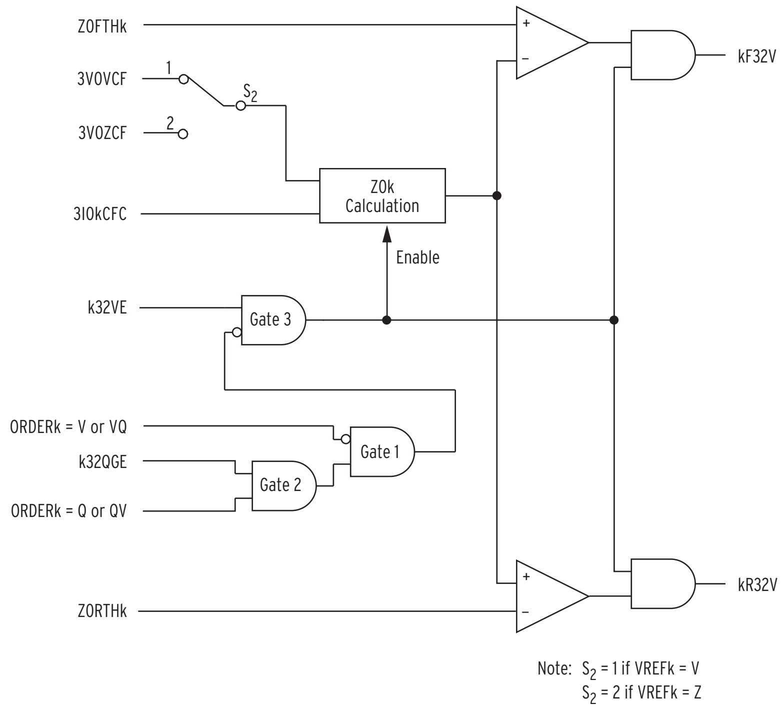


Figure 4.52 Zero-Sequence Directional Calculation Logic

Figure 4.53 combines the logics from *Figure 4.46* and *Figure 4.52* to provide a single directional quantity for the negative-sequence and the zero-sequence directional elements.

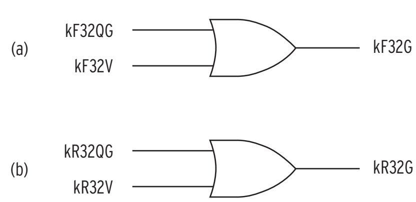


Figure 4.53 Single Negative-Sequence and Zero-Sequence Directional Element Output

Best Choice Function Block

The Best Choice Ground Directional Element logic determines which directional element should operate. This directional element then controls ground-overcurrent elements set for directional control. Although the best choice function is a separate function, the function logic is integrated into both the negative-sequence and zero-sequence directional calculation logics. In *Figure 4.46* and *Figure 4.52*, the two AND gates at the bottom of the figures (Gate 1 and Gate 2) form the best choice function. For the best choice function, the algorithm evaluates the value in the first position of the ORDER setting. In *Figure 4.52*, for example, the ORDER setting for the input into Gate 1 is ORDER[*k*] = V (or VQ). Because the algorithm only evaluates the first position of the ORDER setting, V and VQ produce the same result. If the ORDER[*k*] setting is set to V or VQ, then the input into GATE 1 asserts permanently to a logical 1 (before the inverter). If the ORDER[*k*] setting is set to Q or QV, then the input into Gate 1 asserts permanently to a logical 0.

For example, if you want the Terminal S zero-sequence directional element to take preference over the Terminal S negative-sequence directional element, set the ORDER setting as follows: ORDER = V (or VQ). This setting asserts the input into Gate 1 permanently to a logical 1, but the inverter at the input of Gate 1 changes the value to a permanent logical 0. This zero input turns Gate 1 permanently off, so that the output from Gate 1 is a permanent logical 0. This logical 0 after the inverter asserts the bottom input into Gate 3 permanently, requiring only *k*32VE to assert (see *Figure 4.52*) to enable the Z0*k* calculations.

Consider now the effect of the ORDER setting ORDER = V (or VQ) 1 on the negative-sequence directional logic (*Figure 4.46*). There are three possible scenarios:

- *k*32VE asserts, but not *k*32QGE
- *k*32QGE asserts, but not *k*32VE
- both *k*32QGE and *k*32VE assert.

In general, with the ORDER setting ORDER = V (or VQ), the top input into Gate 1 is a permanent logical 0, but the input turns into a permanent logical 1 through means of the inverter at the input. Also, the bottom input into Gate 2 is a permanent logical 1 because of setting ORDER = V (or VQ).

When *k*32VE asserts (but not *k*32QGE), Gate 2 turns on. Then Gate 1 turns Gate 3 off. When Gate 3 turns off, the Z2*k* calculations cannot be enabled even if *k*32QGE asserts, so Z0*k* takes preference.

When *k*32QGE asserts (but not *k*32VE), Gate 3 asserts (Gate 1 is still turned off), and the Z2*k* calculations begin. Therefore, if you select a combined setting (VQ), and the first choice does not assert, the directional calculations still begin if the second choice asserts.

It is when both *k*32QGE and *k*32VE assert that the relay calls upon best choice logic to select the appropriate value. As before, when *k*32VE asserts, Gate 2 turns on. Then Gate 1 turns Gate 3 off. When Gate 3 turns off, the Z2*k* calculations cannot be enabled, and Z0*k* takes preference.

Directional Control for Phase and Negative-Sequence Overcurrent Elements

Whereas the previous section describes directional elements for faults that involve ground, this section describes directional elements for faults clear of ground. Because negative-sequence quantities are present in all faults except for three-phase faults, a typical use for negative-sequence elements is as a control for both negative- and positive-sequence overcurrent elements. However, phase overcurrent elements also require positive-sequence directional elements because no negative-sequence quantities exist during three-phase faults.

Negative-Sequence Directional Element

Figure 4.54 shows the negative-sequence directional element, which uses the result of *Equation 4.22* (Z2*k*). This element differs from the negative-sequence element used for ground-fault overcurrent elements by not having zero-sequence directional elements.

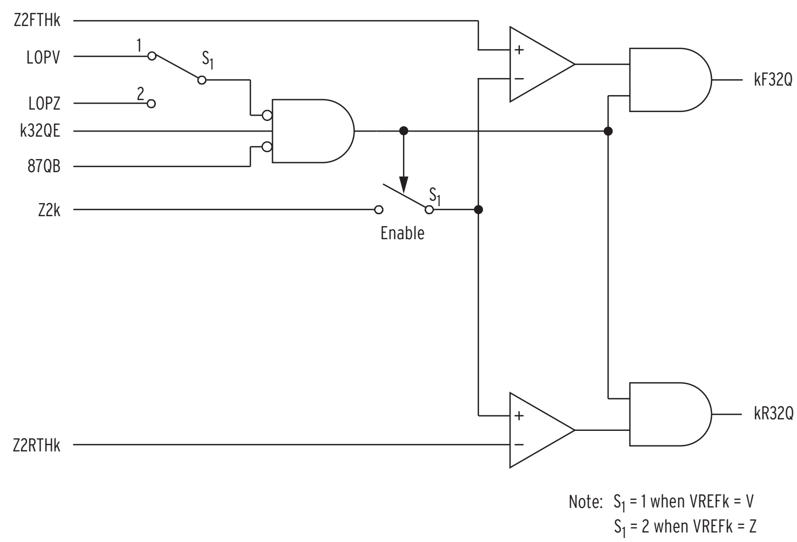


Figure 4.54 Negative-Sequence Directional Element

Phase Directional Element

In general, voltage-polarized elements work well for all types of shunt faults, except for close-in, three-phase faults. Because the voltage goes to zero for these faults, directional elements can lose the reference value and misoperate. To maintain polarizing voltage for close-in, three-phase faults, the SEL-487E uses positive-sequence polarized memory voltage. The complete phase directional element consists of a number of calculations and logic such as that in *Figure 4.55*, *Figure 4.56*, and *Figure 4.57*.

Figure 4.55 shows the positive-sequence directional element characteristic. Using the positive-sequence voltage as reference, the element declares a forward direction if the angle between the positive-sequence voltage and the positive-sequence current is between 300 degrees and 120 degrees (shaded area in *Figure 4.55*). Note that the limits of the characteristic (300 and 120 degrees) are independent of the line angle setting, and fixed at the values indicated in *Figure 4.55*.

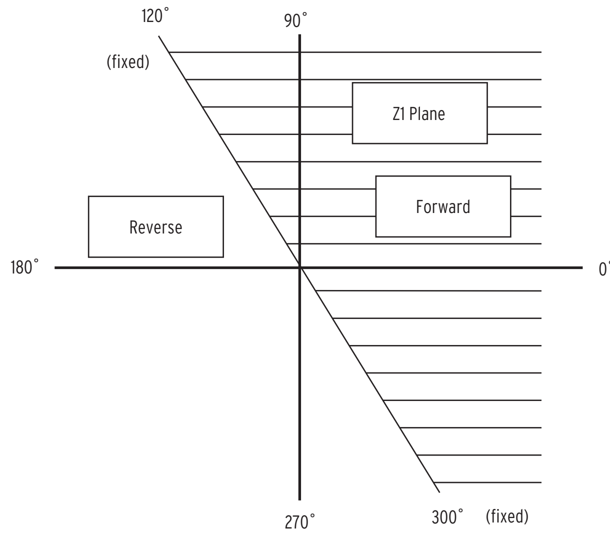


Figure 4.55 Positive-Sequence Directional Element Characteristic

Figure 4.56 shows the logic that calculates the positive-sequence forward (Z1F*k*) and reverse (Z1R*k*) directions. If the positive-sequence voltage is greater than 1 V, and if the positive-sequence current is greater than 10 percent of the nominal current (100 mA for a 1 A CT or 500 mA for a 5 A CT), calculation of Z1*k* begins.

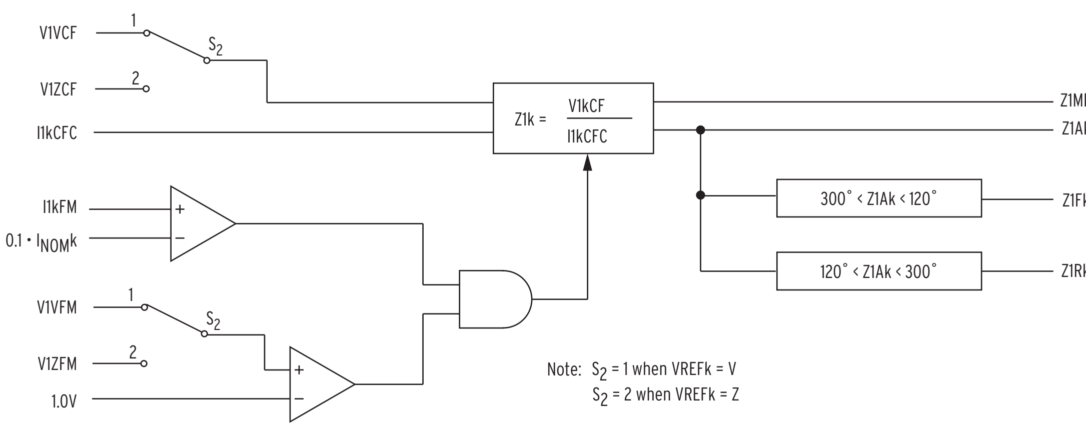


Figure 4.56 Positive-Sequence Directional Element

As for the negative-sequence directional element, the relay calculates a signed quantity to determine the forward and reverse directions. For the positive-sequence directional element, the relay uses positive-sequence phase-to-phase current values and positive-sequence phase-to-phase memory voltage values.

Figure 4.57 shows the algorithm that calculates the positive-sequence memory voltage. This algorithm uses the positive-sequence voltage as a function of the VREF*k* setting. Output VPOL*k* asserts if the absolute value of VA1*p*mem (*p* = V or Z) exceeds 1 V.

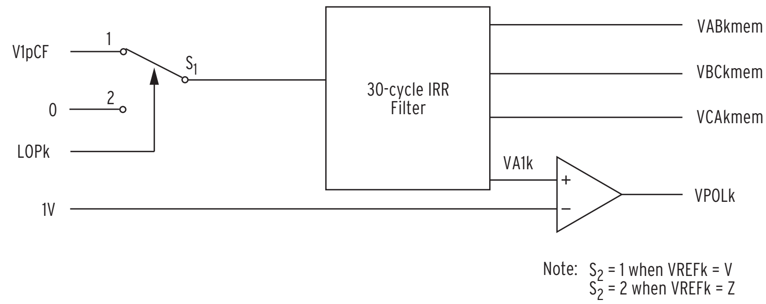


Figure 4.57 Positive-Sequence Memory Voltage

Equation 4.32, *Equation 4.33*, and *Equation 4.34* show the calculation to determine positive-sequence element direction. In contrast to the similar calculation for the negative-sequence element, a positive result indicates a forward direction. A negative result indicates a reverse direction.

$$MABDk = \mathrm{Re}[Z1ANG \bullet (-1)^q IAB \bullet (VABpmem^*)]$$

Equation 4.32

$$MBCDk = \mathrm{Re}[Z1ANG \bullet (-1)^q IBC \bullet (VBCpmem^*)]$$

Equation 4.33

$$MCADk = \mathrm{Re}[Z1ANG \bullet (-1)^q ICA \bullet (VCApmem^*)]$$

Equation 4.34

where:

Re = real part of
Z1ANG = positive-sequence line angle
q = 1 if CTP*k* = N
q = 2 if CTP*k* = P
CTP*k* = CT polarity of Terminal *k*
p = V or Z
* = complex conjugate

Figure 4.58 shows the logic that produces the forward phase declaration (*k*F32P) and the reverse phase declaration (*k*R32P). For the forward direction, the following conditions must be met:

- Magnitudes MABD*k*, MBCD*k*, and MCAD*k* must all be greater than 10 percent of the nominal current
- The directional element function must be enabled (E67*k* = Y)
- VREF cannot be set to OFF
- There must not be a loss of potential
- Either the forward positive-sequence load direction (Z1F*k*, see *Figure 4.56*) must assert, and
- Either the positive-sequence current must be below 10 percent of nominal, or the positive-sequence voltage must be below 1 V.

For the reverse direction, the following conditions must be met:

- MABD*k*, MBCD*k*, and MCAD*k* must all be below –10 percent of the nominal current
- The directional element function must be enabled (E67*k* = Y)
- VREF cannot be set to OFF
- There must not be a loss of potential
- Either the reverse positive-sequence load direction (Z1R*k*, see *Figure 4.56*) must assert, or
- Either the positive-sequence current must be below 10 percent of nominal, or the positive-sequence voltage must be below 1 V.

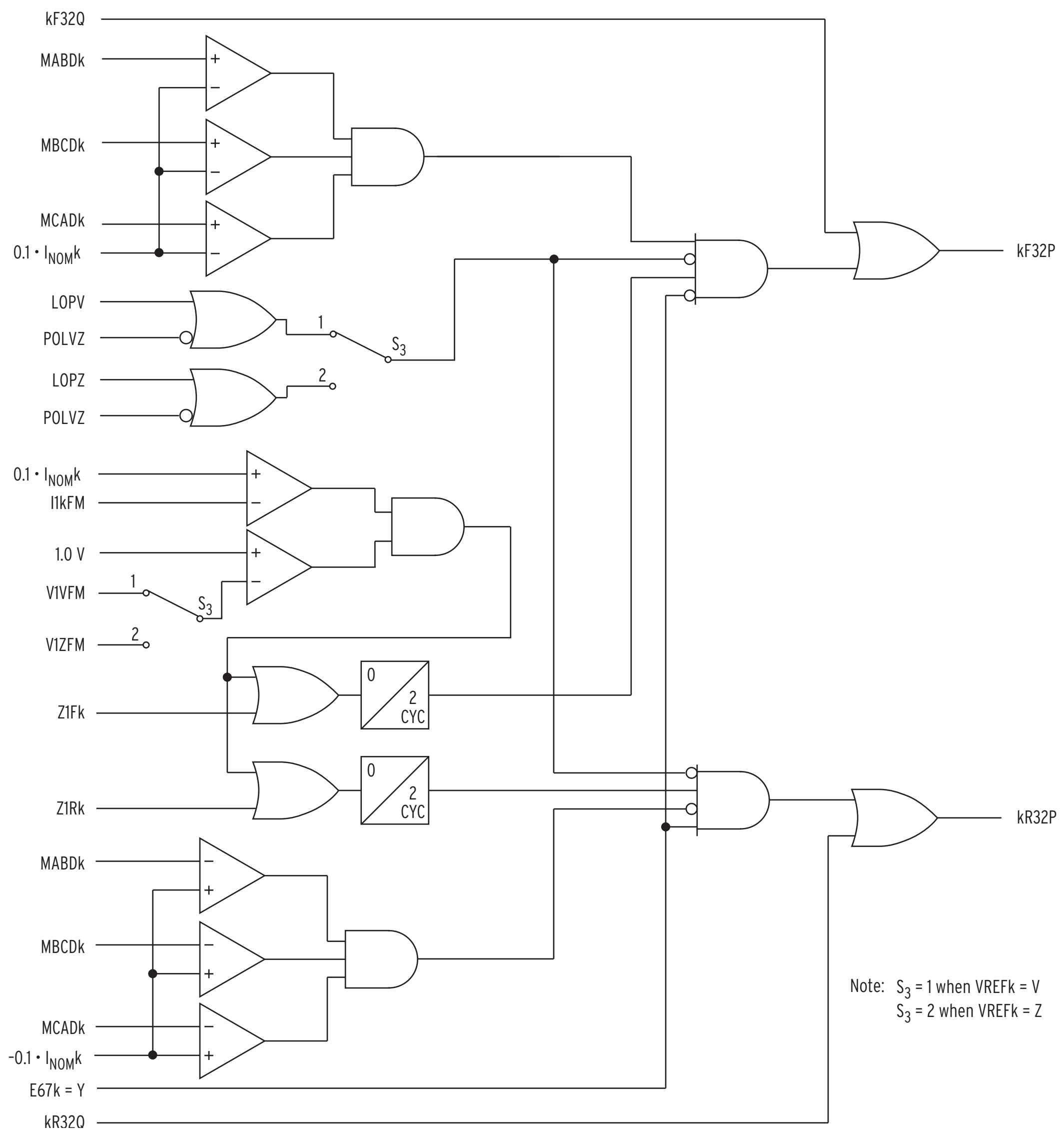


Figure 4.58 Phase Directional Element

Table 4.10 shows examples of torque control equation settings for each overcurrent element (P, Q, G) of Terminal S.

Many utilities prefer to use the current from the transformer neutral as the polarizing quantity. By using the reverse output from the REF elements, you can also use current polarizing as a method of directional control. Be aware that the Best Choice function does not include the REF elements, so include the REF element in specifying the directional control conditions. The last row in *Table 4.10* shows an example that uses the reverse output from REF Element 1 as current polarizing and that includes the REF element in the Best Choice function.

Table 4.10 Directional Element Summary and Example Settings (Terminal S)

E50k Setting	Selected OC Element	Torque-Control Setting for Selected OC Element	Comment
P	50SP1	67SP1TC = SF32P OR SF32G	Include SF32P for bolted, three-phase faults.
Q	50SQ1	67SQ1TC = SF32G	No need to include SF32P (no negative-sequence current for three-phase faults), and SF32G includes negative- and zero-sequence directional elements. (See *Figure 4.53*.)
G	50SG1	67SG1TC = SF32G	No need to include SF32P (no negative-sequence current for three-phase faults), and SF32G includes negative- and zero-sequence directional elements. (See *Figure 4.53*.)
G	50SG1	67SG1TC = REF1RP or SF32G	Relay Word bit REF1RP asserts when the REF element detects a fault external to the REF zone. See the REF elements for more information.

Directional Control Settings

Setting E50 is a composite setting that determines definite-time overcurrent and directional element settings (see E50 element setting for more information). *Table 4.11* summarizes the interaction between the E50, E50*k*, E67*k*, and the 67*k*P*a*TC settings.

Table 4.11 Directional Element Summary

Setting	Range	Purpose
E50	S, T, U, W, X	Select windings that require: 1. definite-time OC elements 2. directional elements (at this point, there is no distinction between selecting OC elements and selecting directional elements)
E50*k*[a]	P, Q, G	After selecting the winding(s) (E50), select the OC elements directional elements from among phase (P), negative-sequence (Q) and zero-sequence (G) if required for each winding. If OC elements are not required, leave E50*k* = OFF.
E67*k*	Y, N	After selecting the winding(s) (E50) and the type of directional elements (E50*k*), enable the directional elements for the windings. For example, if you set E50 = S, E50S = P, and E67S = N, then Winding S has phase OC elements only, (i.e., no directional elements). Setting E67S = Y enables the directional elements for Winding S.
67*k*P*a*TC[b]	SELOGIC Control Equation	State the directional conditions for the phase-OC elements. (See *Table 4.10*.)
67*k*Q*a*TC	SELOGIC Control Equation	State the directional conditions for the negative-sequence OC elements. (See *Table 4.10*.)
67*k*G*a*TC	SELOGIC Control Equation	State the directional conditions for the zero-sequence OC elements. (See *Table 4.10*.)

[a] k = S, T, U, W, X.
[b] a = 1 – 3.

E67[k] (Enable Directional Elements)

For each terminal, enable the directional control for overcurrent elements by setting directional control enable setting E67[*k*]. Setting E67[*k*] = Y enables the directional element for that winding; disable the directional element for that winding by setting E67[*k*] = N.

Setting	Prompt	Range	Default	Category
E67[*k*][a]	Enable Directional Elements Terminal [*k*]	Y, N	N	Group

[a] k = S, T, U, W, X.

CTP[k] (CT Polarity)

Use the CTP[*k*] setting, available only if E67[*k*] =Y, to select the CT polarity for the directional element of each terminal. You cannot select the polarity of the individual phases; the setting applies to all three phases. In *Figure 4.59*, CTS and CTT are installed and connected in the conventional way to provide CT information with the correct polarity for the differential element. However, if you want to use CTT for directional control in the same direction as, for example, CTU, then the polarity of CTT is incorrect.

NOTE: The CTP[k] setting has no effect on the CT polarity of any other element; the setting applies only to the directional element.

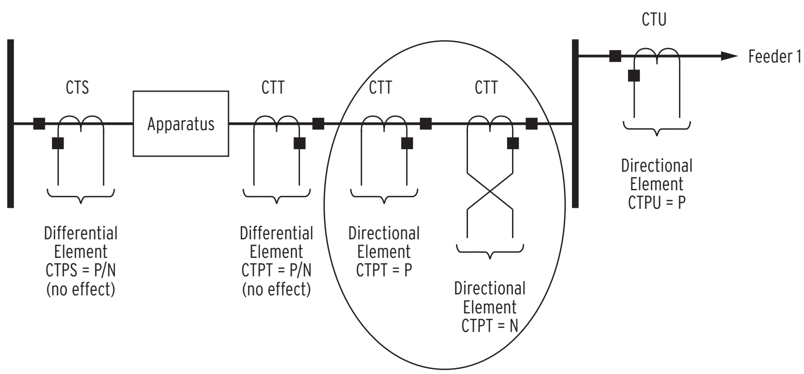


Figure 4.59 CTP[k] Changes the Polarity of the CTs for the Directional Elements

By your setting CTPT = N, the relay internally changes the polarity of CTT for the directional element and interprets the polarity of CTT as if it is the same as the polarity of CTU.

Setting	Prompt	Range	Default	Category
CTP[*k*][a]	Current Transformer Polarity Terminal [*k*]	P, N	P	Group

[a] k = S, T, U, W, X.

Z1ANG[k] (Positive-Sequence Line Impedance Angle)

For each terminal, set the positive-sequence line angle in degrees. This setting is only available if setting E67*k* = Y.

Setting	Prompt	Range	Default	Category
Z1ANG[*k*][a]	Pos.-Seq. Line Impedance Angle	5.0 to 90 degrees	89	Group

[a] k = S, T, U, W, X.

Z0ANG[k] (Zero-Sequence Line Impedance Angle)

For each terminal, set the zero-sequence line angle in degrees. This setting is only available if setting E67*k* = Y and if setting E50*k* includes G.

Setting	Prompt	Range	Default	Category
Z0ANG[*k*][a]	Zero-Seq. Line Impedance Angle	5.00 to 90 degrees	85	Group

[a] k = S, T, U, W, X.

EADVS[k] (Enable Advanced Settings)

Enable the advanced settings by setting EADVS[*k*] = Y. This setting is only available if setting E67*k* = Y. Advanced settings include the following:

50FP[*k*]

50RP[*k*]

Setting	Prompt	Range	Default	Category
EADVS[*k*][a]	Enable Advanced Setting Terminal [*k*]	Y, N	N	Group

[a] k = S, T, U, W, X.

50FP[k] (Forward Direction Overcurrent Pickup)

Setting 50FP[*k*] is the Forward Direction Overcurrent Pickup value that the negative-sequence current (3I2*k*FM) must exceed, and it is one of the conditions that must be true to assert *k*32QGE (see *Figure 4.44*). This setting is only available if setting E67*k* = Y. If setting EADVS[*k*] = N, then the relay internally sets 50FP[*k*] to 0.12 • I_{NOM}[*k*].

Setting	Prompt	Range	Default	Category
50FP [*k*][a]	Forward Dir. O/C Pickup A, sec	0.25 to 5	0.25	Group

[a] k = S, T, U, W, X.

50RP[k] (Reverse Direction Overcurrent Pickup)

Setting 50RP[*k*] is the Reverse Direction Overcurrent Pickup value that the negative-sequence current (3I2*k*FM) must exceed, and it is one of the conditions that must be true to assert *k*32QGE (see *Figure 4.44*). This setting is only available if setting E67*k* = Y. If setting EADVS[*k*] = N, then the relay internally sets 50RP[*k*] to 0.08 • I_{NOM}[*k*].

Setting	Prompt	Range	Default	Category
50RP[*k*][a]	Reverse Dir. O/C Pickup A, sec	0.25 to 5	0.25	Group

[a] k = S, T, U, W, X.

Z2F[k] (Forward Direction Z2 Threshold)

Use Z2F to calculate the Forward Threshold for the negative-sequence voltage-polarized directional elements. This setting is only available if setting E67*k* = Y. If setting EADVS[*k*] = N, then the relay internally sets Z2F[*k*] to –0.5/ I_{NOM}[*k*].

Setting	Prompt	Range	Default	Category
Z2F[*k*][a]	Fwd Dir Z2 Threshold ([RANGE] ohms, sec)	–64.00 to 64.00	–0.1	Group

[a] k = S, T, U, W, X.

Z2R[k] (Reverse Direction Z2 Threshold)

Use Z2R to calculate the reverse threshold for the negative-sequence voltage-polarized directional elements. This setting is only available if setting E67*k* = Y. If setting EADVS[*k*] = N, then the relay internally sets Z2R[*k*] to 0.5/ I_{NOM}[*k*]. When setting the element, be sure to set Z2R greater in value than setting Z2F by at least Z2Fk + 0.5/ I_{NOM}[*k*] secondary.

Setting	Prompt	Range	Default	Category
Z2R[*k*][a]	Rev Dir Z2 Threshold ([RANGE] ohms, sec)	–64.00 to 64.00	0.1	Group

[a] k = S, T, U, W, X.

a2[k] (Positive-Sequence Restraint Factor—k32QE)

The a2 factor is the ratio of the negative-sequence current and the positive-sequence current (I2/I1). This factor increases the security of negative-sequence voltage-polarized directional elements by preventing these elements from operating for negative-sequence current (system unbalance). Negative-sequence current circulates because of line asymmetries, CT saturation during three-phase faults, etc. (see *Figure 4.44*). This setting is only available if setting E67*k* = Y. If setting EADVS[*k*] = N, then the relay internally sets a2[*k*] to 0.1.

Setting	Prompt	Range	Default	Category
a2[*k*][a]	Pos.-Seq. Restraint Factor, I2/I1	0.02 to 0.50	0.1	Group

[a] k = S, T, U, W, X.

Order[k] (Ground Directional Element Priority)

This setting is hidden when E67[*k*] = N or if E50[*k*] does not include G. Also, if the advanced settings EADVS[*k*] = N, then this setting is set to QV.

Setting ORDER can be set to negative-sequence (Q), zero-sequence control (V), or the combination of the two (i.e., QV or VQ). The order in which you enter the directional elements in setting ORDER determines the priority in which these elements operate to provide Best Choice Ground Directional Element logic control.

For example, if setting:

ORDER = **QV**

then the first listed directional element (Q = negative-sequence voltage polarized directional element) is the first priority directional element to provide directional control for the neutral-ground and residual-ground overcurrent elements.

If the negative-sequence voltage-polarized directional element is inoperable (it does not have sufficient operating quantity, as indicated by its internal enable, 32QGE, not being asserted), then the second listed directional element (V = zero-sequence voltage-polarized directional element) provides directional control for the neutral-ground and residual-ground overcurrent elements.

If the zero-sequence voltage-polarized directional element is inoperable (it does not have sufficient operating quantity, as indicated by its internal enable, 32VE, not being asserted), then no directional control is available.

In another example, if setting:

ORDER = **V**

then the zero-sequence voltage-polarized directional element (V = zero-sequence voltage-polarized directional element) provides directional control for the neutral-ground and residual-ground overcurrent elements at all times (assuming it has sufficient operating quantity). If there is insufficient operating quantity during an event (the internal enable 32VE is not asserted), then no directional control is available.

Setting	Prompt	Range	Default	Category
ORDER[*k*][a]	Ground Dir. Element Priority	Q, V, QV, VQ	QV	Group

[a] k = S, T, U, W, X.

k2[k] (Zero-Sequence Current Restraint Factor, I2/I0)

Note the internal enable logic outputs in *Figure 4.44*.

- *k*32QE, the internal enable for the negative-sequence voltage-polarized directional element that controls the negative-sequence and phase overcurrent elements and
- *k*32QGE, the internal enable for the negative-sequence voltage-polarized directional element that controls the zero-sequence overcurrent elements

For the 32QGE internal enable to be on, the negative-sequence current magnitude (3I2*k*FM) must be greater than the zero-sequence current (3I0*k*FM) magnitude multiplied by *k*2:

$|I2| > k2 \bullet |I0|$

This check ensures that the relay uses the most robust analog quantities in making directional decisions for the neutral-ground and residual-ground overcurrent elements. The zero-sequence current (3I0*k*FM), to which we refer in the previous application of the *k*2 factor, is from the residual current, which we derived from phase currents IA, IB, and IC.

The *k*2 factor increases the security of the zero-sequence voltage-polarized directional elements. It keeps the elements from operating for zero-sequence current (system unbalance), which circulates because of line asymmetries, CT saturation during three-phase faults, etc. (see *Figure 4.44*). This setting is only available if setting E67*k* = Y. If setting EADVS[*k*] = N, then the relay internally sets a2[*k*] to 0.1.

Setting	Prompt	Range	Default	Category
k2[*k*][a]	Zero-Seq. Restraint Factor, I2/I0	0.10 to 1.20	0.2	Group

[a] k = S, T, U, W, X.

Z0F[k] (Forward Directional Z0 Threshold)

This setting is only available if setting E67*k* = Y and if setting E50[*k*] includes G. If setting EADVS[*k*] = N, then the relay internally sets Z0F[*k*] to $-0.5 / I_{NOM}[k]$ (I_{NOM} = 1 for a 1 A relay and 5 for a 5 A relay). When setting Z0F[*k*] and Z0R[*k*], be sure that Z0R is greater in value than setting Z0F by at least 0.1 Ω secondary.

Setting	Prompt	Range	Default	Category
Z0F[*k*][a]	Fwd Dir Z0 Threshold (RANGE)	–64.00 to 64.00	–0.1	Group

[a] k = S, T, U, W, X.

Z0R[k] (Reverse Directional Z0 Threshold)

This setting is only available if setting E67*k* = Y and if setting E50[*k*] includes G. If setting EADVS[*k*] = N, then the relay internally sets Z0R[*k*] to $0.5 / I_{NOM}[k]$ (I_{NOM} = 1 for a 1 A relay and 5 for a 5 A relay). When setting Z0F[*k*] and Z0R[*k*], be sure that Z0R is greater in value than setting Z0F by at least 0.1 Ω secondary.

Setting	Prompt	Range	Default	Category
Z0R[*k*][a]	Rev Dir Z0 Threshold	–64.00 to 64.00	0.1	Group

[a] k = S, T, U, W, X.

a0[k] (Positive-Sequence Current Restraint Factor, I0/I1)

This setting is only available if setting E67*k* = Y and if setting E50[*k*] includes G. The a0 factor increases the security of the zero-sequence voltage-polarized directional element. This factor keeps the elements from operating for zero-sequence current (system unbalance), which circulates because of line asymmetries, CT saturation during three-phase faults, etc.

The zero-sequence current (I_0), to which we referred in the application of the a0 factor, is from the residual current (IG), which we derived from phase currents I_A, I_B, and I_C: $3I_0 = I_G = I_A + I_B + I_C$.

Setting	Prompt	Range	Default	Category
a0[*k*][a]	Pos.-Seq. Restraint Factor, I0/I1	0.02 to 0.50	0.1	Group

[a] k = S, T, U, W, X.

Unbalance Current Elements

Use the current unbalance logic to detect unbalance among the three-phase current magnitudes during normal system operating conditions. For each terminal in the E46 setting, the relay uses *Equation 4.35* to calculate the average current.

$$I_{AVEk} = \frac{(IAkFM + IBkFM + ICkFM)}{3} \qquad \textbf{Equation 4.35}$$

Figure 4.60 shows the logic that uses the result of *Equation 4.35* ($I_{AVE}k$) to calculate the unbalance for the A-phase. Calculations begin only if the E46 setting includes the terminal and if the average current is larger than five percent of the nominal current. After calculating the percentage difference between the individual phase current and the terminal average current, the logic compares this result to the value of setting 46*k*PU. If the result exceeds the setting value, then 46*k* assert.

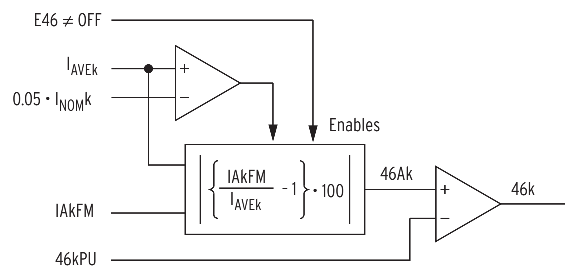


Figure 4.60 Unbalance Logic for Terminal k, Phase A

Figure 4.61 shows the logic that prevents assertion of the unbalance element during fault conditions and after closure of a terminal circuit breaker.

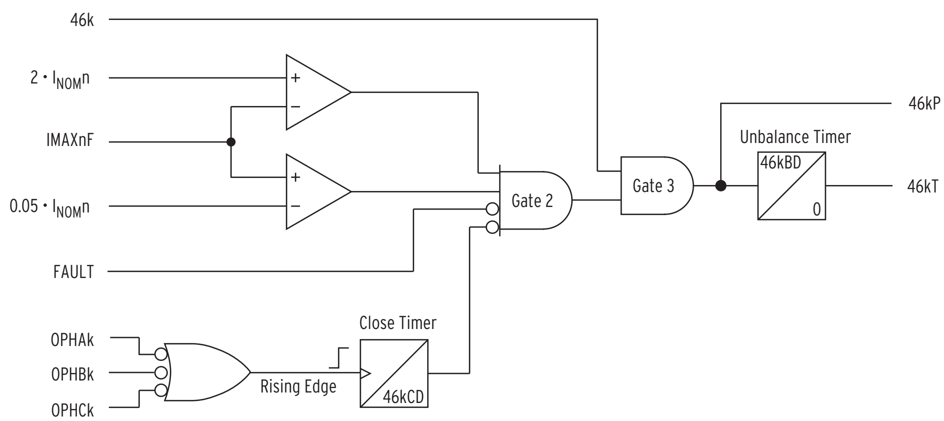


Figure 4.61 Unbalance Blocking Logic for Terminal D

The current unbalance logic does not operate if any of the following conditions are true:

- ➤ The maximum terminal current is greater than $2 \bullet I_{NOM}$, indicating a system fault
- ➤ The Relay Word bit FAULT asserts
- ➤ The circuit breaker has been closed (open-phase detection elements have deasserted)

After the circuit breaker closes (and current flows), all three open-phase detection elements (OPHA*k*, OPHB*k*, and OPHC*k*) deassert. When the first open phase detection element deasserts, the Close Timer starts and asserts for a time period equal to the 46*k*CD time setting, during which time Gate 2 is turned off. If one of the phases fails to close, AND Gate 2 is not turned off, and, provided I_{MAX} is above five percent I_{NOM}, but below $2 \bullet I_{NOM}$, Gate 3 turns on. When Gate 3 turns on, Relay Word bit 46*k*P asserts and the Unbalance Timer starts timing. If Gate 3 is turned on for a period equal to the 46*k*BD setting, then Relay Word bit 46*k*T asserts.

Unbalance Current Settings

46[k]PU (Current Unbalance Pickup)

Set the percentage unbalance among the three phases of a particular winding.

Setting	Prompt	Range	Default	Category
46[*k*]PU[a]	Terminal [*k*] Current Unbalance Pickup	5 to 100%	20	Group

[a] k = S, T, U, W, X.

46[k]CD (Close Delay)

Set the time for the current to settle after closing the circuit breaker. During this time, Gate 2 in *Figure 4.61* is turned off; the unbalance function is inoperative.

Setting	Prompt	Range	Default	Category
46[*k*]CD[a]	Terminal [*k*] Close Delay	5.00 to 600 cycles	10	Group

[a] k = S, T, U, W, X.

46[k]BD (Current Unbalance Delay)

The unbalance timer starts timing when the unbalance among the three phases exceeds the 46[*k*] setting. Use setting 46[*k*]BD to specify how long unbalance must persist before the elements provide an output.

Setting	Prompt	Range	Default	Category
46[*k*]BD[a]	Terminal [*n*] Current Unbalance Delay	0.00 to 6000 cycles	10	Group

[a] k = S, T, U, W, X.

Volt/Hertz Elements

Overexcitation occurs when system conditions cause the magnetic core of a transformer to saturate. These system conditions are an overvoltage condition, an underfrequency condition, (or a combination of the two conditions). The Volts/hertz function in the SEL-487E combines these two system conditions into one element by calculating the ratio of normalized voltage to normalized frequency (V/Hz). This ratio is proportional to the flux in the transformer core, and therefore, also proportional to any over- or underexcitation of the transformer core. Because transformer core saturation is different for loaded and unloaded transformers, the volts per hertz element provides two levels of definite time V/Hz protection. In addition, the element also provides two user-defined curves so that you can form an inverse type of V/Hz characteristic.

Definite Time Elements

Figure 4.62(a) shows the definite-time characteristic when only Level 1 is active, and *Figure 4.62*(b) shows the characteristic when Level 2 is active.

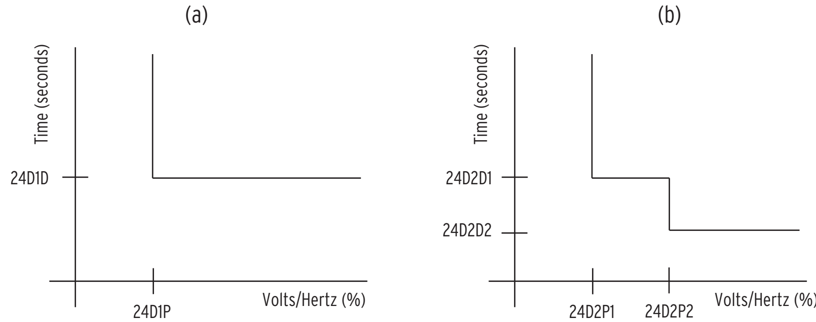


Figure 4.62 Levels 1 and 2 V/Hz

Figure 4.63 shows the definite-time V/Hz logic. To enable the Level 1 element, set Group setting E24 = Y (24CCS is at the default setting = OFF). With the Level 1 element active, only the top part of the logic (up to the V/Hz timer) is active.

After selecting the appropriate voltage (V if FRQST = V or Z if FRQST = Z), the logic normalizes the measured voltage (maximum of the secondary line-to-line voltages) and the measured frequency to the VNOM*k* and NFREQ values. To form the V/Hz per-unit value, the logic divides the normalized voltage by the normalized frequency and multiplies the result by 100 to calculate a percentage to form analog quantity 24RPU.

In Comparator C1, the logic compares 24RPU against the 24D1P setting value. If 24RPU exceeds the 24D1P setting value, and if SELOGIC control equation 24TC is asserted, then Gate 1 turns on and the V/Hz conditional timer starts timing. If Gate 1 remains turned on until expiration of the 24D1D time setting, then Relay Word bit 24D1T asserts.

Note that Level 2 of the definite-time element uses counters instead of conditional timers, to avoid resetting the conditional timer when 24RPU momentarily dips below the threshold setting. To enable Level 2, set 24CCS = DD. Setting 24CCS to DD asserts one input of both Gate 2 and Gate 3. In Comparator 2, the logic compares 24RPU against the 24D2P1 setting value, and in Comparator 3, the logic compares 24RPU against the 24D2P2 setting value. If SELOGIC control equation 24TC is asserted, Gate 2 turns on when 24RPU exceeds the 24D2P1 setting value, and Gate 3 turns on when 24RPU exceeds the 24D2P2 setting value. In turn, Counter 1 starts when Gate 2 turns on and Counter 2 starts when Gate 3 turns on.

Each counter has two outputs. When either counter reaches a count that equals the timer setting (24D2D1 or 24D2D2), Relay Word bit 24D2T asserts (because these are counters, the time will be longer if 24RPU fell below the threshold setting). When both counters are reset (count = 0), Relay Word bit 24D2R asserts.

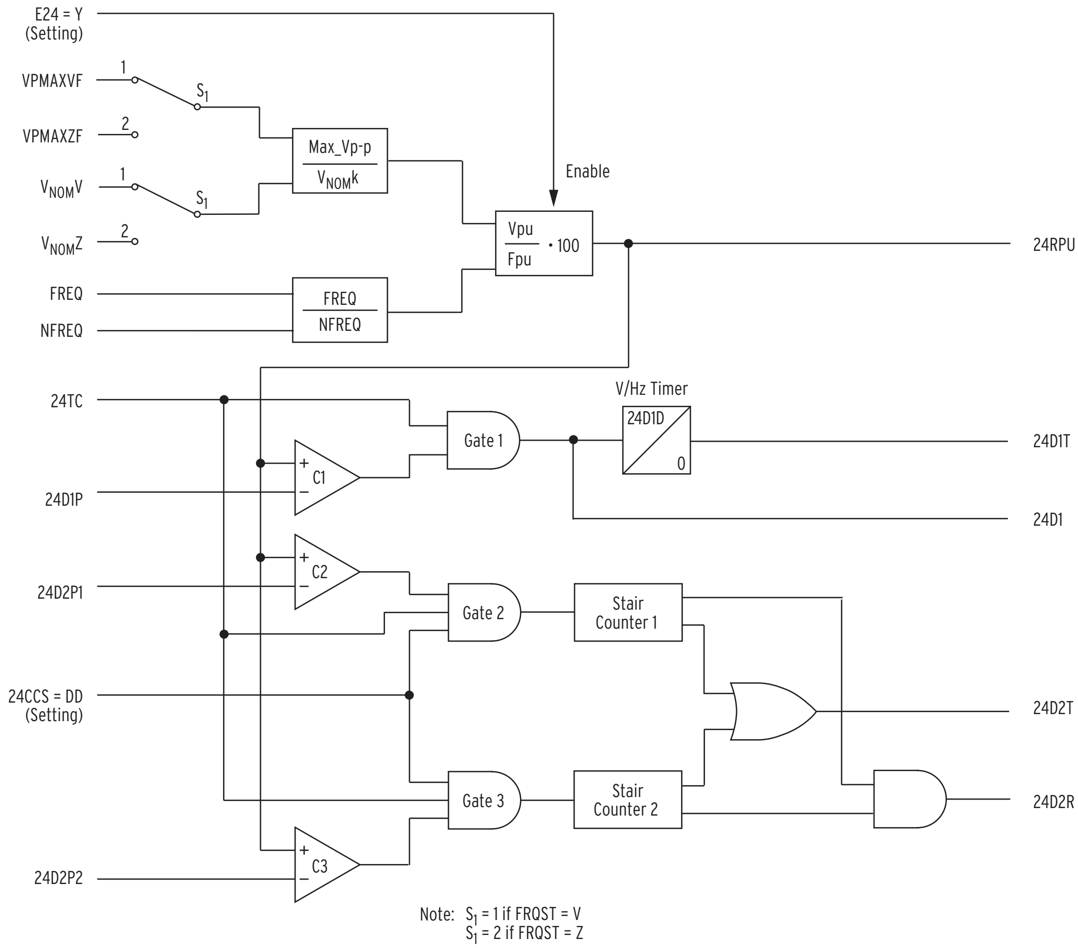


Figure 4.63 Two-Level, Definite-Time V/Hz Logic

User-Defined Curves

Figure 4.64 shows the logic for the user-defined curves. Use setting 24CCS to select either User-Defined Element 1 (24CCS = U1), or both User-Defined Element 1 and User-Defined Element 2 (24CCS = U2). Each element has a separate torque control setting (24U1TC and 24U2TC), and 24RPU is the analog quantity the V/Hz logic calculated in *Figure 4.63*.

These user-defined curves consist of as many as 20 points (24U101-24U120 and 24U201-24U220) to form characteristics suitable for most applications. For each point, enter the V/Hz value and the time associated with that particular V/Hz value. Because the relay calculates the time after linear interpolation of the V/Hz values, enter as many points as possible for accurate time results.

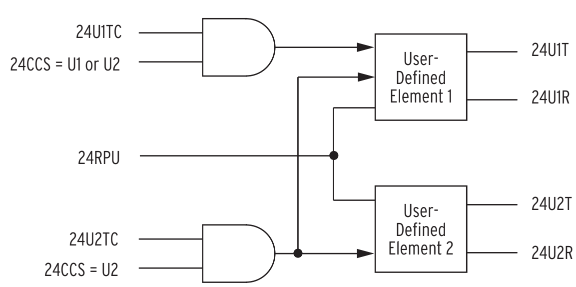


Figure 4.64 Logic for the User-Defined Curves

For example, assume that you obtain the V/Hz characteristic in *Figure 4.65* from a transformer manufacturer. To program this characteristic, you need to enter any number of points between 3 and 20. *Figure 4.65* shows three such points:

- Point 24U101: V/Hz = 110 (percentage) and the operate time = 33 (seconds)
- Point 24U102: V/Hz = 150 (percentage) and the operate time = 22 (seconds)
- Point 24U103: V/Hz = 200 (percentage) and the operate time = 14 (seconds)

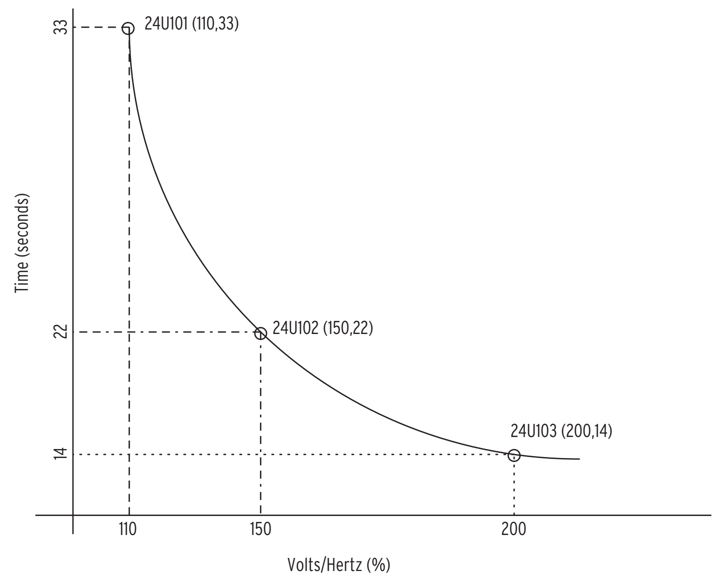


Figure 4.65 V/Hz Curve from Manufacturer

Figure 4.66(a) shows a programmed curve from entry of only three points. Clearly, this programmed curve is much different from the original curve, and the time calculations will be inaccurate. *Figure 4.66*(b) shows a programmed curve, obtained after entry of 16 points, superimposed on the original curve. With more points, the programmed curve closely follows the original curve, and the time calculations are accurate.

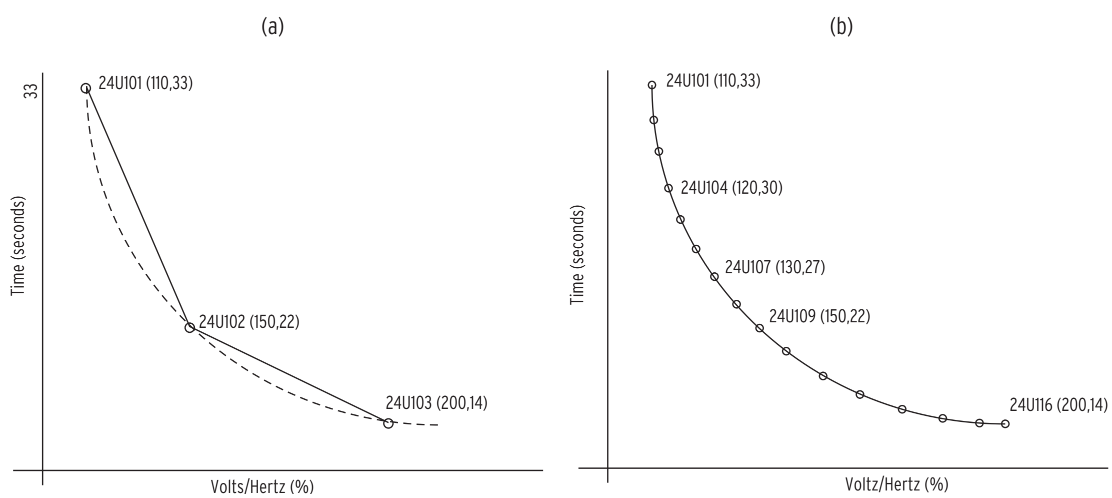


Figure 4.66 Three- and Sixteen-Point Curves

Each element has two output Relay Word bits. When the element times out, Relay Word bits 24U1T (Element 1) and 24U2T (Element 2) assert. When the elements are reset, Relay Word bits 24U1R (Element 1) and 24U2R (Element 2) assert.

Volts/Hertz Settings

24D1P (Level 1 Overexcitation Pickup)

After enabling the V/Hz elements (E24 = Y), set the Level 1 percentage overexcitation with the 24D1P setting. If you want to use the Level 1 element only, leave the 24CCS setting at the default value (24CCS = OFF).

Setting	Prompt	Range	Default	Category
24D1P	Level 1 Volts/Hertz P/U	100 to 200%	110	Group

24D1D (Level 1 Time Delay)

When the system V/Hz exceeds the 24D1P setting value, and if SELOGIC control equation 24TC is asserted, the V/Hz conditional timer starts timing. Set the delay (in seconds) for which the timer must run before the 24D1D setting asserts the output.

Setting	Prompt	Range	Default	Category
24D1D	Level 1 Time Delay	0.04 to 400 sec.	10	Group

24TC (Definite Time V/Hz Torque Control)

Use the torque-control setting to specify conditions under which the definite-time V/Hz elements must be active. This setting controls all levels of the definite-time elements. The default setting is 1, so that one input into Gates 1-3 in *Figure 4.63* is asserted permanently.

Setting	Prompt	Range	Default	Category
24TC	Volts/Hertz Torque control	SELOGIC control equation	1	Group

24CCS (Level 2 Composite Curve)

This setting selects which of the V/Hz elements are active, as *Table 4.12* shows.

Table 4.12 Active V/Hz Elements as a Function of the 24CCS Setting

Setting	Active V/Hz Element			
24CCS =	Level 1 DD	Level 2 DD	Level 1 UD	Level 2 UD
OFF	Yes	No	No	No
DD	Yes	Yes	No	No
U1	Yes	No	Yes	No
U2	Yes	No	Yes	Yes

where:

DD = Definite-time element

UD = User-defined element

Although the Level 1 DD element is active by default, you can deactivate this element with the 24TC setting.

Setting	Prompt	Range	Default	Category
24CCS	Level 2 Composite Curve	OFF, DD, U1, U2	OFF	Group

24D2P1 (Level 2 Overexcitation Pickup)

To enable the Level 2 percentage overexcitation pickup setting, set E24 = Y and 24CSS = DD. With 24CSS = DD, both Level 1 and Level 2 definite-time V/Hz elements are active (see *Table 4.12*).

Setting	Prompt	Range	Default	Category
24D2P1	Level 2 Volts/Hertz Alarm P/U	100 to 200%	105	Group

24D2D1 (Level 1 Time Delay)

When the system V/Hz exceeds the 24D2P1 setting value, and if SELOGIC control equation 24TC is asserted, Stair Counter 1 (*Figure 4.63*) starts timing. Set the delay (in seconds) for which the timer must run before the 24D2D1 setting asserts the output. Although the counter counts in discrete steps, for time calibration the counter is the same as for a conditional timer.

Setting	Prompt	Range	Default	Category
24D2D1	Level 2 Alarm Time Delay	0.04 to 400 sec	10	Group

24D2P2 (Level 2 Overexcitation Pickup)

To enable the Level 2 percentage overexcitation pickup setting, set E24 = Y and 24CCS = DD. With 24CCS = DD, both Level 1 and Level 2 definite-time V/Hz elements are active (see *Table 4.12*).

Setting	Prompt	Range	Default	Category
24D2P2	Level 2 Volts/Hertz Trip P/U	101 to 200%	110	Group

24D2D2 (Level 2 Time Delay)

When the system V/Hz exceeds the 24D2P2 setting value, and if SELOGIC control equation 24TC is asserted, Stair Counter 2 starts timing. Set the delay (in seconds) for which the timer must run before asserting the output with the 24D2D2 setting. Although the counter counts in discrete steps, time calibration for the counter is the same as for a conditional timer.

Setting	Prompt	Range	Default	Category
24D2D2	Level 2 Alarm Time Delay	0.04 to 400 sec	5	Group

24U1TC (User-Defined Curve 1 Torque Control)

Use the torque-control setting to specify conditions under which the user-defined V/Hz Curve 1 must be active. The default setting is 1, so one input into each of Gate 1, Gate 2, and Gate 3 in *Figure 4.63* is asserted permanently.

Setting	Prompt	Range	Default	Category
24U1TC	User Defined Curve 1 Torque Control	SELOGIC control equation	1	Group

24U1NP (Number of Points for User-Defined Curve 1)

Form user-defined curves by entering as many as 20 points that the relay interpolates to form a particular V/Hz characteristic. Use setting 24U1NP to specify the number of points for Curve 1 (see *Figure 4.65* and *Figure 4.66*).

Setting	Prompt	Range	Default	Category
24U1NP	Number of Points on User 1 Curve	3 to 20	3	Group

24U1[ii] (Data Points for User-Defined Curve 1)

Enter the data point here to form the user-defined curve. The data point format is <volts per hertz>(comma)<time> (i.e., 115,30).

The units are volts per hertz in percent and time in seconds.

Setting	Prompt	Range	Default	Category
24U1[*ii*][a]	User Def. Curve 1, Point [*ii*]	100 to 200%, 0.04 to 400 sec	200, 400	Group

[a] [ii] = 01–20.

24U1CR (User-Defined Curve 1)

Specify the Curve 1 reset time with the 24U1CR setting. This setting is only an absolute value if the element has timed out (if 24U1T has asserted). If there is interruption of the Curve 1 timing, then the reset time is proportional to the elapsed time. For example, assume there is an overexcitation condition on the system and Curve 1 starts timing. At the 60 percent mark, the system overexcitation condition disappears, and Curve 1 stops timing. Because the timing interruption was at the 60 percent mark, the reset time is also 60 percent of the 24U1CR setting.

Setting	Prompt	Range	Default	Category
24U1CR	User Def. Curve 1 Reset Time	0.01 to 400 sec	0.01	Group

24U2TC (User-Defined Curve 2 Torque Control)

Use the torque-control setting to specify conditions under which the user-defined V/Hz Curve 2 must be active. The default setting is 1, so the top input into the Curve 2 AND gate in *Figure 4.63* is asserted permanently.

Setting	Prompt	Range	Default	Category
24U2TC	User Defined Curve 2 Torque Control	SELOGIC control equation	1	Group

24U2NP (Number of Points for User-Defined Curve 2)

Form user-defined curves by entering as many as 20 points that the relay interpolates to form a particular V/Hz characteristic. Use setting 24U2NP to specify the number of points for Curve 2 (see *Figure 4.65* and *Figure 4.66*).

Setting	Prompt	Range	Default	Category
24U2NP	Number of Point on User 2 Curve	3 to 20	3	Group

24U2[ii] (Data Points for User-Defined Curve 2)

Enter the data point here to form the user-defined curve. The data point format is <volts per hertz>(comma)<time> (i.e., 115,30).

The units are volts per hertz in percent and time in seconds.

Setting	Prompt	Range	Default	Category
24U2[*ii*][a]	User Def. Curve 2, Point [*ii*]	100 to 200%, 0.04 to 400 sec	200, 400	Group

[a] [ii] = 01–20.

24U2CR (User-Defined Curve 2 Reset Time)

Specify the Curve 1 reset time with the 24U2CR setting. This setting is only an absolute value if the element has timed out (if 24U2T has asserted). If there is interruption of the Curve 2 timing, then the reset time is proportional to the elapsed time. For example, assume there is an overexcitation condition on the system and Curve 2 starts timing. At the 60 percent mark, the system overexcitation condition disappears and Curve 2 stops timing. Because the timing interruption was at the 60 percent mark, the reset time is also 60 percent of the 24U2CR setting.

Setting	Prompt	Range	Default	Category
24U2CR	User Def. Curve 2 Reset Time	0.01 to 400 sec	0.01	Group

Over-/Undervoltage Elements

The SEL-487E relay offers as many as five undervoltage and five overvoltage elements. Each of these 10 elements has two levels, for a total of 20 under-and overvoltage elements. *Figure 4.67* shows the undervoltage elements, and *Figure 4.68* shows the overvoltage elements.

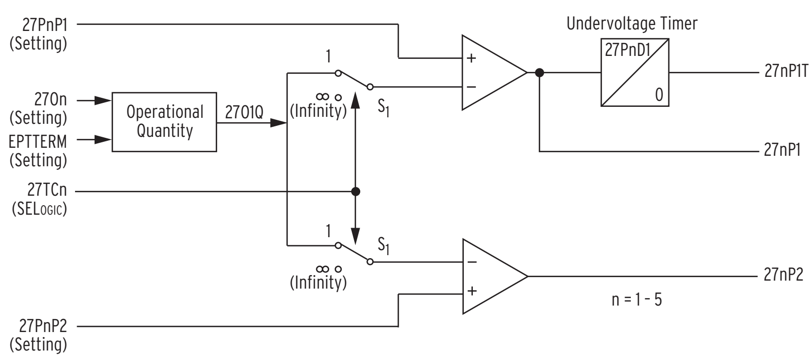


Figure 4.67 Undervoltage Elements

Although each under- and overvoltage element offers two levels, only Level 1 has a timer. If your application requires a time delay for the Level 2 elements, use a programmable timer to delay the output.

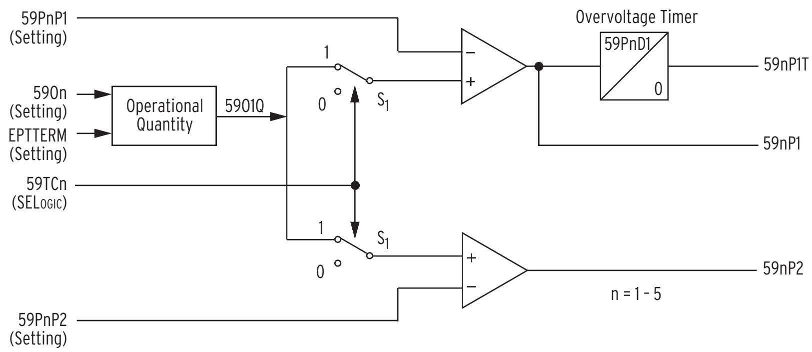


Figure 4.68 Overvoltage Elements

Select any one of the voltage elements from *Table 4.13* as an input quantity. You can select the same quantity for the undervoltage element as for an overvoltage element. Be sure that the PT terminal is enabled with the Group EPTTERM setting. For example, if EPTTERM = V, then only voltage values from the V potential transformer are available for selection.

Table 4.13 Available Input Quantities (Secondary Quantities)

Voltage Quantity	Description
VA*p*FM[a]	A-phase-to-neutral voltage magnitude
VB*p*FM	B-phase-to-neutral voltage magnitude
VC*p*FM	C-phase-to-neutral voltage magnitude
VAB*p*FM	A-phase-to-B-phase voltage magnitude
VBC*p*FM	B-phase-to-C-phase voltage magnitude
VCA*p*FM	C-phase-to-A-phase voltage magnitude
V1*p*M	Positive-sequence voltage magnitude
3V2*p*M	Negative-sequence voltage magnitude
3V0*p*M	Zero-sequence voltage
VNMIN*p*F	Minimum filtered phase-to-neutral voltage
VPMIN*p*F	Minimum filtered phase-to-phase voltage
VNMAX*p*F	Maximum filtered phase-to-neutral voltage
VPMAX*p*F	Maximum filtered phase-to-phase voltage
VA*p*RMS	A-phase-to-neutral rms voltage
VB*p*RMS	B-phase-to-neutral rms voltage
VC*p*RMS	C-phase-to-neutral rms voltage
VNMAX*p*R	Maximum rms phase-to-neutral voltage
VNMIN*p*R	Minimum rms phase-to-neutral voltage
VAB*p*RMS	AB-phase-to-phase rms voltage
VBC*p*RMS	BC-phase-to-phase rms voltage
VCA*p*RMS	CA-phase-to-phase rms voltage
VPMAX*p*R	Maximum rms phase-to-phase voltage
VPMIN*p*R	Minimum rms phase-to-phase voltage

[a] p = V or Z.

Under-/Overvoltage Settings

EPTTERM (Enable PT Terminals)

Identify which of the PT terminals the relay processes. If a PT terminal is not enabled with the EPTTERM setting, then the voltage quantities from that PT terminal are not available as inputs into the voltage elements.

Setting	Prompt	Range	Default	Category
EPTTERM	Enable Voltage Terminals	OFF or combo of V, Z[a]	OFF	Group

[a] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

E59 (Enable Overvoltage Elements)

Select the number of overvoltage elements (1–5) you require for your application. This setting is not available if EPTTERM = OFF.

Setting	Prompt	Range	Default	Category
E59	Enable Over Voltage Elements	N, 1 to 5	N	Group

E27 (Enable Undervoltage Elements)

Select the number of undervoltage elements (1–5) you require for your application. This setting is not available if EPTTERM = OFF.

Setting	Prompt	Range	Default	Category
E27	Enable Under Voltage Elements	N, 1 to 5	N	Group

27On (Undervoltage Element Operating Quantity)

Select the desired operating quantity for each voltage terminal from *Table 4.13*. Only voltage quantities from enabled voltage terminals are available.

Setting	Prompt	Range	Default	Category
27O[*n*][a]	U/V Element [*n*] Operating Quantity	See Table 4.13	VNMINVF	27O[*n*]

[a] n = 1–5.

27P[n]P1 (Undervoltage Level 1 Pickup)

Set pickup values for the voltage values below which you want the Level 1 undervoltage elements to assert.

Setting	Prompt	Range	Default	Category
27P[*n*]P1[a]	U/V Element [*n*] Level 1 P/U	2.00 to 300 sec.	20	Group

[a] n = 1–5.

27P[n]P2 (Undervoltage Level 2 Pickup)

Set pickup values for the voltage values below which you want the Level 2 undervoltage elements to assert.

Setting	Prompt	Range	Default	Category
27P[*n*]P2[a]	U/V Element [*n*] Level 2 P/U	2.00 to 300 sec.	15	Group

[a] n = 1–5.

27TC (Undervoltage Torque Control)

Use the torque-control setting to specify conditions under which the undervoltage elements must be active. There is only one setting for both Level 1 and Level 2 elements. With the default setting equal to 1, both levels are active permanently.

Setting	Prompt	Range	Default	Category
27TC[*n*][a]	U/V Element [*n*] Torque Control	SELOGIC Equation	1	Group

[a] n = 1–5.

27P[n]D1 (Undervoltage Level 1 Time Delay)

When the system voltage falls below the undervoltage setting value, the undervoltage timer starts timing. Set the delay (in cycles) for which the timer must run before the 27P*n*D1 setting asserts the output.

Setting	Prompt	Range	Default	Category
27P[n]D1[a]	U/V Element [*n*] Level 1 Delay	0.00 to 16000 cyc.	10	Group

[a] n = 1–5.

59O[n] (Overvoltage Element Operating Quantity)

Select from *Table 4.13* the desired operating quantity for each voltage terminal. Only voltage quantities from enabled voltage terminals (see Group EPTTERM setting) are available.

Setting	Prompt	Range	Default	Category
59O[*n*][a]	O/V Element [*n*] Operating Quantity	See *Table 4.13*	VNMINVF	Group

[a] n = 1–5.

59P[n]P1 (Overvoltage Level 1 Pickup)

Set pickup values for the voltage values above which you want the Level 1 overvoltage elements to assert.

Setting	Prompt	Range	Default	Category
59P[*n*]P1[a]	O/V Element [*n*] Level 1 P/U	2.00 to 300 sec.	76	Group

[a] n = 1–5.

59P[n]P2 (Overvoltage Level 2 Pickup)

Set pickup values for the voltage value above which you want the Level 2 overvoltage elements to assert.

Setting	Prompt	Range	Default	Category
59P[*n*]P2[a]	O/V Element [*n*] Level 2 P/U	2.00 to 300 sec.	80	Group

[a] n = 1–5.

59TC[n] (Overvoltage Torque Control)

Use the torque-control setting to specify conditions under which the overvoltage elements must be active. There is only one setting for both Level 1 and Level 2 elements. With the default setting equal to 1, both levels are active permanently.

Setting	Prompt	Range	Default	Category
59TC[*n*][a]	O/V Element [*n*] Torque Control	SELOGIC Equation	1	Group

[a] n = 1–5.

59P[n]D1 (Overvoltage Level 1 Time Delay)

When the system voltage exceeds the overvoltage setting value, the overvoltage timer starts timing. Set the delay (in cycles) for which the timer must run before the 59P*n*D1 setting asserts the output.

Setting	Prompt	Range	Default	Category
59P[*n*]D1[a]	O/V Element [*n*] Level 1 Delay	0.00 to 16000 cyc.	10	Group

[a] n = 1–5.

Over-/Underfrequency Elements

Use the relay frequency elements for such abnormal frequency protection as underfrequency load shedding.

Figure 4.69 shows the logic for the six levels of over-/underfrequency elements in the SEL-487E relay. The frequency elements use positive-sequence voltage from either the V (V1VFM) or Z (V1ZFM) PTs. Use of positive-sequence voltage ensures correct frequency element operation even if two of the phase voltages collapse completely.

Each frequency element can operate as an overfrequency or as an underfrequency element, depending on its pickup setting. If the element pickup setting (81D*n*P, *n* = 1-6) is less than the nominal system frequency setting, NFREQ, the element operates as an underfrequency element, picking up if measured frequency is less than the set point. If the pickup setting is greater than NFREQ, the element operates as an overfrequency element, picking up if measured frequency is greater than the set point.

All frequency elements are disabled if any one of the following conditions is true:

- The appropriate positive-sequence voltage (V1VFM or V1ZFM) is less than the 81UVSP setting
- No frequency elements are selected (E81 = N)

➤ No PTs are selected (EPTTERM = N)

➤ No primary frequency source is selected (FRQST = OFF)

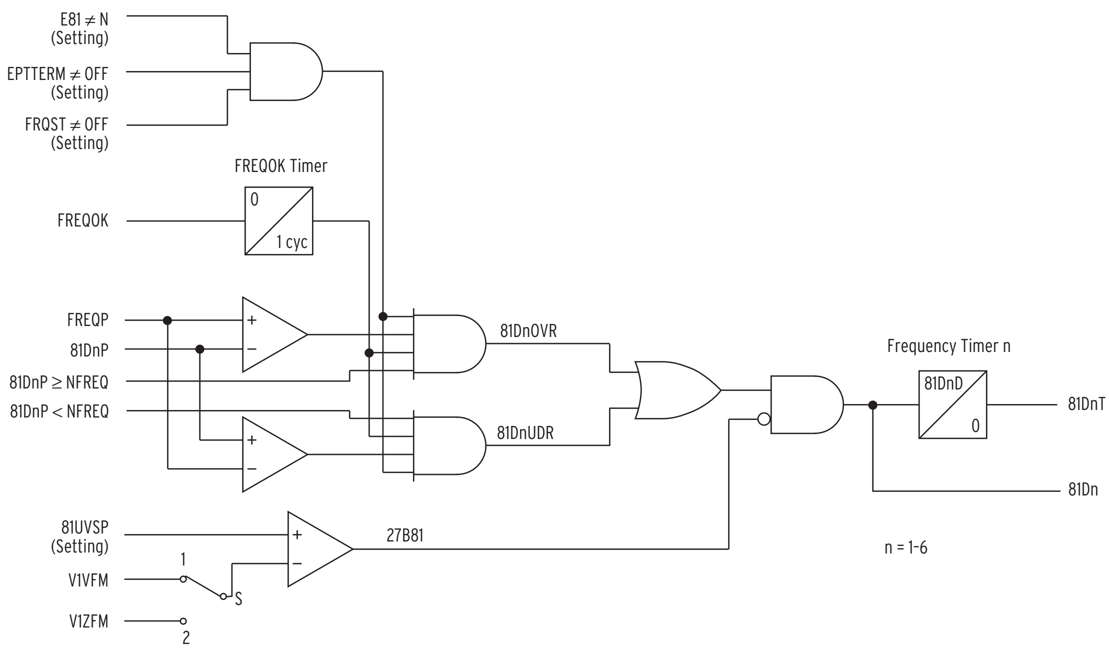


Figure 4.69 Frequency Element Logic

Note that Relay Word bit 27B81 controls all six frequency elements. Relay Word bit 27B81 asserts to logical 1 and blocks frequency element operations if the appropriate voltage (V1VFM or V1ZFM) drops below pickup setting 81UVSP. This control prevents erroneous frequency element operations during system faults.

Over-/Underfrequency Element Settings

EPTTERM (Enable PT Terminals)

Identify which of the PT terminals the relay processes. If a PT terminal is not enabled with the EPTTERM setting, then the voltage quantities from that PT terminal are not available as inputs into the voltage elements.

Setting	Prompt	Range	Default	Category
EPTTERM	Enable Voltage Terminals	OFF or combo of V, Z[a]	OFF	Group

[a] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

E81 (Enable 81 Elements)

Set E81 to enable as many as six over-/underfrequency elements. When E81 = N, the relay disables the frequency elements and hides corresponding settings; you do not need to enter these hidden settings.

Setting	Prompt	Range	Default	Category
E81	Enable Frequency Elements	N, 1 to 6	N	Group

FRQST (Primary Frequency Source Terminal)

Global setting FRQST identifies which PT (V or Z) is the primary frequency source for the frequency elements. If a PT terminal is not enabled with the EPTTERM setting, then the voltage quantities from that PT terminal are not available as inputs into the voltage elements.

Setting	Prompt	Range	Default	Category
FRQST	Primary Frequency Source Terminal	OFF, V, Z	V	Global

81UVSP (81 Element Undervoltage Supervision)

This setting applies to all six frequency elements. If the appropriate positive-sequence voltage (V1VFM or V1ZFM) falls below the 81UVSP setting, all frequency elements are disabled.

Setting	Prompt	Range	Default	Category
81UVSP	81 Element Under Voltage Super	20.00 to 200 sec.	56	Group

81D[n]P (Level [n] Pickup)

Set the value at which you want the frequency element for each of six levels to assert. For a value of 81D*n*P less than the nominal system frequency NFREQ (50 or 60 Hz), the element operates as an underfrequency element. For a value greater than NFREQ, the element operates as an overfrequency element. Note that *n* can be one of six levels, 1–6.

Setting	Prompt	Range	Default	Category
81D[*n*]P[a]	Level [*n*] Pickup	40.01 to 69.99 Hz	61.00	Group

[a] n = 1–6.

81D[n]D (Level [n] Time Delay)

Select a time in seconds that you want frequency elements to wait before asserting.

Setting	Prompt	Range	Default	Category
81D[*n*]D[a]	Level [*n*] Delay	0.04 to 400.00 sec.	2	Group

[a] n = 1–6.

Breaker Failure Elements

There are five breaker failure elements in the relay, one for each of the five windings. Use the EBFL Group setting to enable the appropriate windings necessary for your particular application. *Figure 4.70* and *Figure 4.71* show the breaker failure logic. In *Figure 4.70*, three comparators test the three-phase currents against the 50FPU*k* settings, and one comparator tests the neutral current against the INFPU*k* setting. SELOGIC setting ENINBF*k* allows the neutral breaker failure function to be conditional if system unbalance conditions could cause inadvertent initiation of the neutral element, such as might occur in single-pole tripping systems. When any phase current exceeds the 50FPU*k* setting, or the neutral current exceeds the INFPU*k* setting, the appropriate Relay Word bit asserts (IA*k*BF, IB*k*BF, IC*k*BF, and/or IN*k*BF).

Each phase current comparator is supervised by the associated open-phase detectors OPHp*k*, (*k* = S, T, U, W, X). The neutral current comparator is supervised by the all three poles open detector (OPH*k*). The open-phase detectors provide subcycle resetting of all input currents, even when subsidence current is present.

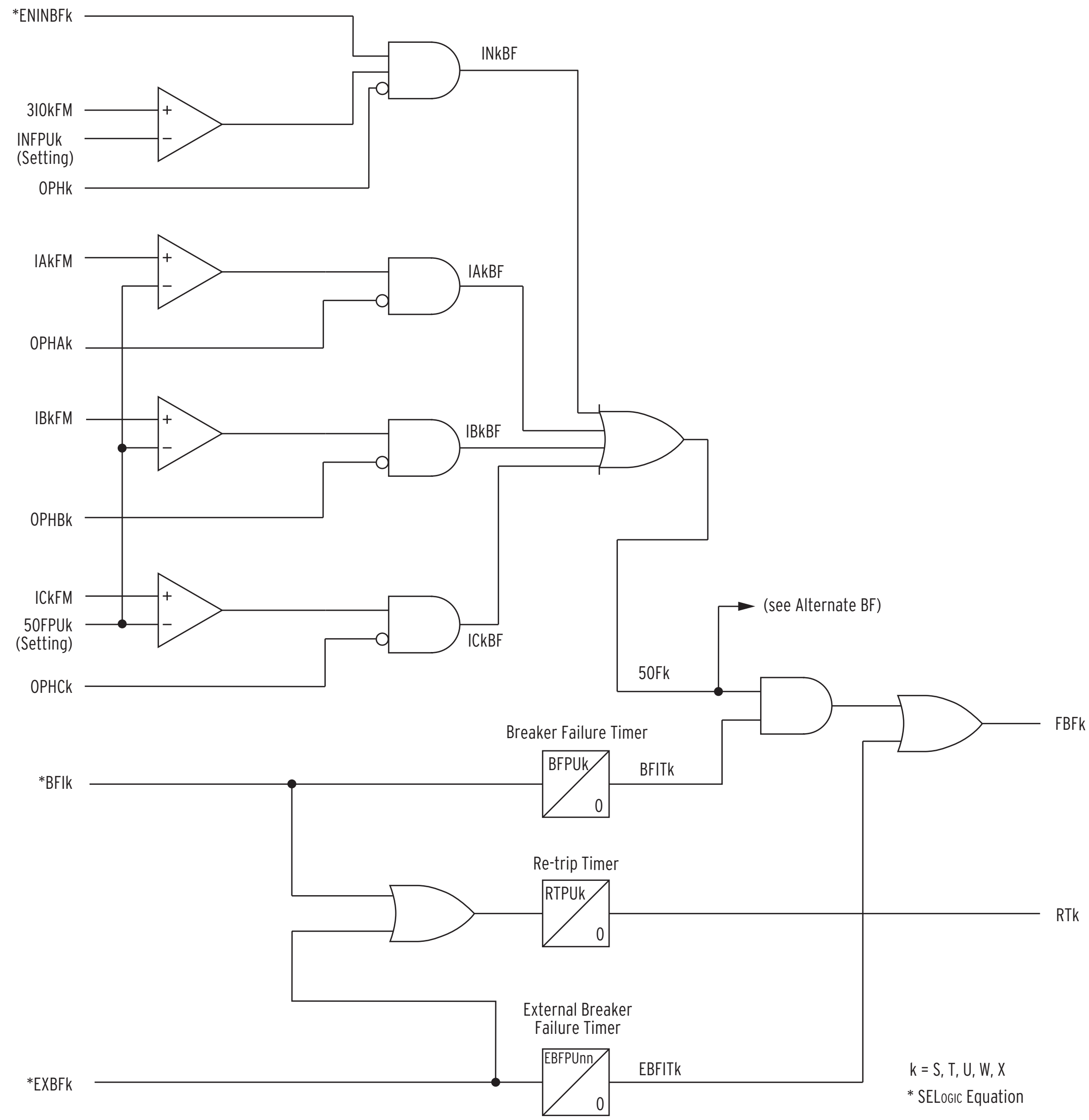


Figure 4.70 Breaker Failure Logic for Terminal k

Input BFI*k* is a SELOGIC control equation that provides the breaker failure initiate signal. When BFI*k* asserts, both the breaker failure timer and the re-trip timer start timing. When the re-trip timer expires, RT*k* asserts, and when the breaker failure timer expires, BFIT*k* asserts. If 50F*k* is asserted when BFIT*k* asserts, the breaker failure output, FBF*k*, asserts. Note that BFI*k* must be present for the entire duration of the breaker failure timer setting. If BFI*k* is not present constantly, the timers reset when BFI*k* falls away (see alternate initiate logic in *Figure 4.71*).

EXBF*k* (SELOGIC control equation) is the input for the case when breaker failure initiates from a protection function alone (when there is no current supervision), such as when the Buchholz relay operates on an unloaded transformer. When EXBF*k* asserts, both the external breaker failure timer and the re-trip timer start timing. When the re-trip timer expires, RT*k* asserts, and when the external breaker failure timer expires, the breaker failure output, FBF*k*, asserts.

Figure 4.71 shows an alternate breaker failure initiate logic in which one has the flexibility to apply one of many other breaker failure philosophies. When using the alternate initiate logic, connect the breaker failure initiate signal to ATBFI*k* (instead of to BFI*k* in *Figure 4.70*). Then connect the output of the alternate initiate logic, ABFIT*k*, to BFI*k* (*Figure 4.70*). This ensures assertion of the FBF*k* Relay Word bits when a breaker failure occurs.

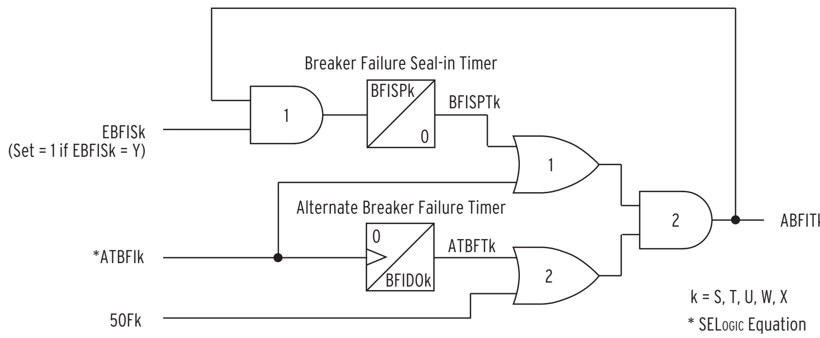


Figure 4.71 Alternate Breaker Failure Logic for Terminal k

Breaker failure initiate signal is not present for the duration of the breaker failure time.

One use of the alternate initiate logic is to ensure that Relay Word bit ABFIT*k* (and BFI*k*) is asserted for the duration of the breaker failure time. To achieve this goal, we must keep AND Gate 2 asserted for the duration of the breaker failure time. In general, on the rising edge of the initiate signal (ATBFI*k*), the output of the Alternate Breaker Failure Timer (ATBFT*k*) asserts and the output of the logic (ABFIT*k*) asserts for the BFIDO*k* time setting. At this point, ATBFI*k* (through the bottom input of OR Gate 1) and ATBFT*k* keep AND Gate 2 asserted. However, ATBFI*k* is about to fall away, so we need to commutate ATBFI*k* from the bottom input to the top input of OR Gate 1 via the breaker failure seal-in timer.

For the breaker failure seal-in timer to expire, EBFIS*k* must be set to Y, and ABFIT*k* must be asserted for longer than the BFISP*k* time setting. Therefore, set the BFISP*k* time setting long enough to avoid spurious assertion but shorter than the expected duration of the breaker failure initiate signal. When the breaker failure seal-in timer expires, BFISPT*k* asserts, completing the commutation of ATBFI*k* from the bottom input to the top input of OR Gate 1. This ensures that ABFIT*k* stays asserted when ATBFI*k* falls away.

There are two ways to control the bottom input into AND Gate 2. One can use the drop-off time setting (BFIDO*k*) of the alternate breaker failure timer or the flow of current (50F*k*). Consider carefully the primary application before choosing the current option. Fault current in installations that require the opening of two breakers to clear a fault (breaker-and-a-half or ring bus installations, for example) may only be available after one of the breakers opens. For these installations, set BFIDO*k* long enough to ensure the availability of that fault current when ATBFT*k* deasserts.

To illustrate this, consider fault F1 (*Figure 4.72*), for which both Circuit Breaker 52-S and Circuit Breaker 52-T must operate to clear the fault. For certain faults, the current distribution may be such that Circuit Breaker 52-S carries the bulk of the fault current, with very little current flowing through Circuit Breaker 52-T.

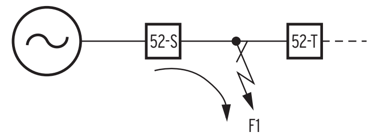


Figure 4.72 Current Distribution for Fault F1 With Circuit Breaker 52-S and Circuit Breaker 52-T Closed

Because of the current distribution, Terminal 52-T may only have enough current to assert the breaker failure current element threshold when Circuit Breaker 52-S opens, as shown in *Figure 4.73*.

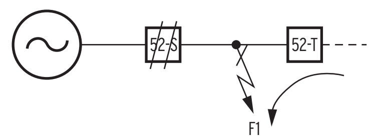


Figure 4.73 Current Flow for Fault F1 After Circuit Breaker 52-S Opened

Protection philosophy that requires the current to be present for the duration of the breaker failure.

Use the alternate initiate logic if your protection philosophy calls for the current and initiate signal to be present throughout the breaker failure timing process. In *Figure 4.70*, the logic only checks whether current is present after the breaker failure timer has expired.

Because the breaker failure initiate signal is present all the time, we do not need the seal-in circuit in *Figure 4.71*. Therefore, set EBFIS*k* = N and set BFIDO*k* = 0.00. With these settings, ABFIT*k* asserts only if both the initiate signal and sufficient current are present for the duration of the breaker failure process.

Breaker Failure Settings

EBFL (Enable Breaker Fail)

Set EBFL to enable breaker failure protection for the specific terminals in your application. The EBFL setting considers for selection only terminals that you include in the ECTTERM setting.

Setting	Prompt	Range	Default	Category
EBFL	Enable Breaker Fail Prot.	OFF or combo of S, T, U, W, X[a]	OFF	Group

[a] "Combo" means "combination"; enter these "combo" settings delimited with either commas or spaces.

EXBF[k] (Enable External Breaker Fail)

EXBF*k* (SELOGIC control equation) is the input for the case when breaker failure results from a protection function alone (no current supervision), such as when the Buchholz relay operates on an unloaded transformer. Use the setting to specify conditions under which the external breaker input must be active. There is a setting for each of the enabled terminals. If you set EXBF*k* = 1, the input is asserted permanently.

Setting	Prompt	Range	Default	Category
EXBF[*k*]	Enable External Breaker Fail – BKR [*k*]	SELOGIC Equation	NA	Group

EBFPU[k] (External Breaker Failure Initiation Pickup)

For each enabled terminal, select a time in cycles that you want the external breaker failure element to wait before asserting.

Setting	Prompt	Range	Default	Category
EBFPU[*k*][a]	Ext. Brkr Fail Init PU Delay [*k*]	0.00 to 6000 cyc.	6.00	Group

[a] k = S, T, U, W, X.

50FPU[k] (Fault Current Pickup)

The setting 50FPU[*k*] is the current pickup setting in amps secondary for the breaker failure overcurrent element of each enabled terminal.

Setting	Prompt	Range	Default	Category
50FPU[*k*]	Fault Current Pickup—KR [*k*]	0.50 to 50.00 sec.	10	Group

BFPU[k] (Breaker Failure Initiation Pickup Delay)

For each enabled terminal, select a time in cycles that you want the breaker failure timer to wait before asserting.

Setting	Prompt	Range	Default	Category
BFPU[*k*]	Brkr Fail Init Pickup Delay BKR [*k*]	0.00 to 6000 cyc.	6	Group

RTPU[k] (Retrip Delay)

For each enabled terminal, select a time in cycles that you want the retrip timer to wait before asserting.

Setting	Prompt	Range	Default	Category
RTPU[*k*]	Retrip Delay—BKR [*k*]	0.00 to 6000 cyc.	3	Group

BFI[k] (Breaker Fail Initiate)

Use the BFI[*k*] setting (SELOGIC control equation) to specify conditions under which the breaker failure initiate input must be active. There is a setting for each of the enabled terminals. If you set BFI[*k*] = 1, the input is asserted permanently.

Setting	Prompt	Range	Default	Category
BFI[*k*]	Breaker Fail Initiate—BKR [*k*]	SELOGIC Equation	NA	Group

ATBFI[k] (Alternate Breaker Fail Initiate)

Use the ATBFI[*k*] setting (SELOGIC control equation) to specify conditions under which the alternate breaker failure initiate input must be active. When using the ATBFI[*k*] setting, be sure to set ABFIT*k* = BFI*k*. There is a setting for each of the enabled terminals. If you set ABFIT*k* = 1, the input is asserted permanently.

Setting	Prompt	Range	Default	Category
ATBFI[*k*]	Alt Breaker Fail Initiate—BKR [*k*]	SELOGIC Equation	NA	Group

ENINBF[k] (Enable Neutral Breaker Fail)

Use the ENINBF*k* setting (SELOGIC control equation) to specify conditions under which the neutral breaker input must be active. There is a setting for each of the enabled terminals. If you set ENINBF*k* = 1, the input is asserted permanently.

Setting	Prompt	Range	Default	Category
ENINBF[*k*]	Enable Neutral Breaker Failure—BKR [*k*]	SELOGIC Equation	NA	Group

INFPU[k] (Neutral Current Pickup)

INFPU[*k*] is the current pickup setting in secondary amps for the neutral breaker failure overcurrent element of each enabled terminal. The range is 0.10 to 10 for a 1 A relay.

Setting	Prompt	Range	Default	Category
INFPU[*k*]	Neutral Current Pickup—BKR [*k*]	0.50 to 50.00 sec.	0.5	Group

EBFIS[k] (Breaker Fail Initiate Seal-In)

Enable the breaker failure seal-in timer circuit by setting EBFIS*k* = Y (see *Figure 4.71*).

Setting	Prompt	Range	Default	Category
EBFIS[*k*]	Breaker Fail Initiate Seal-In—BKR [*k*]	Y, N	N	Group

BFISP[k] (Breaker Fail Initiate Seal-In Delay)

Select a time in cycles that you want the breaker failure seal-in timer to wait before asserting (see *Figure 4.71*).

Setting	Prompt	Range	Default	Category
BFISP[*k*]	Brkr Fail Init Seal-In Delay—BKR[*k*]	0.00 to 1000 cyc.	3	Group

BFIDO[k] (Alternate Breaker Failure Timer)

Select a time in cycles that you want the alternate breaker failure timer to wait before asserting (see *Figure 4.71*).

Setting	Prompt	Range	Default	Category
BFIDO[*k*]	Brkr Fail Init Dropout Delay—BKR[*k*]	0.00 to 1000	1.5	Group

Over-/Underpower Element

The SEL-487E offers 10 overpower elements and 10 underpower elements. Use Group setting E32 to enable the number of power elements you want. Typical applications of power elements are the following:

- Overpower and/or underpower protection/control
- Reverse power protection/control
- VAR control for capacitor banks

The SEL-487E uses the IEEE convention for power measurement, as *Figure 4.74* and *Figure 4.75* illustrate.

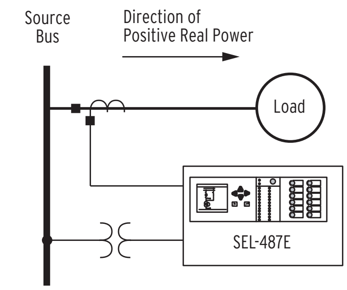


Figure 4.74 Primary Plant Connections

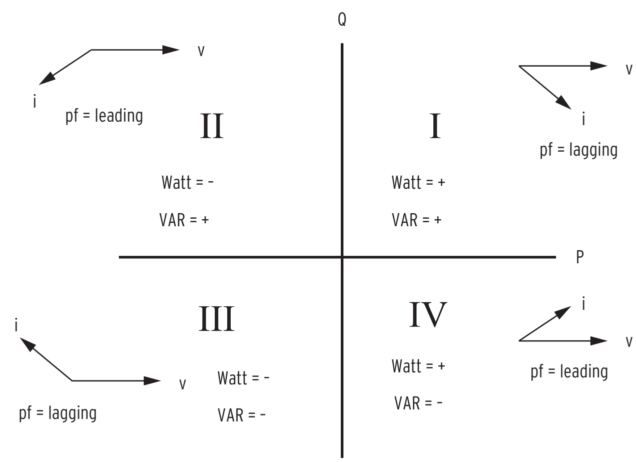


Figure 4.75 Complex Power Measurement Conventions

Figure 4.76 shows an installation with the direction of real power as indicated. CT S and CT T are the HV and LV CTs, connected in the conventional way to supply the differential elements with the correct polarity CT inputs. In this installation, be sure to specify operating quantities from CT S to comply with the IEEE convention.

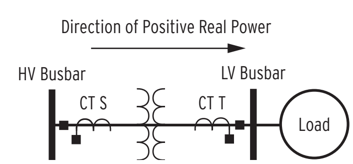


Figure 4.76 Selection of Operating Quantities

Input quantities for the 10 power elements are not fixed; make your selection from the three-phase power elements in *Table 4.14*. All analog quantities in *Table 4.14* are fundamental secondary values and include power quantities for single terminals as well as combined terminals.

Table 4.14 Power Element Operating Quantities (Secondary Values)

Analog Quantity	Description
3P*m*F[a]	Fundamental three-phase active power, terminal *m*
3Q*m*F	Fundamental three-phase reactive power, terminal *m*
3P*qp*F[b]	Fundamental three-phase active power, combined terminals *qp*
3Q*qp*F	Fundamental three-phase reactive power, combined terminals *qp*

[a] m = S, T, U, W, X.
[b] qp = ST, TU, UW, WX.

Figure 4.77 shows the logic for the overpower element, and *Figure 4.81* shows the logic for the underpower element. There are four conditions that must be met to enable both over- or underpower logic:

- An operating quantity (32OPO*nn*) must be specified
- Power calculations (EPCAL) must be enabled
- Over-/underpower elements must be specified (E32)
- SELOGIC control equation E32OP*nn* must be asserted

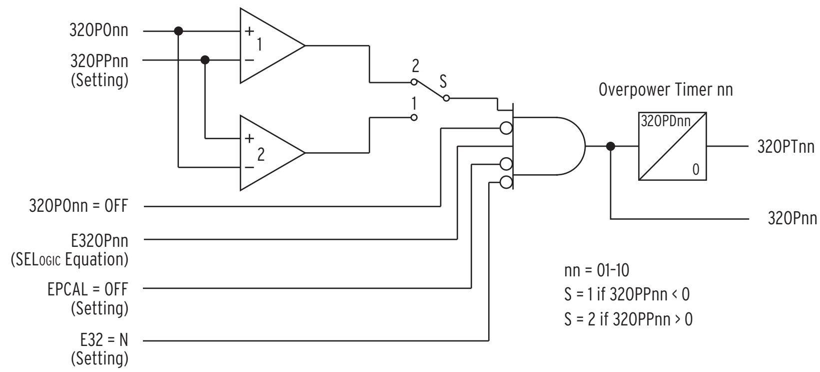


Figure 4.77 Overpower Element Logic

Input 32OPO*nn* is the power quantity (see *Table 4.14*) that the logic compares against the 32OPP*nn* setting. In general, the output of a comparator asserts to logical 1 when the (+) quantity exceeds the (–) quantity. Switch S selects the appropriate comparator as a function of the 32OPP*nn* setting. For example, if 32OPP*nn* < 0 (negative value), then Switch S is in position 1 and Comparator 2 is in use. In this case, the output of Comparator 2 asserts to logical 1 when the 32OPP*nn* setting value exceeds the 32OPO*nn* analog quantity.

Conversely, if 32OPP*nn* > 0 (positive value), then Switch S is in position 2, and Comparator 1 is in use. In this case, the output of Comparator 1 asserts to logical 1 when the 32OPO*nn* analog quantity exceeds the 32OPP*nn* setting value.

As an example, assume that you want to assert an output when the fundamental three-phase active power of Terminal S exceeds 54 VA secondary in the direction of the load flow. From *Table 4.14*, select 3PSF (fundamental three-phase active power) as the operating quantity. Using the first power element, set 32OPO01 = 3PSF. From *Figure 4.75*, the direction of the load flow is positive in the first and fourth quadrants. Therefore, set the threshold to a positive value (32OPP01 = +54). If you want to control the load in the reverse direction, then set 32OPP01 = –54. *Figure 4.78* shows a case where the control direction is towards the load, and *Figure 4.79* shows a case where the control direction is away from the load.

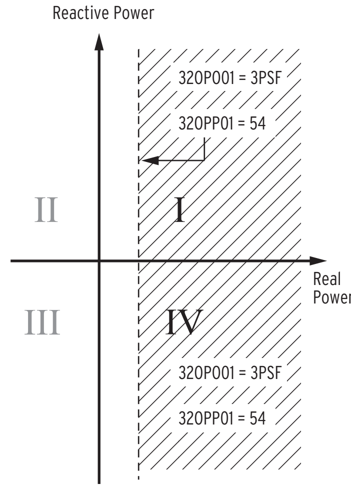


Figure 4.78 Load Flow Towards Load

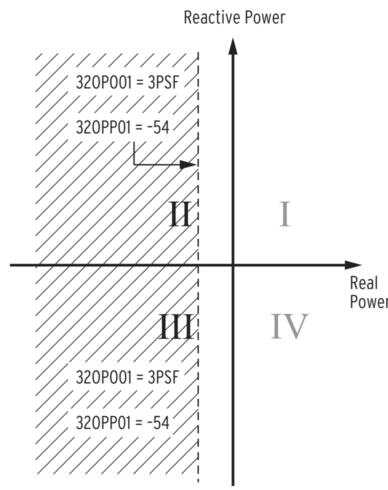


Figure 4.79 Reverse Load Flow

Use SELOGIC control equation E32OP*nn* to state the conditions when the power elements must be active. Output 32OP*nn* is the instantaneous output when the AND gate turns on, and 32OPT*nn* is the time-delayed output.

The sign of the pickup setting also determines the directional control for the reactive power element. In *Figure 4.80*, the top shaded area shows a case where the direction of the fundamental three-phase reactive power (3QPSF) is towards the load. The bottom shaded area shows a case where the flow is in the reverse direction.

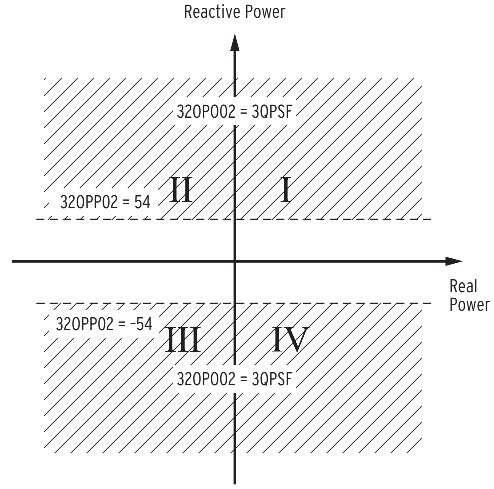


Figure 4.80 Reactive Power Characteristic

Figure 4.81 shows the logic for the underpower element. This element is the same as the overpower element.

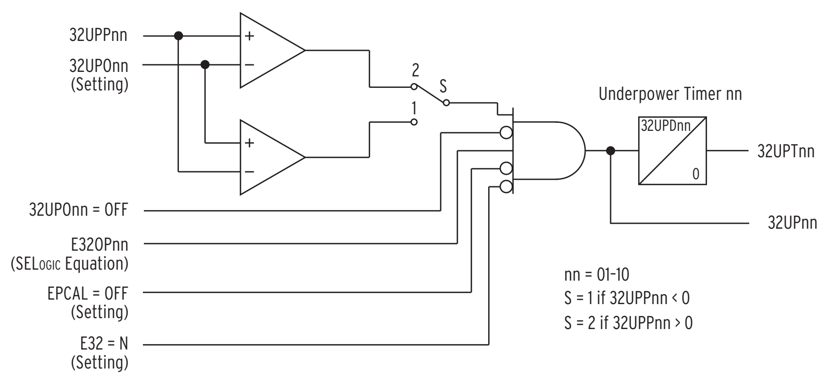


Figure 4.81 Underpower Element Logic

Over-/Underpower Element Settings

E32 (Enable Over-/Underpower)

Set E32 to the number of power elements for the specific terminals in your application. The E32 setting considers for selection only terminals that you include in the ECTTERM and the EPCAL settings.

Setting	Prompt	Range	Default	Category
E32	Enable Over/Underpower Elements	N, 1 to 10	N	Group

32OPO[gg] (Overpower Operating Quantities)

Select the analog quantity (see *Table 4.14*) for each of the enabled (E32 setting) power elements. The 32OPO[*gg*] setting considers for selection only terminals that you include in the ECTTERM setting and the EPCAL setting.

Setting	Prompt	Range	Default	Category
32OPO[*gg*][a]	Overpower Op. Qty. Elem [*gg*]	OFF, (see *Table 4.14*)	OFF	Group

[a] [gg] = 01–10.

32OPP[gg] (Overpower Pickup)

The 32OPP[*gg*] setting is the overpower pickup and directional control setting for each of the enabled overpower elements in secondary VA. In general, a setting with a positive sign controls power in the direction of the load (see *Figure 4.74* and *Figure 4.75*), and a setting with a negative sign controls power in the reverse direction (see *Figure 4.79* and *Figure 4.80*). Analog quantities in *Table 4.14* are in secondary quantities, so you do not need any conversions.

Setting	Prompt	Range	Default	Category
32OPP[*gg*][a]	Overpower Pickup Elem [*gg*] VA, sec	–20000.00 to 20000.00 (5 A) –4000.00 to 4000.00 (1 A)	2000	Group

[a] [gg] = 01–10.

32OPD[gg] (Overpower Delay)

For each enabled overpower element, select a time in cycles that you want the element(s) to wait before asserting.

Setting	Prompt	Range	Default	Category
32OPD[*gg*][a]	Overpower Delay Elem [*gg*]	0.00 to 16000 cyc.	10	Group

[a] [gg] = 01–10.

E32OP[gg] (Torque Control)

Use the torque-control setting to specify conditions under which the overpower elements must be active. With the default setting of NA, the element is switched off.

Setting	Prompt	Range	Default	Category
E32UP[*gg*][a]	Enable Overpower Elem [*gg*]	SELOGIC control equation	NA	Group

[a] [gg] = 01–10.

32UPO[gg] (Underpower Operating Quantities)

Select the analog quantity (see *Table 4.14*) for each of the enabled (set in the E32 setting) power elements. The 32UPO[*gg*] setting considers for selection only terminals that you include in the ECTTERM setting and the EPCAL setting.

Setting	Prompt	Range	Default	Category
32UPO[*gg*][a]	Underpower Op. Qty. Elem [*gg*]	OFF, (see *Table 4.14*)	OFF	Group

[a] [gg] = 01–10.

32UPP[gg] (Underpower Pickup)

The 32UPP[*gg*] setting is the underpower pickup and directional control setting for each of the enabled overpower elements in secondary VA. In general, a setting with a positive sign controls power in the direction of the load (see *Figure 4.74* and *Figure 4.75*), and a setting with a negative sign controls power in the reverse direction (see *Figure 4.79* and *Figure 4.80*). Analog quantities in *Table 4.14* are in secondary quantities, so you do not need any conversions.

Setting	Prompt	Range	Default	Category
32UPP[*gg*][a]	Underpower Pickup Elem [*gg*] VA,sec)	–20000 to 20000	1.00	Group

[a] [gg] = 01–10.

32UPD[gg] (Underpower Delay)

For each enabled underpower element, select a time in cycles that you want the element(s) to wait before asserting.

Setting	Prompt	Range	Default	Category
32UPD[*gg*][a]	Underpower Delay Elem [*gg*]	0.00 to 16000 cyc.	10	Group

[a] [gg] = 01–10.

E32UP[gg] (Torque Control)

Use the torque-control setting to specify conditions under which the underpower elements must be active. With the default setting of NA, the element is switched off.

Setting	Prompt	Range	Default	Category
E32UP[*gg*][a]	Enable Underpower Elem [*gg*]	SELOGIC control equation	NA	Group

[a] [gg] = 01–10.

Trip Logic

To provide settings for selective tripping between unit faults and system faults, the SEL-487E includes six trip logics. Use the logic in *Figure 4.82* for transformer (unit) faults and the logic in *Figure 4.83* (one for each of the five breakers) for system faults. Although you set the input quantities separately for each of the six logics, there exists only one Minimum Trip Duration timer and only one reset setting (RSTTRGT) for all the logics.

In *Figure 4.82*, the Transformer Trip timer starts when SELOGIC control equation TRXFMR asserts for one processing interval. Assertion of this equation immediately asserts output TRPXFMR. Output TRPXFMR remains asserted for the Minimum Trip Duration timer (TDURD) setting regardless of the status of input TRXFMR. When output TRPXFMR asserts, the logic seals TRPXFMR in through the AND gate under the following conditions:

- SELOGIC control equation RSTTRGT is deasserted (global setting)
- The target reset (TRGTR) input is deasserted
- The unlatch input (ULTXFMR) is deasserted
- The ECTTERM setting includes the terminal name

Relay Word bit TRGTR asserts when either you press the front-panel **{TARGET RESET}** pushbutton or you issue the ASCII **TAR R** command.

Once latched, TRPXFMR remains asserted until any (or all) of the following happens:

- ➤ SELOGIC control equation RSTTRGT asserts
- ➤ The target reset (TRGTR) input asserts
- ➤ The unlatch input (ULTXFMR) asserts

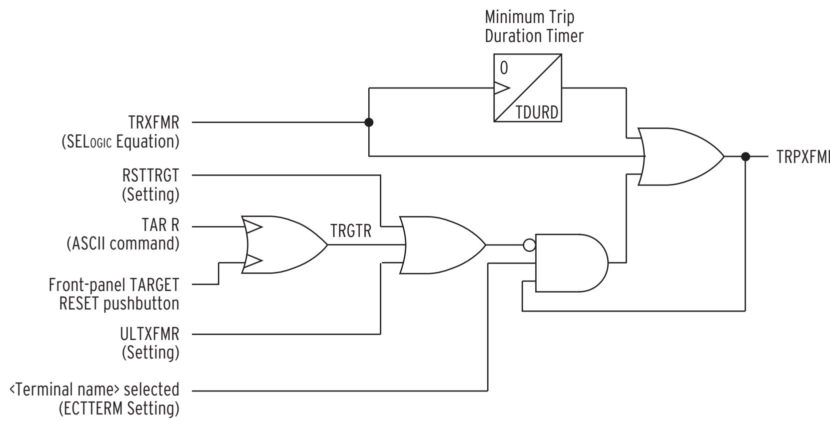


Figure 4.82 Transformer Trip Logic

Figure 4.83 shows the trip logic for each of the five circuit breakers. The logic itself is identical, but there are trip (TR*k*) and trip unlatch (ULTR*k*) equations for each of the five circuit breakers.

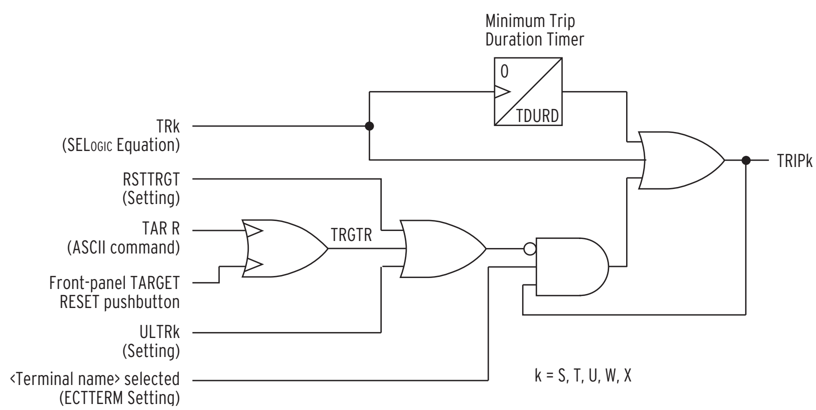


Figure 4.83 Circuit Breaker Trip Logic

Trip Logic Settings

TRXFMR (Trip Transformer)

Specify the conditions under which all the circuit breaker must trip with the TRXFMR setting. Default settings are the differential and restricted earth-fault trip outputs.

Setting	Prompt	Range	Default	Category
TRXFMR	Trip Transformer	SELOGIC control equation	87R OR REFF1	Group

ULTXFMR (Unlatch Trip Transformer)

Specify the conditions to unlatch the transformer trip output command (TRPXFMR). The default setting is Relay Word bit TRGTR.

Setting	Prompt	Range	Default	Category
ULTXFMR	Unlatch Trip Transformer	SELOGIC control equation	TRGTR	Group

TR[k] (Trip Terminal)

Specify the conditions under which each of the enabled circuit breakers must trip with the TR[*k*] setting. Default settings are the phase and negative-sequence overcurrent elements.

Setting	Prompt	Range	Default	Category
TR[*k*][a]	Trip Terminal [*k*]	SELOGIC control equation	50[*k*]P1 OR 50[*k*]Q1	Group

[a] k = S, T, U, W, X.

ULTR[k] (Unlatch Trip Terminal)

NOTE: Changing setting groups when the trip duration timer is running extends the duration by 3.5–4 cycles. The timer does not reset during this delay.

Specify the conditions to unlatch each of the enabled circuit breaker trip outputs with the ULTR[*k*] setting. The default setting is Relay Word bit TRGTR.

Setting	Prompt	Range	Default	Category
ULTR[*k*][a]	Unlatch Trip Terminal [*k*]	SELOGIC control equation	TRGTR	Group

[a] k = S, T, U, W, X.

TDURD (Minimum Trip Duration Timer)

There is only one minimum trip duration timer for all five terminals. Set this delay (in cycles) slightly longer than the trip time of the slowest circuit breaker.

Setting	Prompt	Range	Default	Category
TDURD	Minimum Trip Duration	2.000 to 8000 cycles	5.00	Group

Close Logic

Figure 4.84 shows the close logic that removes the close command to the circuit breaker after a set time. If the ECTTERM setting includes the terminal name, and if the unlatch input SELOGIC control equation (ULCL*k*) is deasserted, the two bottom inputs of the AND gate are logical 1. When SELOGIC control equation CL*k* asserts, the AND gate turns on. When the gate turns on, the Close Failure timer asserts and seals itself in through the OR gate for a time equal to the CFD setting, or until ULCL*k* asserts. With the Close Failure timer sealed in, output CLS*k* is also sealed in for the CFD time setting.

The close failure timer is unaffected by a setting group change. The timer starts timing in the present setting group, continues to run for the intermediate time between setting groups, and completes timing in the new setting group.

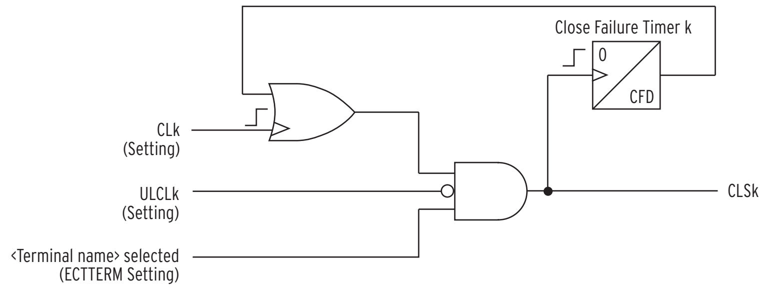


Figure 4.84 Close Logic for Breaker k

Close Logic Settings

CL[k] (Close SELOGIC Control Equation)

Specify the conditions under which the circuit breaker must close with the CL[*k]* setting. The default setting is local bit LB10, which controls close operations from the front panel. This settings category is hidden when ECTTERM = OFF.

Setting	Prompt	Range	Default	Category
CL[*k*][a]	Close Terminal [*k*]	SELOGIC control equation	LB10	Group

[a] k = S, T, U, W, X.

ULCL[k] (Unlatch Close SELOGIC Control Equation)

Specify the conditions to unlatch the close output command (CLS*k*) and reset the close failure timer. Default settings are the 52A breaker auxiliary contacts that assert when the breakers close.

Setting	Prompt	Range	Default	Category
ULCL[*k*][a]	Unlatch Close Terminal [*k*]	SELOGIC control equation	52CL[*k*]	Group

[a] k = S, T, U, W, X.

Open-Phase Detector Logic

Subsidence current results from energy trapped in a CT magnetizing branch after a circuit breaker opens to clear a fault or interrupt load. This current exponentially decays and delays the resetting of instantaneous overcurrent elements used for breaker failure protection. Breaker failure protection requires fast open phase detection to ensure fast resetting of instantaneous overcurrent elements. *Figure 4.85* shows open phase logic that asserts SEL-487E open phase detection elements OPHϕ*k* (ϕ=A, B, C, and *k* = S, T, U, W, X) in less than one cycle, even during subsidence current conditions.

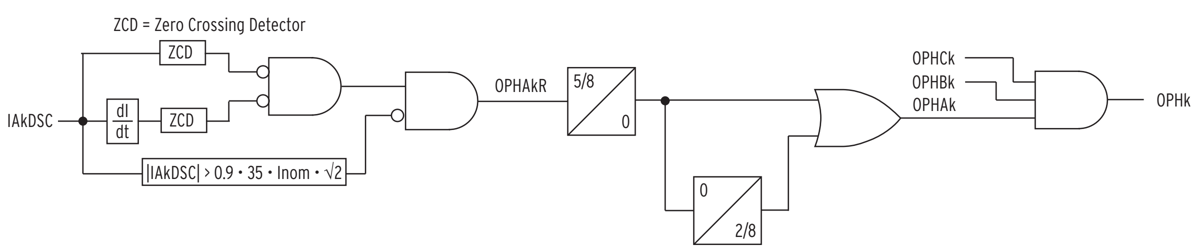


Figure 4.85 A-Phase Open-Phase Detection Logic

The logic measures the zero crossings and maximum and minimum current values of each phase. The relay declares an open phase when the logic does not detect a zero crossing or current value within 5/8 of a power system cycle since the previous measurement. OPHk, the output of the logic, asserts when all three phases of a particular winding assert.

Loss-of-Potential (LOP) Logic

Directional elements are voltage polarized, so loss of potential can cause the directional elements to misoperate. To prevent directional element misoperation, the LOP logic blocks the directional elements for a particular PT (V or Z) after detecting a blown PT fuse.

In general, the following three conditions cause a loss of potential:

- Incorrect operating procedures
- System faults
- Blown PT fuse(s)

Incorrect operating procedures include incidents such as energizing the relay without PT fuses after maintenance. Although the LOP logic alarms for this condition, the logic primarily detects the occurrence of blown PT fuses when the relay is in service.

To distinguish an LOP condition from a system fault condition, the LOP logic correlates the change in voltage with a change in current. Because a system fault causes a change in both voltage and current, the LOP logic compares the present values of the positive-sequence current and angle to the values of the positive-sequence current and angle of the previous cycle. In separate calculations, the LOP logic also compares the present values of the negative-sequence current to the value of the negative-sequence current of the previous cycle.

Figure 4.86 shows the logic that calculates the change in current for Terminal S; other terminals have similar logics. For each terminal included in the ECTTERM setting, the logic calculates the change in current, I*k*DELTA (*k* = S, T, U, W, X), for three possible conditions:

1. Change in positive-sequence current angle is greater than five degrees, provided that the present positive-sequence current magnitude and that of a cycle ago are greater than five percent of the nominal current (nominal current is 5 A or 1 A).
2. Change in positive-sequence current magnitude is greater than two percent of nominal current (5 A or 1 A).
3. Change in negative-sequence current magnitude is greater than six percent of nominal current (5 A or 1 A).

NOTE: The LOP logic only evaluates the change in current for current terminals included in the ECTTERM setting.

When any one of these three conditions is true, Relay Word bit ISDELTA asserts, causing Output IDELTA to assert. When IDELTA asserts, the IDELTA Timer maintains the output for 15 cycles. During these 15 cycles, AND Gate 2 (see *Figure 4.86*) cannot turn on, and an LOPV condition is not possible.

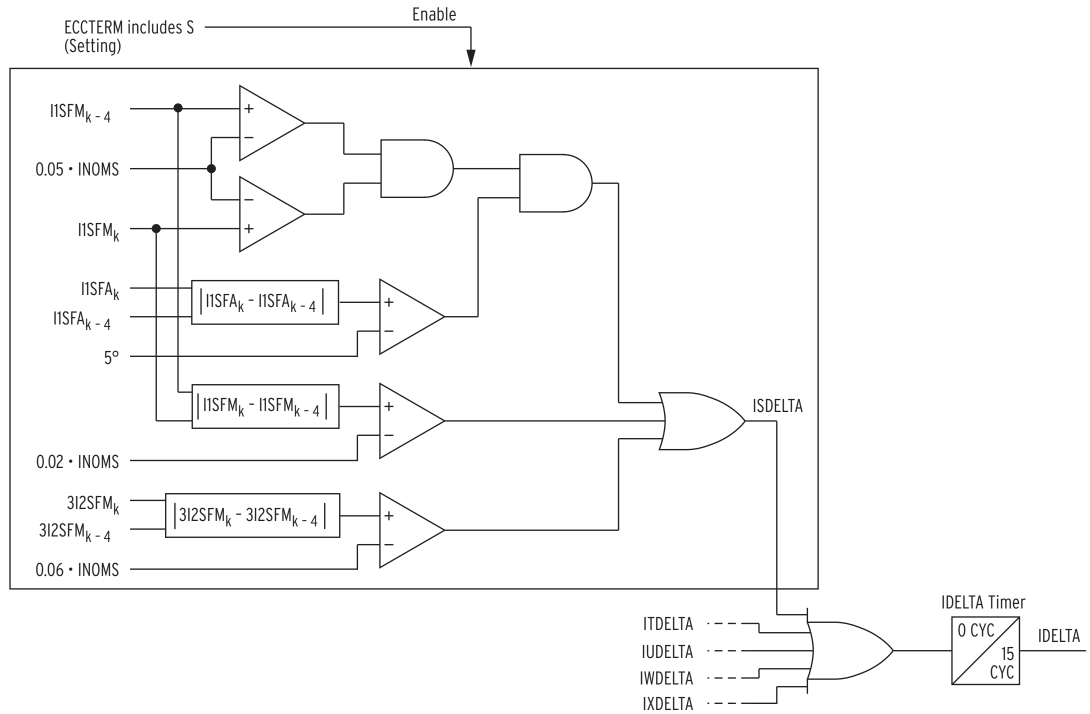


Figure 4.86 Logic that Calculates the Change in Current

Figure 4.87 shows the LOP logic for PT V; PT Z has similar logic. Whereas the delta current calculations determine the difference in current, the LOP logic calculates the ratio of the present voltage and the voltage one cycle earlier. AND Gate 1 turns on when the following three conditions are true:

- ➤ EPTTERM includes PT V
- ➤ The ratio of the present voltage and the voltage one cycle earlier is below 0.9 (also turns AND Gate 3 off)
- ➤ The voltage from one cycle earlier is higher than 10 percent of the nominal voltage of PT V

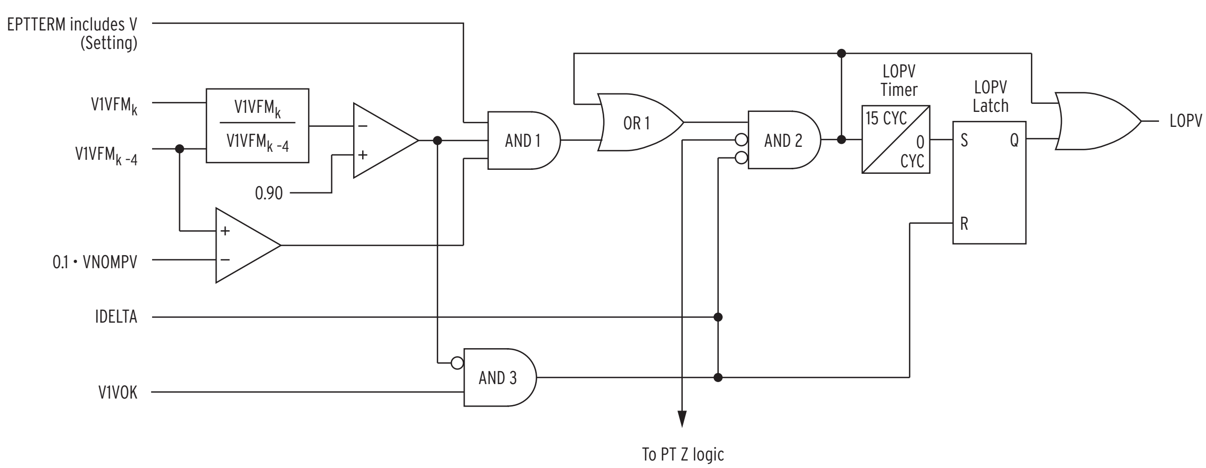


Figure 4.87 LOP Logic for Potential Transformer V

AND Gate 1 turns on when there is a drop in voltage greater than 10 percent in the positive-sequence voltage. If there is a simultaneous change in current (IDELTA asserts), then the drop is the result of a system fault, and AND Gate 2 does not turn on. However, if IDELTA does not assert, (no corresponding change in current), then the voltage drop is the result of a loss of potential condition. When all three input conditions are true, AND Gate 2 asserts. When AND Gate 2 asserts, the following takes place:

- AND Gate 2 seals itself in through OR Gate 1
- Output LOPV asserts and blocks all directional elements that have PT V as reference voltage (VREFk settings)
- The 15-cycle LOPV Timer starts. If the LOP condition lasts for 15 cycles, then the LOPV Timer expires and asserts the LOPV Latch, which latches the LOPV output. The LOPV Latch resets only when AND Gate 3 turns on.

Figure 4.88 shows the logic for detecting an abnormal voltage condition when the transformer is energized, or when a particular winding picks up load. When the circuit breaker is open, the open-phase detection (OPH*k*) asserts. Closing the circuit breaker does not necessarily cause OPH*k* to deassert; OPH*k* deasserts only when current flows. On the falling edge of OPH*k*, the OPH Timer asserts LD (load detected) for 130 cycles, thus asserting the bottom input into AND Gate 1. If the positive-sequence voltage is greater than 75 percent and the negative-sequence voltage (3V2) is less than 60 percent, the logic declares the condition as a possible missing or blown fuse, and it starts the PT Timer. If the condition persists for 120 cycles, then the PT Timer expires and sets the PT Latch. This setting of the PT Latch then asserts Output VALARMV. When the positive-sequence voltage is greater than 85 percent of the nominal voltage, and the ratio of negative-sequence (3V2) voltage to positive-sequence voltage is below 30 percent, Relay Word bit V1VOK asserts, and the PT Latch resets.

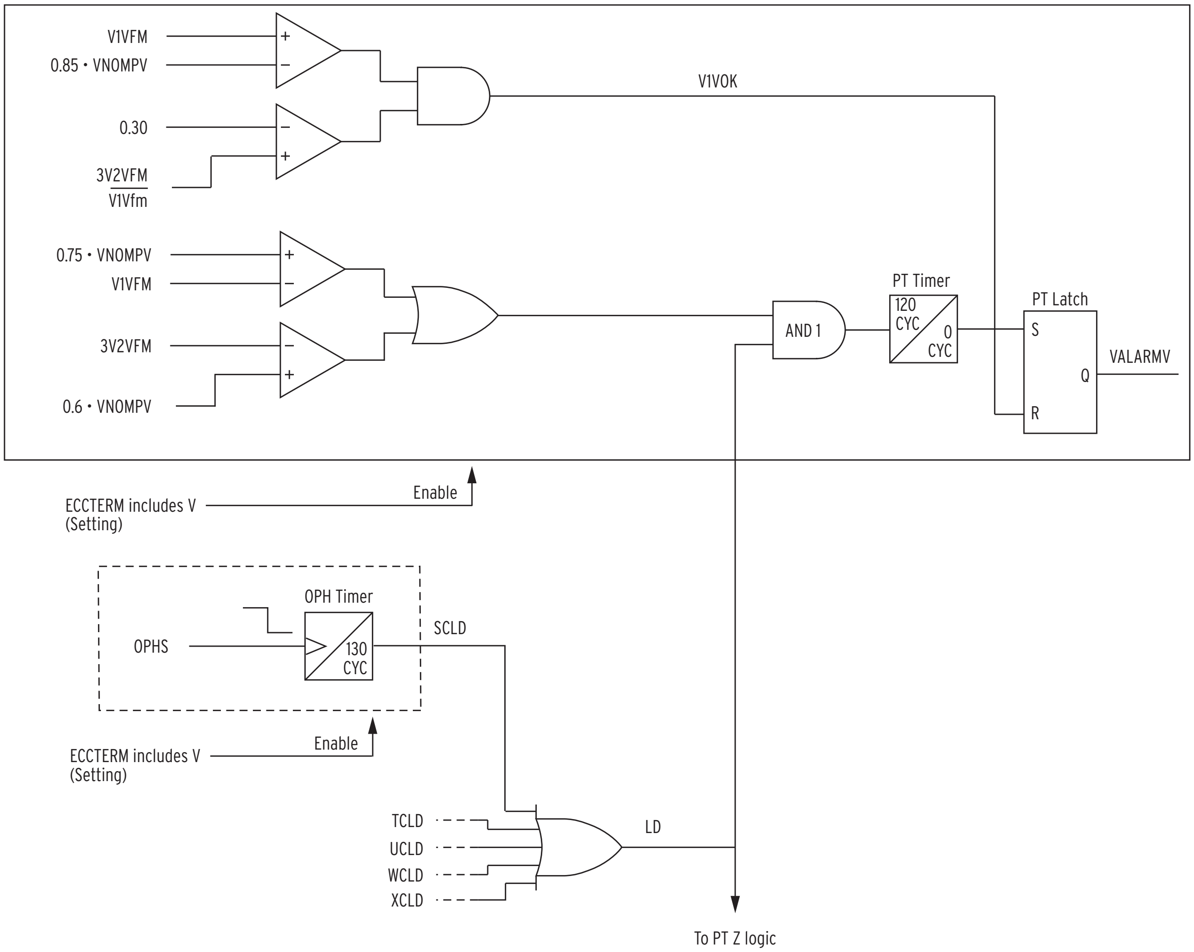


Figure 4.88 Logic to Detect Abnormal Voltage Condition

Circuit Breaker Status

Figure 4.89 shows the circuit breaker status logic, which uses the combination of breaker 52A (normally open) auxiliary contact and the open phase detection function, OPH*k* (*k* = S, T, U, W, X). Because 52B (normally closed) contacts are not always available, and as a means to reduce the number of I/O required, the 52B contacts are not required in the logic. However, for applications where the protection philosophy requires a 52B (normally closed) contact, wire the 52B contact into the relay, but use the negated form of the 52B contact in the logic (i.e., NOT 52B (52A_*k*: = NOT IN101)).

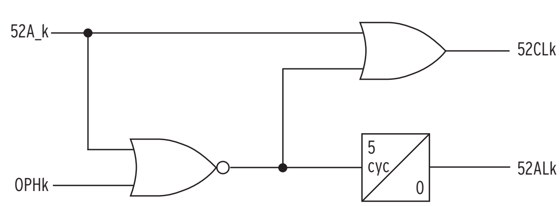


Figure 4.89 Circuit Breaker Status

Relay Word bits 52CL*k* assert when the breaker is closed. Open phase detection logic (OPH*k*) Relay Word bits are included in the circuit breaker status logic to guard against delayed breaker status declaration resulting from possible breaker auxiliary contact misalignment. If a discrepancy between the open phase detection logic and the breaker auxiliary contact exists for as long as five cycles, the logic generates an alarm that indicates one of the following:

- Possible auxiliary contact supply voltage failure
- Possible failure in an auxiliary contact connection circuit
- Possible failure of auxiliary contact mechanism

Element Output Summary

More advanced protection elements, such as the differential and directional elements, require more than one diagram to completely describe the operation of these elements. Although the final diagram of each element shows the output of the element, having the outputs of all protection elements in a single location clarifies the appropriate Relay Word bit for use in trip equations. *Table 4.15* summarizes the protection elements and shows the outputs of each element for use in trip equation(s) of a conventional transformer application.

Table 4.15 Summary of Protection Element Outputs (Sheet 1 of 2)

Element	Input(s)	Output(s)
Phase-differential element	Choose among Windings S, T, U, W, or X	Unrestraint: 87U (OR combination of 87UA, 87UB and 87UC) Restraint: 87R (OR combination of 87RA, 87RB and 87RC)
Negative-sequence differential element	Choose among Windings S, T, U, W, or X	87Q
Restricted earth fault element	Operating (polarizing) quantity: choose among IY1, IY2, IY3 Reference quantity: Choose among Windings S, T, U, W, or X	Forward direction: REFF*n* (internal fault) Reverse direction: REFR*n* (external fault)[a]
Phase definite-time (50) overcurrent elements	A-phase, B-phase, and C-phase current from selected windings	**Non-directional** Instantaneous: 50*k*P*n* Instantaneous, torque-controlled: 67*k*P*n* (set 67*k*P*n*TC = (<control conditions>) Time delayed: 67*k*P*n*T (set 67*k*P*n*TC = 1, then set 67*k*P*n*D to desired time delay) **Directional** Instantaneous: 67*k*P*n* (set 67*k*P*n*TC = (<directional conditions>) Instantaneous, torque-controlled: 67*k*P*n* (set 67*k*P*n*TC = (<control conditions>)) Time delayed: 67*k*P*n*T (set 67*k*P*n*TC = 1, then set 67*k*P*n*D to desired time delay)
Phase (51) time- overcurrent elements (IDMT)	10 independent elements; select inputs (operating quantities) for each element from *Table 4.5*	Instantaneous: 51S*m* Timed: 51T*m*

Table 4.15 Summary of Protection Element Outputs (Sheet 2 of 2)

Element	Input(s)	Output(s)
Directional element	Current: A-phase, B-phase, and C-phase current from selected windings. Voltage: PT V or PT Z	Voltage-polarized ground only Forward: *k*F32V Reverse: *k*R32V Voltage-polarized negative-sequence only Forward: *k*F32QG Reverse: *k*R32QG Voltage-polarized ground and negative-sequence (OR combination of elements above) Forward: *k*F32G (*k*F32V OR *k*F32QG) Reverse: *k*R32G (*k*R32V OR *k*R32QG) Voltage-polarized phase only Forward: *k*F32P Reverse: *k*R32P
Unbalance current elements	A-phase, B-phase, and C-phase current from selected windings	Instantaneous: 46*k*P Timed: 46*k*T
Volts/hertz element	Select between PT V or PT Z	**Definite-time elements** Instantaneous: 24D1 Timed: 24D1T, 24D2T **User-defined elements** 24U1T, 24U2T
Over-/undervoltage element	Voltage: see *Table 4.13*	**Under voltage** Instantaneous: 27*p*P1 Timed: 27*p*P1T Instantaneous: 27*p*P2 **Over voltage** Instantaneous: 59*p*P1 Timed: 59*p*P1T Instantaneous: 59*p*P2
Over-/underfrequency element	Select between PT V or PT Z	Over/under frequency Instantaneous: 81D*b* Timed: 81D*b*T
Breaker failure elements	A-phase, B-phase, and C-phase current from selected windings; initiating inputs	Retrip: RT*k* Breaker failure: FBF*k*
Over-/underpower element	10 independent elements; select inputs (operating quantities) for each element from *Table 4.5*	**Over power** Instantaneous: 32OP*m* Timed: 32OPT*m* **Under power** Instantaneous: 32UP*m* Timed: 32UPT*m*

[a] n = 1–3
k = S, T, U, W, X
m = 1–10
p = 1–5
a = 1–2
b = 1–6

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Section 5

Monitoring and Metering

Overview

The SEL-487E Relay provides extensive capabilities for monitoring transformer components and metering important power system parameters. The relay provides the following useful features:

- ➤ *Global Enables (Monitor Settings) on page 5.1*
- ➤ *Circuit Breaker Monitor on page 5.2*
- ➤ *Station DC Battery System Monitor on page 5.14*
- ➤ *Thermal Element on page 5.19*
- ➤ *Through-Fault Element on page 5.42*
- ➤ *Thermal Demand and Rolling Demand on page 5.47*
- ➤ *Demand Element Settings on page 5.51*
- ➤ *Analog Signal Profiling on page 5.52*
- ➤ *Metering on page 5.54*

Global Enables (Monitor Settings)

Table 5.1 shows the enable settings for the monitoring functions. Be sure to first enable the particular monitoring function to make the function settings available. Setting BK_SEL is the first tier of the breaker monitor settings. Include all the breakers of the application in the BK_SEL setting, then select those breakers you want to monitor with the EBMON setting. Breakers that are not included in the BK_SEL are not available for selection with the EBMON setting.

Table 5.1 Monitor Enable Settings

Label	Prompt	Default
EDCMON	Station DC Battery Monitor (Y, N)	N
BK_SEL	Breaker Selection (OFF or combo of S, T, U, W, X)[a]	S, T
EBMON	Enable BK Monitoring (OFF or combo of S, T, U, W, X)	OFF
ETHFLTM	Enable Through Fault Monitoring (Y, N)	N
ETHERM	Enable Transformer Thermal Element (Y, N)	N

[a] "Combo" means "combination of"; enter these "combo" settings delimited with either commas or spaces.

Circuit Breaker Monitor

Overview

The SEL-487E features advanced circuit breaker monitoring. *Figure 5.1* shows that the relay processes phase currents, circuit breaker auxiliary contacts, and the substation dc battery voltages to detect out-of-tolerance and maximum life circuit breaker parameters. These parameters include current interrupted, operating times, and contact wear. By using SEL-487E monitoring, maintenance personnel can determine the extent of a developing circuit breaker problem and select an appropriate response to correct the problem.

These monitoring features are available online in real-time; you can detect impending problems immediately. The result is better power system reliability and improved circuit breaker life expectancy. One of the many circuit breaker monitor features is the circuit breaker contact wear monitor. The SEL-487E tracks the number of circuit breaker close-open operations and respective fault interrupting levels for each of two circuit breakers. The relay uses data from the circuit breaker manufacturer to compare the recorded operational data with the manufacturer's recommended maintenance requirements. The SEL-487E notifies you when each set of circuit breaker pole contacts exceeds preset wear thresholds. Using this information, you can operate your substation more economically by accurately scheduling circuit breaker maintenance. You can also collect the following data on these circuit breaker parameters:

- Electrical operating time (per phase)
- Mechanical operating time (3-phase)
- Circuit breaker inactivity time (3-phase)
- Interrupted current (per phase)
- Motor run time (3-phase)

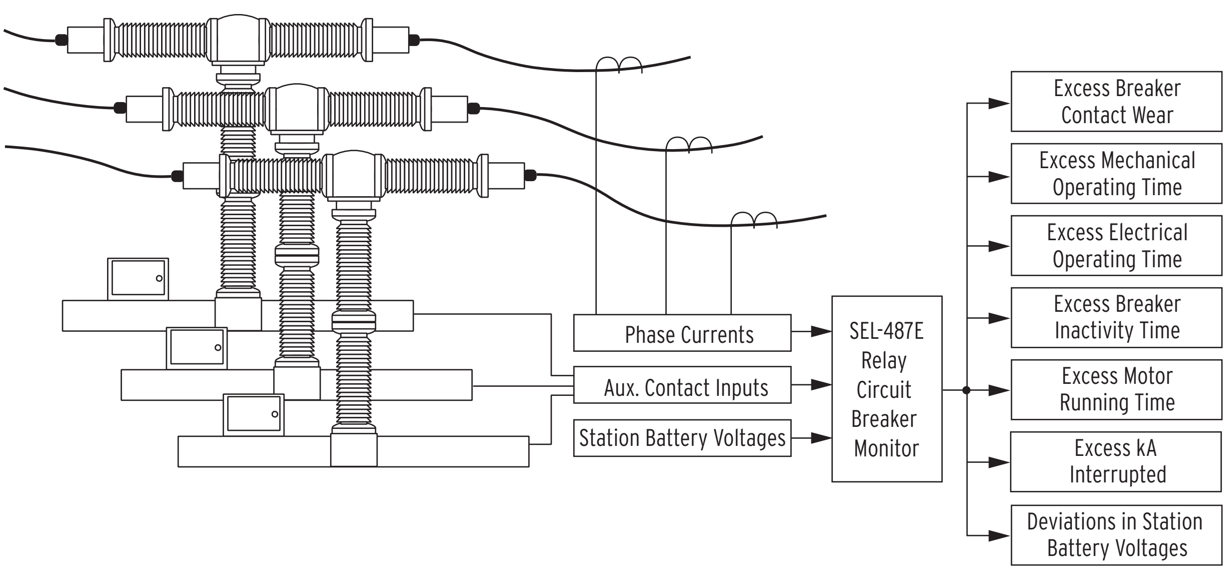


Figure 5.1 SEL-487E Intelligent Circuit Breaker Monitor

Enabling the Circuit Breaker Monitor

After selecting the circuit breaker with the BK_SEL setting, configure these circuit breaker monitors by using the settings listed in *Table 5.2* for up to five circuit breakers. All monitoring calculations are on a three-pole basis, except for the Interrupted Current calculations and the electrical operating time, which are on a per-phase basis.

Set the breaker ID with the B*k*_ID settings (*k* = S, T, U, W, X). Be sure to include the breaker in the SEL_BK setting, else the breaker setting will not be available. This B*k*_ID name appears in all breaker related reports. State the appropriate breaker normally open (NO) input for each breaker with the 52A_*k* settings. For default settings, the relay assigns Input IN101 through IN10*n* as the input values, depending on the number of enabled breakers.

Table 5.2 Circuit Breaker Monitor Configuration

Name	Description	Range	Default
B*k*_ID[a]	Breaker *k* Identifier (40 characters)	Breaker *k*	B*k*_ID
52A_*k*	NO Contact Input—BK*k* (SELOGIC Control Equation)	IN10*n*[b]	52A_*k*

[a] k = S, T, U, W, X.
[b] n = 1 if k = S, 2 if k = T, 3 if k = U, etc.

Circuit Breaker Contact Wear Monitor

The circuit breaker contact wear monitor in the SEL-487E provides information that helps you schedule circuit breaker maintenance. This monitoring function accumulates the number of close-open operations and integrates the per-phase current during each opening operation. The element compares this information to a predefined circuit breaker maintenance curve to calculate the percent contact wear on a per-pole basis. The circuit breaker maintenance curve also incorporates the accumulated fault current arcing time (ΣI^2t), assuming an identical arcing time for each trip. You can obtain the one-cycle arcing time from circuit breaker manufacturer data.

The SEL-487E updates and stores the contact wear information and the number of trip operations in nonvolatile memory. You can view this information through any communications port. Any phase wear percentage that exceeds the threshold setting B*k*BCWAT asserts an alarm Relay Word bit for each phase of each enabled circuit breaker. Alarm output B*k*BCWAL, is the OR combination of all the individual phase information, as shown in *Figure 5.2*. You can use these Relay Word bits in a SELOGIC® control equation to alert operations personnel, or you can control other functions such as blocking reclosing. The relay clips or limits the maximum reported circuit breaker wear percentage at 150 percent.

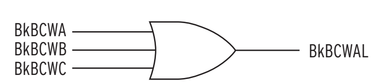


Figure 5.2 Alarm Relay Word Bits

The SEL-487E integrates currents and increments the trip counters for the contact wear monitor each time the SELOGIC control equation BM*k*TRP asserts. The default settings cause the contact wear monitor to integrate and increment each time the trip logic asserts.

Using the Circuit Breaker Contact Wear Monitor

Perform the following specific steps to use the circuit breaker contact wear monitor:

Step 1. Enable the circuit breaker monitor. See *Table 5.1*.

Step 2. Load the manufacturer's circuit breaker maintenance data.

Step 3. Preload any existing circuit breaker wear (if setting up the contact wear monitor on a circuit breaker with preexisting service time).

Step 4. Program the SELOGIC control equations for trip and close conditions.

Load Manufacturer Circuit Breaker Maintenance Data

Load the maintenance data supplied by the circuit breaker manufacturer. Circuit breaker maintenance information lists the number of permissible operating cycles (close/open operations) for a given current interruption level. *Table 5.3* shows typical circuit breaker maintenance information from an actual SF6 circuit breaker. The log/log plot of *Figure 5.3* is the circuit breaker maintenance curve, produced from the *Table 5.3* data.

Table 5.3 Circuit Breaker Maintenance Information—Example

Current Interruption Level (kA)	Permissible Close/Open Operations[a]
0.00–1.2	10000
2.00	3700
3.00	1500
5.00	400
8.00	150
10.00	85
20.00	12

[a] The action of a circuit breaker closing and then later opening is considered one close/open operation.

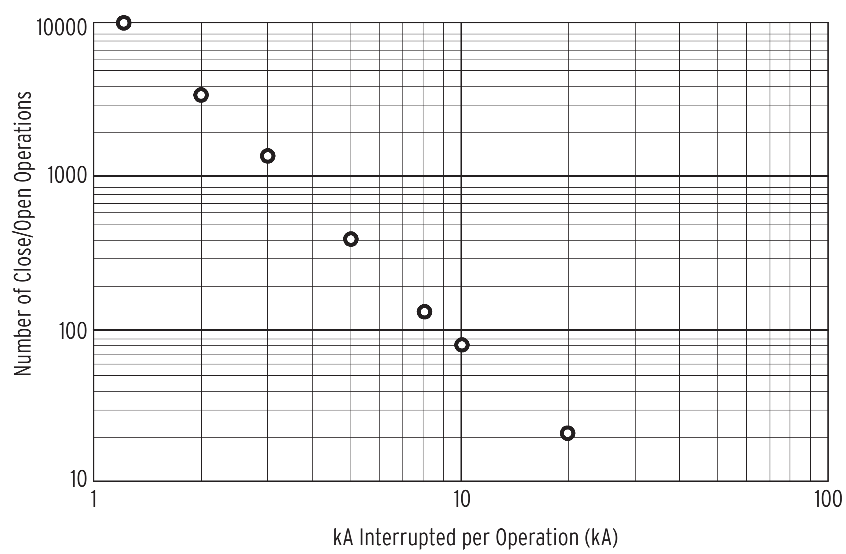


Figure 5.3 Circuit Breaker Maintenance Curve (Manufacturer's Data)

The three set points necessary to reproduce this circuit breaker maintenance curve in the SEL-487E are listed in *Table 5.4*.

Table 5.4 Contact Wear Monitor Settings—Circuit Breaker S

Setting	Definition	Range
B*k*COSP1[a]	Close/Open set point 1—max	0–65000 close/open operations
B*k*COSP2	Close/Open set point 2—mid	0–65000 close/open operations
B*k*COSP3	Close/Open set point 3—min	0–65000 close/open operations
B*k*KASP1[b]	kA Interrupted set point 1—min	1.0–999 kA in 0.1 kA steps
B*k*KASP2	kA Interrupted set point 2—mid	1.0–999 kA in 0.1 kA steps
B*k*KASP3[b]	kA Interrupted set point 3—max	1.0–999 kA in 0.1 kA steps

[a] k = S, T, U, W, X.
[b] The ratio of settings BkKASP3/BkKASP1 must be in the range: 5 ≤ BkKASP3/BkKASP1 ≤ 100.

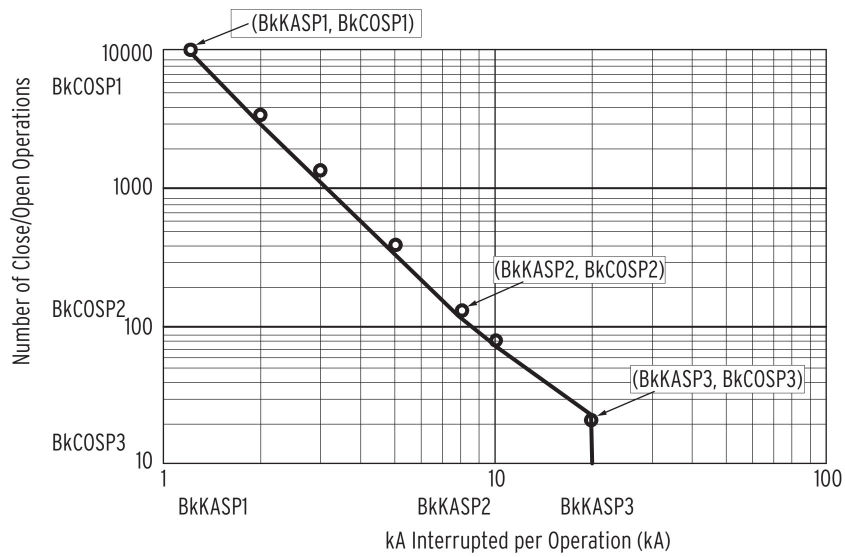


Figure 5.4 Circuit Breaker Contact Wear Curve With SEL-487E Settings

Circuit Breaker Contact Wear Curve Details. Circuit breaker maintenance information from the two end values of *Table 5.3* or *Figure 5.3* determine set point (B*k*KASP1, B*k*COSP1) and set point (B*k*KASP3, B*k*COSP3) for the contact wear curve of *Figure 5.4*. Set point (B*k*KASP2, B*k*COSP2) is the middle maintenance point in these data. There are two philosophies for selecting the middle set point. One method places the middle set point to provide the best “curve-fit” for your plot of the manufacturer’s circuit breaker maintenance data of *Figure 5.3*. Another philosophy is to set the middle point based on actual experience or fault studies of the typical system faults.

EXAMPLE 5.1 Creating the Circuit Breaker Contact Wear Curve

Acquire the manufacturer's maintenance information (this example uses the data of Table 5.3 for Circuit Breaker 5). If you receive the data in tabular form, plot the manufacturer's maintenance information on log/log paper in a manner similar to Figure 5.3.

Choose the left and right set points from the extremes of the curve you just plotted. Select the left set point on the contact wear curve corresponding to (B5KASP1, B5COSP1) by setting B5KASP1 := 1.2 and B5COSP1 := 10000. Plot the right set point (B5KASP3, B5COSP3) by setting B5KASP3 := 20.0 and B5COSP3 := 12.

Choose the midpoint of the contact wear curve based on your experience and system fault studies. The majority of operations for a typical circuit breaker are to interrupt single-line-to-ground faults. Therefore, plot the midpoint (B5KASP2, B5COSP2) by setting B5KASP2 at or slightly greater than the expected single-line-to-ground fault current: B5KASP2 := 8.0 and B5COSP2 := 150.

There are two other notable portions of the circuit breaker contact wear curve in *Figure 5.4*. The curve is horizontal below the left set point (B5KASP1, B5COSP1). This is the close/open operation limit regardless of interrupted current value (for the *Example 5.1* circuit breaker, this is at B5COSP1 := 10000). Some manufacturers call this point the mechanical circuit breaker service life.

Another part of the circuit breaker maintenance curve falls vertically at the right set point (B5KASP3, B5COSP3). This is the maximum interrupted current limit (for the *Example 5.1* circuit breaker, this is at B5KASP3 := 20.0). If the interrupted current exceeds setting B5KASP3, the relay sets contact wear at 105 percent.

EXAMPLE 5.2 I^2t Criteria Application

Some circuit breaker manufacturers do not provide a circuit breaker maintenance curve, but specify the accumulated fault current arcing time (ΣI^2t) for circuit breaker maintenance. For example, manufacturer's data specify ΣI^2t per phase at 750 kA^2-seconds for a particular circuit breaker, at a rated arcing duration for each trip of 1 cycle. The circuit breaker maximum interrupting current rating is 40 kA, and the continuous load current rating is 2 kA.

You can construct the contact wear curve for this circuit breaker from the specified ΣI^2t. Choose BkKASP1 := 2.0 (the continuous current rating) and BkKASP3 := 40.0 (the maximum interrupting current rating). Choose the middle of the contact wear curve based on experience and system fault studies. The majority of faults a typical circuit breaker interrupts are single-line-to-ground faults. Therefore, set BkKASP2 at or slightly greater than the expected single-line-to-ground fault current (BkKASP2 := 10.0 kA in this example). From the following equations, calculate these settings points to obtain the number of close/open operations:

$$\text{BkCOSP1} = \frac{\sum I^2 t}{(\text{BkKASP1})^2 \bullet t_{arc}} = \frac{750}{2^2 \bullet (0.01667 \bullet 1)} := 11250$$

Equation 5.1

$$\text{BkCOSP2} = \frac{\sum I^2 t}{(\text{BkKASP2})^2 \bullet t_{arc}} = \frac{750}{10^2 \bullet (0.01667 \bullet 1)} := 450$$

Equation 5.2

$$\mathrm{BkCOSP3} = \frac{\sum I^2 t}{(\mathrm{BkKASP3})^2 \bullet t_{arc}} = \frac{750}{40^2 \bullet (0.01667 \bullet 1)} := 28$$

Equation 5.3

In these equations, t_{arc} is the arcing time in seconds; $t_{arc} = (1/f_{nom}) \bullet$ (arc duration in cycles); f_{nom} is the nominal power system frequency (50 Hz or 60 Hz). These calculations show the number of close/open operations rounded to the nearest unit.

Preloading Contact Wear Data

Upon the first commissioning of the SEL-487E, the associated circuit breakers can already have some wear. You can preload a separate amount of wear for each pole of each circuit breaker (see *Preload Breaker Wear on page 5.13* to preload existing contact wear data). The relay accepts integer values of percentage wear as great as 100 percent. The relay adds the incremental contact wear at the next circuit breaker monitor initiation (and at all subsequent initiations) to the preloaded value to obtain a total wear value. The limit for reporting circuit breaker contact wear is 150 percent for each pole.

Circuit Breaker Monitor Trip Initiation Settings: BMkTRP. The SEL-487E employs SELOGIC control equations to initiate the circuit breaker monitor. For Circuit Breaker S, this setting is BMSTRP. When detecting a rising edge (a transition from logical 0 to logical 1) of the initiation settings, the relay accumulates the interrupted rms currents and advances the trip counter by one count. Because the SEL-487E support three-pole tripping only, there is only one SELOGIC control equation for each breaker.

Initiation settings can include both internal and external tripping conditions. In order to capture trip information initiated by devices other than the SEL-487E, you must program the SELOGIC control equation BM*k*TRP to sense these trips.

EXAMPLE 5.3 Circuit Breaker Monitor External Trip Initiation

Connect external trip signals to the relay control inputs. This example uses input IN101; you can use any control inputs that are appropriate for your installation.

If you want Circuit Breaker Monitor S to initiate for the trip element TRIP, or for external trips (IN101), set these SELOGIC control equations from the **SET M** ASCII command or the ACSELERATOR QuickSet **Breaker Monitor Settings** tree view:

BMSTRP := **TRIPS OR IN101** Breaker Monitor 3-Phase Trip Initiate

Circuit Breaker Monitor Close Initiation Settings: BMkCLS. The SEL-487E employs SELOGIC control equations to initiate the circuit breaker monitor duration timers for close functions. For Circuit Breaker S, this setting is BMSCLS. These SELOGIC control equations use Relay Word bits to determine when the circuit breaker monitor times mechanical closing and electrical closing. Because the SEL-487E support three-pole tripping only, there is only one SELOGIC control equation for each breaker.

Other Circuit Breaker Monitor Functions

kA Interrupt Monitoring

The SEL-487E monitors the amount of phase current that each pole of the circuit breaker interrupts at each trip operation. The relay records the interrupted current as a percentage of the circuit breaker maximum interrupting rating specified by the manufacturer. Set the maximum interruption current with setting B*k*MKAI (Maximum kA Interrupt Rating—BK*k*). If the percent of current interrupt that the relay records exceeds threshold setting B*k*KAIAT (kA Interrupt Capacity Alarm Thresh—BK*k*), the relay asserts breaker monitor alarm Relay Word bit B*k*KAIAL.

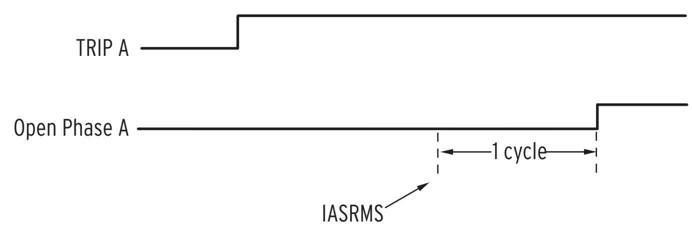


Figure 5.5 kA Interrupted for Circuit Breaker S, A-Phase

NOTE: kA Interrupting data is not recorded if the OPH asserts more than 100ms after BkESOAL asserts. If OPH asserts in less than 100ms after BkESOAL asserts, the kA interrupting data is still recorded.

IASRMS is the RMS value one cycle before the OPHAS bit asserts for phase A, Winding S. Similar calculation applies for phases B and C.

Mechanical Operating Time

The mechanical operating time is the time between trip initiation or close initiation and the subsequent circuit breaker 52A normally-open contact status change. (When 52A_*k* asserts, the particular circuit breaker is considered closed). The SEL-487E measures the tripping times for each breaker from the assertion of the respective BM*k*TRP Relay Word bit to the dropout of the respective 52A_*k* Relay Word bit. Similarly, for mechanical closing time, the relay measures the closing times for each breaker from the assertion of the BM*k*CLS Relay Word bit to the pickup of the 52A_*k* Relay Word bit. The relay compares these tripping or closing times to the mechanical slow operation time thresholds for tripping and closing, B*k*MSTRT and B*k*MSCLT, respectively. When trip or close times exceed these thresholds, the relay issues a mechanical slow operation alarm, B*k*MSOAL, for 5 seconds. See *Figure 5.6* for a Circuit Breaker S timing diagram.

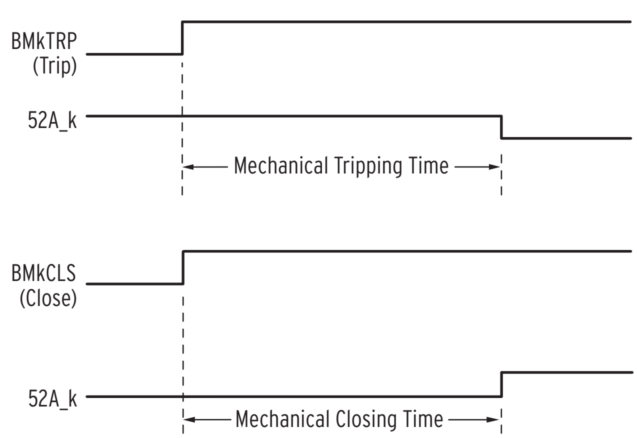


Figure 5.6 Mechanical Operating Time for Circuit Breaker 5

EXAMPLE 5.4 Mechanical Operating Time Settings

Use Circuit Breaker S for this example. Connect the circuit breaker normally-open 52A contact through station battery power to IN101; you can use any other control inputs that are appropriate for your installation. The control voltage for this example is 125 Vdc.

52A_S := **IN101** N/O Control Input—BKS (SELOGIC control equation)

Connect an external trip signal to IN102, and an external close signal to IN103. Use the default settings for input debounce time. Set the mechanical operating time threshold for the slow trip alarm (BSMSTRT) at 30 ms, and the slow close alarm threshold (BSMSCLT) at 70 ms. Use your company standard practices to determine these settings for your application. For this example, enter the following settings:

BSMSTRT := **30** Mechanical Slow Trip Alarm Threshold—BKS (1-999 ms)

BSMSCLT := **70** Mechanical Slow Close Alarm Threshold—BKS (1-999 ms)

BMSTRP := **TRIPS OR IN102** Breaker Monitor Trip—BKS (SELOGIC control equation)

BMSCLS := **CLS OR IN103** Breaker Monitor Close—BKS (SELOGIC control equation)

Assertion of the Relay Word bit B1MSOAL indicates any one of the following four conditions:

- The mechanical operating time for a trip operation exceeds 30 ms (the slow trip alarm setting)
- The mechanical operating time for a close operation exceeds 70 ms (the slow close setting)
- No 52A_S status change occurred during the time BSMSTRT plus approximately 100 ms after trip initiation (a trip time-out condition)
- No 52A_S status change occurred during the time BSMSCLT plus approximately 100 ms after close initiation (a close timeout condition)

The relay makes a further check on the auxiliary circuit breaker (52A) contacts by testing whether these circuit breaker contacts have changed state within approximately 100 ms after the end of the trip or close threshold times. Thus, this additional check serves as the trip time-out and close time-out condition. This check verifies that the circuit breaker actually closed or opened, and it alerts you if maintenance is required on the circuit breaker mechanical linkages or auxiliary (52) contacts.

Electrical Operating Time

The electrical operating time is the time between trip or close initiation and an open phase status change, by measuring the tripping time for each phase from the assertion of the BM*k*TRP Relay Word bit to the time the relay detects an open phase condition. Similarly, the relay measures electrical operating time for closing each phase from the assertion of BM*k*CLS to the restoration of phase quantities. The relay compares these tripping or closing times to the electrical slow operation time thresholds for tripping and closing, B*k*ESTRT and B*k*ESCLT, respectively. When trip or close times exceed these thresholds, the relay issues an electrical slow operation alarm, B*k*ESOAL, for 5 seconds. *Figure 5.7* shows the timing diagram for Circuit Breaker S.

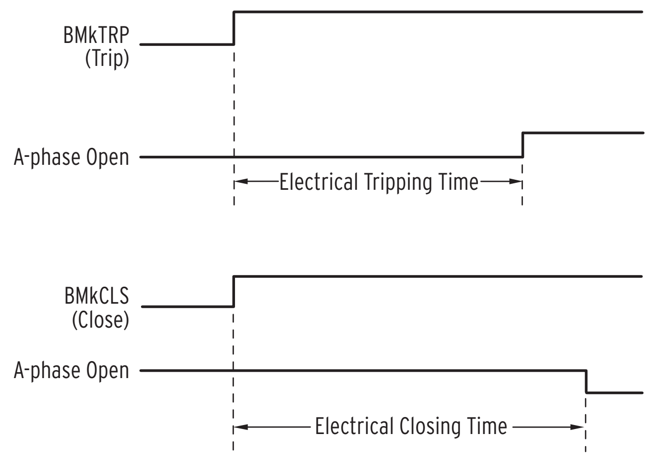


Figure 5.7 Electrical Operating Time for Circuit Breaker S A-Phase

The relay further checks the circuit breaker by testing whether the circuit breaker has interrupted or restored current within 100 ms after the end of the trip or close threshold times. Thus, this additional check serves as the trip time-out and close time-out condition. This verifies that the circuit breaker actually closed or opened, and alerts you if maintenance is required on circuit breaker mechanical linkages.

Circuit Breaker Inactivity Time Elapsed

The SEL-487E circuit breaker inactivity time monitor detects the elapsed time (measured in days) since the last trip or close operation of a circuit breaker. Use setting B*k*ITAT to set the circuit breaker inactivity time. An alarm Relay Word bit, B*k*BITAL, asserts if the elapsed time exceeds a predefined setting. This alarm is useful to detect circuit breakers that are not operated on a regular basis. These circuit breakers can fail to operate when needed to perform a protection trip.

EXAMPLE 5.5 Inactivity Time Settings

Use Circuit Breaker S for this example. To assert an alarm if Circuit Breaker S has not operated within the last 365 days, enter the following settings:

B1ITAT := **365** Inactivity Time Alarm Thresh—BK1 (N, 1–9999 days)

Assertion of the Relay Word bit B1BITAL indicates that it has been more than 365 days since the last Circuit Breaker 1 operation.

When testing the inactivity timer, you must measure actual relay clock transitions across time 00:00:00.000 (to increment the day counter). If you set the relay to a specific date, enable the circuit breaker monitor (EBMON := Y), then advance the date setting to a new date, the inactivity timer shows only 1 day of elapsed time.

Motor Running Time

The SEL-487E circuit breaker monitor measures circuit breaker motor running time. Depending on your particular circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressed air motor. An alarm asserts if the elapsed motor running time exceeds the predefined threshold setting B*k*MRTAT.

Setting B*k*MRTIN is a SELOGIC control equation to activate the motor running timer. The rising edge of BkMRTIN indicates the motor starting time; a falling edge indicates the motor stop time. The motor running time logic asserts the alarm Relay Word bit, B*k*MRTAL, for 5 seconds when the motor running time exceeds the predefined threshold. Setting B*k*MRTIN to logical 0 disables the motor running time feature of the circuit breaker monitor.

EXAMPLE 5.6 Motor Running Time Settings

Use Circuit Breaker 1 for this example.

Connect the motor control contact to IN101.

To determine the motor run time value, take the circuit breaker out of service using your company standard circuit breaker maintenance policy. Issue a trip and close command while you measure the time that the circuit breaker motor requires for recharging the spring or reestablishing the return air pressure to normal. Add 20 percent to this time measurement to avoid false alarms. Use the resulting time value for the motor running time alarm setting BSMRTAL.

The control voltage for this example is 125 Vdc. The recharge time measurement for this circuit breaker was 20 seconds; add 20 percent (4 seconds) to give an alarm time of 24 seconds. To set the motor running time alarm threshold at 24 seconds, enter the following settings:

BSMRTIN := **IN101** Motor Run Time Control Input—BKS (SELOGIC control equation)

BSMRTAT := **24** Motor Run Time Alarm Threshold—BKS (1–9999 seconds)

Assertion of the Relay Word bit BSMRTAL indicates the following condition: motor running time exceeds 24 seconds because IN101 was asserted for more than 24 seconds.

BREAKER Command

Use the **BRE** command to access vital information about the condition of substation circuit breakers and preset or reset circuit breaker monitor data. The SEL-487E monitors two separate circuit breakers; you must specify Circuit Breaker 1 and Circuit Breaker 2 for most **BRE** commands, as shown in *Table 5.5*.

Table 5.5 BRE Command Structure[a]

Command	Description
BRE C A	Clear all circuit breaker monitor data to zero.
BRE R A	Clear all circuit breaker monitor data to zero.
BRE *k* C	Clear Circuit Breaker *k* data to zero.
BRE *k*R	Clear Circuit Breaker *k* data to zero.
BRE *k*	Display the breaker report for the most recent Circuit Breaker *k* operation.
BRE *k* H	Display history data for the last 128 Circuit Breaker *k* operations.
BRE *k* P	Preload previously accumulated Circuit Breaker *k* data.

[a] k = S, T, U, W, X.

The **BRE *k* C** and **BRE *k* R** commands reset the accumulated circuit breaker monitor data for the specified circuit breaker. If you do not specify a circuit breaker, then the clear commands **BRE C A** and **BRE R A** clear all data for all circuit breakers.

The **BRE *k*** commands display the circuit breaker report for the most recent circuit operation. Furthermore, the relay also displays the operation summary and the circuit breaker alarms. When the circuit breaker maintenance curve reaches 150 percent for a particular pole, the percentage wear for this pole remains at 150 percent (even if additional current is interrupted) until reset. However, the relay continues to advance the operation counter to as many as 9999999 operations per pole until reset. Accumulated circuit breaker wear/operations data are retained if the relay loses power or if the circuit breaker monitor is disabled (EBMON := N).

Circuit Breaker Report

NOTE: Either BMkTRP or BMkCLS must be set for dc data to be displayed.

Figure 5.8 is a sample breaker report (shown with typical data). The relay reports dc battery monitor voltages for the minimum dc voltage during a 20-cycle period at circuit breaker monitor trip initiation (BM*k*TRPϕ) and for a 30-cycle window at circuit breaker monitor close initiation (BM*k*CLS). The circuit breaker report contains data only for options that you have enabled.

(For the most recent operation)

```
=>>BRE S <Enter>

Relay 1                                      Date: 04/07/2008  Time: 23:31:48.184
Station A                                    Serial Number: 2008030645

Breaker S

Breaker S Report
                               Trip A  Trip B  Trip C   Cls A   Cls B   Cls C
Avg Elect Op Time (ms)           50.0   48.0   48.0   60.0   58.3   58.7
Last Elect Op Time (ms)          56.2   58.4   58.4   66.9   68.2   68.7

                                Trip    Cls
Avg Mech Op Time (ms)            52.2   66.4
Last Mech Op Time (ms)           61.2   68.2

Last Op Minimum DC1 (V)          115.8

Inactivity Time (days)           5       2

                               Pole A  Pole B  Pole C
Accum Pri Current (kA)          5.997 13.9898 7.99588
Accum Contact Wear (%)            0.5     0.5     0.5
Max Interrupted Current (%)       3.0    13.0     5.0
Last Interrupted Current(%)       3.0    13.0     5.0

Number of Operations                5

                                Alarm   Total Count
Mechanical Operating Time       MSOAL       0
Electrical Operating Time       ESOAL       4
Breaker Inactivity Time         BITAL       0
Current (kA) Interrupted        KAIAL       0

LAST BREAKER MONITOR RESET   04/07/2008   20:10:07.121

=>>
```

Figure 5.8 Breaker S Report

Breaker History

The SEL-487E displays the circuit breaker history report when you issue the **BRE *k* H** command. The report consists of as many as 128 circuit breaker monitor events stored in nonvolatile memory. These events are determined by settings BM*k*TRP and BM*k*CLS. The breaker history report is similar to *Figure 5.9* (shown with typical data).

```
=>>BRE S H <Enter>

Relay 1                                    Date: 04/07/2008  Time: 22:26:13.848
Station A                                  Serial Number: 2008030645

Breaker S

Breaker S History Report

No.    Date        Time         Bkr.Op   Op Time(ms)    Pri I   VDC1
                                        Elect Mech(3p)   (A)     (V)
1    04/07/2008  22:25:51.570  Cls C     51              501
2    04/07/2008  22:25:51.570  Cls B     50              499
3    04/07/2008  22:25:51.569  Cls A     51       59     500     116
4    04/07/2008  22:24:43.195  Cls C     50              500
5    04/07/2008  22:24:43.195  Cls B     49              499
6    04/07/2008  22:24:43.195  Cls A     50       60     500     116
7    04/07/2008  22:24:29.520  Cls C     50              231
8    04/07/2008  22:24:29.520  Cls B     49              229
9    04/07/2008  22:24:29.520  Cls A     51       59     228     117


=>>
```

Figure 5.9 Breaker S History Report

Preload Breaker Wear

You can preload a separate contact wear value for each pole of each circuit breaker by using the commands **BRE *k* P**. The relay adds the incremental contact wear at all subsequent circuit breaker monitor initiations to your preloaded value to obtain a total wear value. You can enter integer values of percentage wear from 1 percent to 100 percent. In addition to preloading contact wear data, you can enter values for previous operations and accumulated currents. The maximum number of operations or accumulated primary current (in kA) you can enter is 9999999. *Figure 5.10* shows the circuit breaker preload terminal screen.

```
=>>BRE S P <Enter>
Breaker S: Preload Contact Wear, Operation Counters, and Accumulated Currents

Accum Contact Wear (%)    A-phase % =  0.6 ? 15
                          B-phase % =  0.6 ? 23
                          C-phase % =  0.6 ? 12

Accum Num of Operations          =       6 ? 32

Accum Pri Current (kA)    Trip A = 7.49624 ? 10
                          Trip B = 19.6937 ? 20
                          Trip C = 10.4943 ? 15

                           Pole A     Pole B     Pole C

Accum Contact Wear (%)      15.0       23.0       12.0
Accum Num of Operations      32
Accum Pri Current (kA)    10.0000    20.0000    15.0000

Are you sure (Y/N)?Y
Breaker Preload Data Stored
=>>
```

Figure 5.10 Breaker S Preload Data

When performing circuit breaker testing, capture the **BRE *k* P** information (write the date or use a terminal screen capture) before testing. Test the circuit breaker, then enter the previously recorded preload data with the **BRE *k* P** command. Using this method, you can eliminate testing operations from actual usage data in the circuit breaker monitor.

Compressed ASCII Circuit Breaker Report

You can retrieve a Compressed ASCII circuit breaker report by using the **CBR** command from any communications port. The relay arranges items in the Compressed ASCII circuit breaker report in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order. The information presented below explains the message and serves as a guide to the items in a Compressed ASCII configuration circuit breaker report. The format of the Compressed ASCII **CBR** message is the following:

```
=>>CBR <Enter>
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-487E-R100-V0-Z001001-D20080326","0e57"
"BID","013F"
"Breaker S","039F"
"AVG_TR_ELE","LST_TR_ELE","AVG_CL_ELE","LST_CL_ELE","0E1C"
50.0,58.3,50.0,50.0,"03C7"
48.0,64.5,50.0,50.0,"03CD"
48.0,58.3,50.0,50.0,"03CE"
"AVG_TR_MEC","LST_TR_MEC","LST_TR_mDC","TR_INAC[d]","AVG_CL_MEC","LST_CL_MEC","L
ST_CL_mDC","CL_INAC[d]","1CB8"
123,231,5.8,0,234,220.0,5.8,0,"052C"
"ACC_I[kA]","ACC_WEAR%","MAX_INT_I%","LAST_INT_I%","0D55"
10.0,15.0,3.0,3.0,"0355"
20.0,23.0,13.0,11.4,"03B9"
15.0,12.0,5.0,5.0,"035B"
"NUM_OPS","AVG_MOT_RT","LST_MOT_RT","RST_MONTH","RST_DAY","RST_YEAR","RST_HOUR",
"RST_MIN","RST_SEC","1B4C"
32,223,322,4,7,2008,20,10,7,"04F8"
"BID","013F"
"Breaker T","03A0"
.
.
.
"Breaker U","03A1"
.
.
.
"Breaker W","03A3"
.
.
.
"Breaker X","03A4"
.
.
.

=>>
```

The relay reports the data as A-phase in the first line, B-phase in the second line, and C-phase in the third line.

Station DC Battery System Monitor

The SEL-487E automatically monitors one station battery system health by measuring the dc voltage, ac ripple, and voltage between each battery terminal and ground. Four voltage thresholds give you the ability to create five sensing zones (low failure, low warning, normal, high warning, and high failure) for the dc voltage.

The ac ripple quantity indicates battery charger health. When configuring the ac ripple setting DC1RP, we can define the ripple content of a dc supply as the peak-to-peak ac component of the output supply waveform.

The relay also makes measurements between the battery terminal voltages and station ground to detect positive and negative dc ground faults. *Figure 5.11* shows a typical battery dc system.

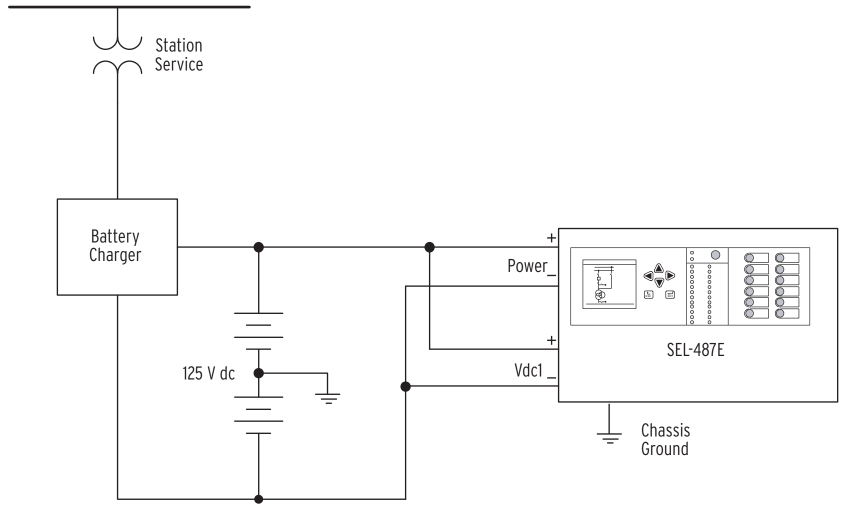


Figure 5.11 Typical Station DC Battery System

The dc monitor alarms for undervoltage or overvoltage dc battery conditions in five sensing regions. The following describes how to apply the dc battery monitor to a typical 125 Vdc protection battery system connected to a SEL-487E on terminals **Y25(+)** and **Y26(-)** (see *Figure 14.1* for the terminals). Adjust the values used here to meet the specifications of your company.

Battery Voltage

When setting the station dc battery monitor, determine the minimum and maximum dc levels in the battery system. In addition, establish the threshold levels for different battery system states or conditions. The following voltage levels describe these battery system conditions:

- Trip/Close—the lowest dc voltage point at which circuit breaker trip and close operations occur
- Open-circuit—the dc battery voltage when all cells are fully charged and disconnected from the battery charger or load
- Float low—the lowest charging voltage supplied by the battery charger
- Float high—the highest charging voltage supplied by the battery charger
- Equalize mode—a procedure during which the batteries are overcharged intentionally for a pre-selected time in order to bring all cells to a uniform output

Set the low end of the allowable dc battery system voltage according to the recommendations of C37.90-1989 (R1994) IEEE Standard for Relays and Relay Systems Associated with Electric Power. *Section 6.4* in this standard is titled *Allowable Variation from Rated Voltage for Voltage Operated Auxiliary Relays*. This section calls for an 80 percent low-end voltage and 28, 56, 140, or 280 Vdc high-end voltages for the popular nominal station battery voltages. *Table 5.6* lists expected battery voltages under various conditions using commonly accepted per-cell voltages.

Table 5.6 Example DC Battery Voltage Conditions

Condition	Calculation	Battery Voltage (Vdc)
Trip/Close	80% • 125 Vdc	100.0
Open-Circuit	60 (cells) • 2.06 (volts/cell)	123.6
Float Low	60 (cells) • 2.15 (volts/cell)	129.0
Float High	60 (cells) • 2.23 (volts/cell)	133.8
Equalize Mode	60 (cells) • 2.33 (volts/cell)	139.8
Trip/Close	80% • 48 Vdc	38.4
Open Circuit	24 (cells) • 2.06 (volts/cell)	49.4
Float Low	24 (cells) • 2.15 (volts/cell)	51.6
Float High	24 (cells) • 2.23 (volts/cell)	53.5
Equalize Mode	24 (cells) • 2.33 (volts/cell)	55.9
Trip/Close	80% • 24 Vdc	19.2
Open Circuit	12 (cells) • 2.06 (volts/cell)	24.7
Float Low	12 (cells) • 2.15 (volts/cell)	25.8
Float High	12 (cells) • 2.23 (volts/cell)	26.8
Equalize Mode	12 (cells) • 2.33 (volts/cell)	28.0

NOTE: First enable Station DC Monitoring with the EDCMON setting to access the dc battery monitor settings. When EDCMON = Y the relay processes inputs from the monitor terminals.

Use the expected battery voltages of *Table 5.7* to determine the SEL-487E station dc battery monitor threshold settings. *Table 5.7* shows these threshold settings for a nominal 125 Vdc battery system.

Table 5.7 Example DC Battery Monitor Settings—125 Vdc for Relay A

Setting	Description	Indication	Value (Vdc)
DCLFP	Low-fail threshold	Poor battery performance	100
DCLWP	Low-warning threshold	Charger malfunction	127
DCHWP	High-warning threshold	Equalization	137
DCHFP	High-fail threshold	Charger malfunction	142

AC Ripple

Another method for determining whether the substation battery charger has failed is to monitor the amount of ac ripple on the station dc battery system. The *IEEE C37.90-1989* standard also identifies an "*Allowable AC Component in DC Control Voltage Supply*" *(Section 6.5)* as an alternating component (ripple) of 5 percent peak or less. (This definition is valid if the minimum instantaneous battery voltage is not less than 80 percent of the rated voltage.) The SEL-487E measures ac ripple as a peak-to-peak waveform, consequently, DCRP should be set at or greater than 10 percent (2 • 5% peak) of the equalizing voltage. *Table 5.8* shows the ac ripple threshold settings for this example.

Table 5.8 Example DC Battery Monitor Settings—AC Ripple Voltages

Setting	Description	Indication	Value (Vac)
DCRP	AC ripple threshold	Charger malfunction	14

DC Ground

If a battery system is centered around chassis ground, then the magnitude of the voltage measured from the positive terminal to ground and from the negative terminal of the battery to ground should be approximately one half of the nominal battery system voltage. The ratio of the positive-to-ground battery voltage to the negative-to-ground battery voltage is 1 to 1, or 1.00. *Equation 5.4* is the balanced (no grounding) ratio for a 125-Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{62.50\ V}{62.50\ V} = 1.00$$

Equation 5.4

If either terminal is partially or completely shorted to chassis ground, then the terminal voltage will be less than the nominal terminal-to-ground voltage. This causes the ratio of positive voltage to negative voltage to differ from 1.00. *Equation 5.5* is an example of the unbalanced (grounding) ratio for a partial short circuit to ground on the negative side of a 125-Vdc battery system.

$$k = \frac{Vdc1_{pos}}{Vdc1_{neg}} = \frac{62.50\ V}{59.10\ V} = 1.06$$

Equation 5.5

The SEL-487E uses this voltage ratio to calculate a ground detection factor. *Figure 5.12* shows a graphical representation of the ground detection factor setting and battery system performance.

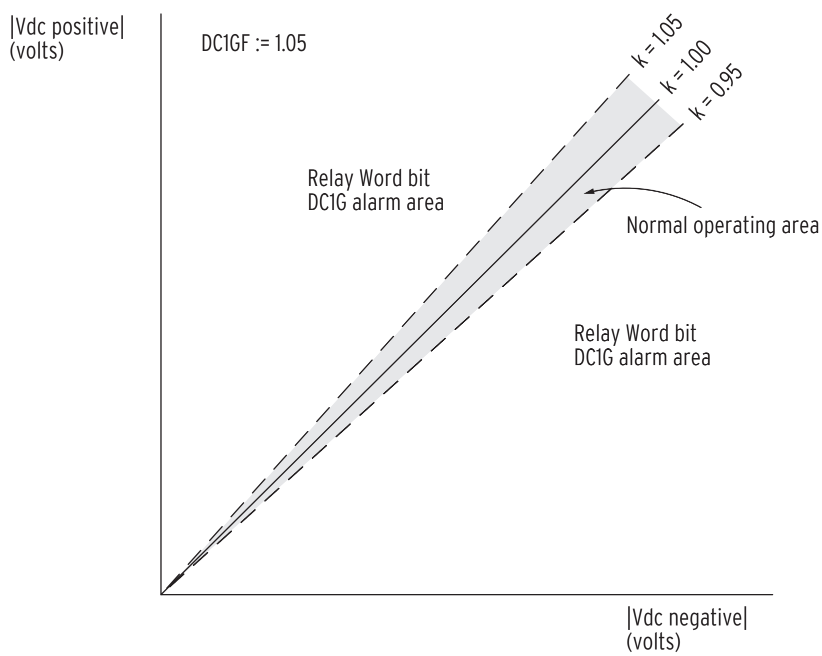


Figure 5.12 Ground Detection Factor Areas

If the ground detection factor ratio exceeds a setting threshold, the relay asserts the DCIG Relay Word bit. To set the ground detection factor threshold, set the DCGF threshold at a value close to 1.05 (the factory default setting) to allow for some slight battery system unbalance of around 5 percent. *Table 5.9* lists the ground detection factor threshold settings for this example.

Table 5.9 Example DC Battery Monitor Settings—Ground Detection Factor (EGADVS := Y)

Setting	Description	Indication	Value
DCGF	Ground detection factor, Mon. 1	Battery wiring ground(s)	1.05

DC Battery Monitor Alarm

You can use the battery monitor Relay Word bits to alert operators for out-of-tolerance conditions in the battery systems. Add the appropriate Relay Word bit to the SELOGIC control equation that drives the relay control output you have selected for alarms. For example, use the b contact of control output OUT108. Set the SELOGIC control equation to include the battery monitor thresholds:

OUT108 := **NOT (HALARM OR SALARM OR DC1F OR DC1W OR DC1R OR DC1G)**
(Output SELOGIC control equation)

This is one method; you can implement many other methods as well. See *Alarm Output on page 2.26* for more information.

DC Battery Monitor Metering

The SEL-487E monitors battery system voltages and records time stamps for voltage excursions. In addition, the relay records maximum and minimum battery voltages. *Figure 5.13* shows a sample dc battery monitor meter report. Use the **MET BAT** command from a communications terminal to obtain this report.

```
=>>MET BAT <Enter>


Relay 1                                      Date: 06/07/2008  Time: 22:51:47.067
Station A                                    Serial Number: 2008030645

Station Battery        VDC      VDCPO     VDCNE      VAC
   VDC1  (V)           115.86     57.32    -58.54     0.01

             VDC1(V)    Date       Time
Minimum       105.86 04/07/2008  22:43:04.022
Enter L-Zone         04/07/2008  22:40:14.162
Exit L-Zone          04/07/2008  22:44:09.223


Maximum       125.86 04/09/2008  12:34:14.321
Enter H-Zone         04/09/2008  12:31:32.543
Exit H-Zone          04/09/2008  12:35:12.657

LAST DC RESET:  01/15/2008  20:10:31.427

=>>
```

Figure 5.13 Battery Metering: Terminal

Any battery voltage between setting DCLWP and the dc battery monitor low limit of 15 Vdc is in the L-Zone. Any battery voltage between setting DCHWP and the dc battery monitor high limit of 300 Vdc is in the H-Zone.

Reset DC Battery Monitor Metering

Use the **MET RBM** command from a communications terminal to reset the dc battery monitor. You can program a SELOGIC control equation RST_BAT (in Monitor settings) to control dc battery monitor reset.

Thermal Element

The SEL-487E provides a thermal element based on *IEEE Standard C57.91-1995, IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers*. Use this element to activate a control action or issue a warning or alarm when your transformer overheats or is in danger of excessive insulation aging or loss of life. Capture current hourly or daily data about your transformer using the thermal event report. The data acquisition interval is one minute, which constitutes the maximum element timing error. This very short time interval makes the element suitable for both thermal protection and control functions.

Operating Characteristic

The SEL-487E thermal element compares top-oil, Θ_{TO}, and winding hot-spot, Θ_H, temperatures against thresholds beyond which a Relay Word bit asserts. You can use these bits to alarm for overheating of the transformer. Top-oil temperature is a calculation of the transformer oil temperature, while hot-spot temperature is a calculation of the hottest point on the transformer winding. The thermal element uses top-oil temperature and hot-spot temperature to calculate the insulation aging acceleration factor, FAA, daily rate of loss of life, RLOL, and total loss of life, TLOL. For each of these quantities you can set a threshold beyond which a Relay Word bit will assert.

The thermal element operates in one of three modes, depending upon the presence or lack of measured temperature inputs:

- Measured ambient and top-oil temperature inputs
- Measured ambient temperature only
- No measured temperature inputs

If the relay receives measured ambient and top-oil temperatures, the thermal element calculates hot-spot temperature (*Figure 5.14*(a)). When the relay receives a measured ambient temperature but not a measured top-oil temperature, the thermal element calculates the top-oil temperature and hotspot temperature (*Figure 5.14*(b)). In the absence of any measured ambient or top-oil temperatures, the thermal element uses a default ambient temperature setting (D_AMB) that you select and calculates the top-oil and hot-spot temperatures (*Figure 5.14*(c)). Regardless of the available measuring inputs, the relay always calculates the top-oil temperature for use in the cooling system efficiency element.

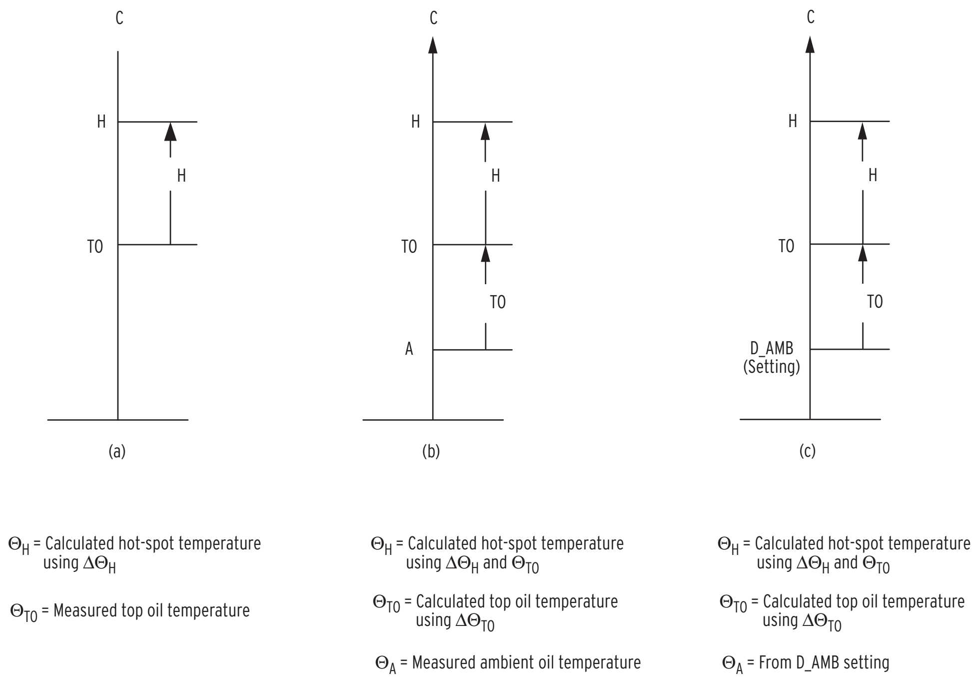


Figure 5.14 Top-Oil and Hot-Spot Temperatures

Thermal Element With Ambient and Top-Oil Temperature Inputs

In this case the relay receives measured ambient and top-oil temperature inputs and uses the top-oil temperature to calculate the hot-spot temperature. Because the ambient temperature is available, the thermal event reports show the ambient temperature. For a single tank, three-phase transformer, there are as many as two thermal inputs: the ambient temperature input and the top-oil input. For independent, single-phase transformers, there normally are as many as four thermal inputs: one ambient temperature input and a top-oil input for each of the three tanks. During a fixed time interval, $\Delta t = 1$ minute, the relay calculates the winding hot-spot temperature at the end of the interval, according to the following expression:

$$\Theta_H = \Theta_{TO} + \Delta\Theta_H$$

Equation 5.6

where:

Θ_H = winding hot-spot temperature, °C
Θ_{TO} = top-oil temperature, °C
$\Delta\Theta_H$ = winding hot-spot rise over top-oil temperature, °C

The relay calculates winding hot-spot rise over top-oil temperature, ΔΘH, according to the following:

$$\Delta\Theta_H = (\Delta\Theta_{H,U} - \Delta\Theta_{H,i}) \bullet \left(1 - e^{\frac{-\Delta t}{60 \bullet T_{hs}}}\right) + \Delta\Theta_{H,i}\,°C$$

Equation 5.7

where:

$\Delta\Theta_{H,U}$ = the ultimate hot-spot rise over top-oil temperature for any load, °C

$\Delta\Theta_{H,i}$ = initial hot-spot rise over top-oil temperature at the start time of the interval, °C

Ths = thermal time constant of hot spot, in hours (set from *Table 5.13*)

Δt = one-minute temperature data acquisition interval

$$\Delta\Theta_{H,U} = K^{2 \bullet EXPm} \bullet THgr°C$$

Equation 5.8

where:

K = load expressed in per unit of transformer nameplate rating according to the cooling system in service (phase rms current divided by the nominal current)

EXP*m* = winding exponent (set from *Table 5.13*)

THgr = rated winding hot-spot rise over top-oil at rated load, °C (set from *Table 5.13*)

Thermal Element With Ambient Temperature Input Only

In this case the relay receives a measured ambient temperature input and uses this input to calculate top-oil and hot-spot temperatures.

Where the relay has a measured ambient temperature input without a top-oil temperature input, you have one thermal input (for ambient temperature) regardless of whether you have a single three-phase transformer or independent single-phase transformers. The relay calculates winding hot-spot temperature, ΘH, according to the equation in the earlier case:

$$\Theta_H = \Theta_{TO} + \Delta\Theta_H$$

Equation 5.9

and calculates top-oil temperature, Θ_{TO}, according to the following:

$$\Theta_{TO} = \Theta_A + \Delta\Theta_{TO}$$

Equation 5.10

where:

Θ_A = ambient temperature, °C

$\Delta\Theta_{TO}$ = top-oil rise over ambient temperature, °C

The relay calculates top-oil rise over ambient temperature according to the following:

$$\Delta\Theta_{TO} := (\Delta\Theta_{TO,U} - \Delta\Theta_{TO,i}) \bullet \left(1 - e^{\frac{-\Delta T}{60 \cdot T_o}}\right) + \Delta\Theta_{TO,i}°C$$

Equation 5.11

where:

$\Delta\Theta_{TO,U}$ = the ultimate top-oil rise over ambient temperature for any load, °C, and is a function of load and the values in *Table 5.13*

$\Delta\Theta_{TO,i}$ = initial top-oil rise over ambient temperature at the start time of the interval, °C ($\Delta\Theta_{TO,i}$)

T_o = thermal top-oil time constant of transformer, in hours

The relay calculates the ultimate top-oil rise over ambient temperature, $\Delta\Theta_{TO,U}$, according to the following expression:

$$\Delta\Theta_{TO,U} = \left(\frac{(K^2 \bullet RATL + 1)}{(RATL + 1)}\right)^{EXPn} \bullet TH_{OR}\,°C$$

Equation 5.12

where:

RATL = ratio of load loss at rated load to no-load loss (set from *Table 5.13*)

EXP*n* = oil exponent (set from *Table 5.13*)

TH_{or} = top-oil rise over ambient temperature at rated load, °C (set from *Table 5.13*)

$$T_O := OTR \bullet \left[\frac{\dfrac{\Delta\Theta_{TO,U}}{THor} - \dfrac{\Delta\Theta_{TO,i}}{THor}}{\left(\dfrac{\Delta\Theta_{TO,U}}{THor}\right)^{\frac{1}{EXPn}} - \left(\dfrac{\Delta\Theta_{TO,i}}{THor}\right)^{\frac{1}{EXPn}}}\right]$$

Equation 5.13

where:

OTR = thermal time constant in hours at rated load with initial top-oil temperature equal to ambient temperature (set from *Table 5.13*)

Thermal Element With No Measured Temperature Inputs

In this case, the relay uses a default ambient temperature value (D_AMB setting) that you select and calculates a hot-spot temperature and top-oil temperature. The relay calculates hot-spot temperature according to the following:

$$\Theta_H = \Theta_{TO} + \Delta\Theta_H$$

Equation 5.14

and the top-oil temperature according to the following:

$$\Theta_{TO} = \Theta_A + \Delta\Theta_{TO}$$

Equation 5.15

The relay has no measured ambient temperature input, so you must select an ambient temperature setting (D_AMB) for the thermal element calculation of top-oil temperature as follows:

$$\Theta_{TO} = D\_AMB + \Delta\Theta_{TO}$$ **Equation 5.16**

where:

D_AMB = user-selectable default ambient temperature

Top-Oil Temperature Comparison to Indicate Cooling System Efficiency

Figure 5.15 shows the logic the relay uses to calculate the difference between the measured top oil temperature and the calculated top oil temperature for Transformer 1. If all probes are in order and all coefficients have been correctly chosen, you can use the element to verify the integrity of both the cooling system and the measuring devices.

Relay Word bits CSE_*x* (*x* = 1, 2, or 3) asserts when the measured top oil temperature is greater than the calculated top oil temperature, indicating that the cooling system (fans and/or pumps) operates below the expected efficiency.

Conversely, when the measured top oil temperature is lower than the calculated top oil temperature, then Relay Word bits CSCM_*x* assert, indicating wrong RTD probe selection or incorrect cooling coefficients settings.

Relay Word bit CSCM is the OR combination of the CSCM_*x* Relay Word bits, and Relay Word bit CSE is the OR combination of the CSE_*x* Relay Word bits.

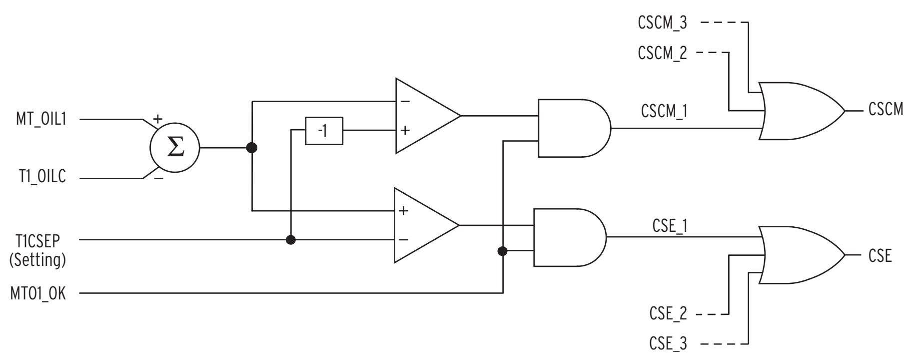


Figure 5.15 Cooling System Efficiency Logic

where:

T*x*CSEP = Cooling System Efficiency Pickup setting, °C, where *x* = 1 if:
TRTYPE = 1 and *x* = 1, 2, 3 if TRTYPE = 3
MT_OIL1 = measured oil temperature
T1_OILC = calculated oil temperature
MT01_OK = RTD assigned to the top oil measurement is healthy

Serial Communications Failure

The SEL-2600 message contains 2 bytes of data that report the status of the SEL-2600. One status bit reports a power supply failure, and a second bit reports a ram failure within the SEL-2600. The relay decodes the status information from the data package and asserts Relay Word bit RTDFL when either failure occurs. If the relay does not receive data from the SEL-2600 for 1.25 seconds, the relay asserts the communications failure Relay Word bit RTDCOMF. If either of these two Relay Word bits assert, the relay de-assert all RTD*mm*OK Relay Word bits.

Insulation Loss of Life

Insulation Aging Acceleration Factor

The relay thermal element uses the hot-spot temperature to calculate an insulation aging acceleration factor, F_{AA}, which indicates how fast the transformer insulation is aging. The relay calculates the insulation aging acceleration factor, F_{AA}, for each time interval, Δt, as follows:

$$F_{AA} := e^{\left(\frac{BFFA}{\Theta_{H,R} + 273} - \frac{BFFA}{\Theta_H + 273}\right)}$$ **Equation 5.17**

where:

FAA = insulation aging acceleration factor
BFFA = a design constant, typically 15000 (set from *Table 5.13*)
ΘH,R = winding hot-spot temperature at rated load (95°C if THwr = 55°C, 110°C if THwr = 65°C)
THwr = average winding rise over ambient at rated load (setting)

Daily Rate of Loss of Life

The relay calculates daily rate of loss of life (RLOL, percent loss of life per day) for a 24-hour period as follows:

$$RLOL := \frac{F_{EQA} \bullet 24}{ILIFE} \bullet 100$$ **Equation 5.18**

where:

RLOL = rate of loss of life in percent per day
ILIFE = expected normal insulation life in hours (set from *Table 5.13*)

The relay stores the RLOL value at midnight each day to provide the user with trend information on the loss of insulation life. The equivalent life at the reference hot-spot temperature (95ºC or 110ºC) that will be consumed in a given time period for a given temperature cycle is:

$$F_{EQA} := \frac{\sum_{n=1}^{N} F_{AA_n} \bullet \Delta t_n}{\sum_{n=1}^{N} \Delta t_n}$$ **Equation 5.19**

where:

FEQA = equivalent insulation aging factor for a total time period
n = index of the time interval
N = total number of time intervals for the time period
FAAn = insulation aging acceleration factor for the time interval, Δtn
Δt = time interval (fixed at 1 minute)

$$N = \frac{24}{\left(\frac{\Delta t}{60}\right)} = \frac{1440}{\Delta t}$$

Equation 5.20

where:

Δt = time interval (fixed at 1 minute)

Because the time intervals and the total time period used in the thermal model will be constant, we can simplify the calculation of F_{EQA} to the following:

$$F_{EQA} := \frac{\sum_{n=1}^{N} F_{AA_n}}{N}$$

Equation 5.21

Total Accumulated Loss of Life

The relay estimates the total accumulated loss of insulation life in percentage of normal insulation life by summing all of the daily RLOL values:

$$TLOL_d := (RLOL_d + TLOL_{d-1})$$

Equation 5.22

where:

$TLOL_d$ = total accumulated loss of life, TLOL
$RLOL_d$ = most recent daily calculation
$TLOL_{d-1}$ = previous TLOL

The relay stores the TLOL value at midnight each day. You can use the **THE P** command to load an initial value of TLOL into the relay.

Estimated Time to Assert TLL Alarm

Estimated time to assert TLL bit:

$$TTLt = \frac{TLOLL - TLOL}{RLOL} \bullet 24$$

Equation 5.23

where:

TLLt = estimated time to assert total loss-of-life alarm, in hours
TLOLL = total loss-of-life limit setting
TLOL = total accumulated loss of life, TLOL
RLOL = most recent daily rate of loss-of-life calculation

Setting Descriptions

Number of Transformers (TRTYPE)

A three-phase transformer can consist of one three-phase core and coil assembly in one physical enclosure or three physically separate single-phase transformers connected externally. Set TRTYPE to either 1 for a Three-Phase Unit, or 3 for three Single-Phase Units.

Label	Prompt	Default
TRTYPE	Number of Transformers (1, 3)	1

Transformer Winding Connections (TRWCON)

If the power transformer winding associated with the thermal element (see *Transformer Winding Selection (TRWSEL)* setting) is delta connected OR if the current transformers associated with this winding are delta connected, set TRWCON = D (delta). Set TRWCON = Y (wye) only if both the power transformer winding AND current transformers are wye-connected.

With TRWCON = Y, the relay uses the measured currents for each phase in the thermal element calculations. This means for three single-phase power transformers (TRTYPE = 3), the thermal element outputs may vary between phases because the phase currents may be different. With TRWCON = D, the relay selects the highest magnitude phase current and sets the other two phase currents to that value to force a balanced condition. In this case, the thermal element outputs for three single-phase transformers will be the same, assuming that each is operating at the same cooling stage and the thermal constants are set identically.

Label	Prompt	Default
TRWCON	Transformer Winding Connection (Y, D)	Y

Transformer Winding Selection (TRWSEL)

The TRWSEL setting determines which power transformer winding corresponds with the measured currents the thermal element uses for calculations. The measured currents the thermal element uses must represent either the total current in or the total current out of the power transformer (not both). TRWSEL allows selection of Windings enabled with the ECTTERM setting (S, T, U, W, X, ST, (two currents added together) TU, UW, or WX) to be the current for the thermal element calculations. Also see *Delta-Connected CTs on page 4.28*.

For a two-winding power transformer, current transformers located on either the high-voltage or low-voltage side would provide the correct current values. You can apply the thermal element on a three-, four- or five- winding power transformer, provided that the TRWSEL setting represents the total current in or out of the power transformer (not both).

Label	Prompt	Default
TRWSEL	Transformer Winding Selection (S, T, … ST … WX)	S

Nominal Winding Voltage (TRWNOM)

Set TRWNOM to the rated line-to-line voltage for the winding you select in the TRWSEL setting. The relay uses TRWNOM and the power transformer MVA rating (see *Cooling Stage MVA Rating (MVAcCSb)* setting) to calculate rated current. The relay then divides measured current by the rated current to determine *k*, which the relay uses in thermal element calculations.

Label	Prompt	Default
TRWNOM	Nominal Winding Voltage in *k*VLL (1.00–1000.00)	132

Enable Default Transformer (EDFTC)

By setting EDFTC = Y, the relay uses the default settings shown in *Table 5.13* for the thermal calculations. When using the default settings, the following settings become unavailable: T*c*THOR*b*, T*c*HGR*b*, T*c*RATL*b*, T*c*OTR*b*, T*c*EXPN*b*, T*c*EXPM*b*, and T*c*THS (*b* = *c* = 1–3).

Label	Prompt	Default
EDFTC	Enable Default Transformer Constants (Y, N)	Y

Winding Temp/ Ambient Temp (THWR)

Rated winding rise over ambient temperature is the difference in degrees Celsius of the winding temperature of a transformer above the ambient temperature. The actual winding temperature will be between the top-oil and hot-spot temperature.

Most power transformers manufactured in 1977 and later are rated for a 65°C rise over ambient. Power transformers manufactured prior to 1977 can be rated for a 55°C rise over ambient. Set THWR for either 55 or 65, based on the rating of the power transformer. This setting determines which set of default transformer constants from *Table 5.13* the relay will use if EDFTC = Y.

Label	Prompt	Default
THWR	TRFR Rated Wdg Temp Rise Over Ambient (55, 65 C)	65

Number of Cooling Stages (NUMCS)

Power transformers generally have a self-cooled rating and one or two stages of forced cooling. Set NUMCS to the maximum number of cooling stages associated with the monitored power transformer.

Label	Prompt	Default
NUMCS	Number of Cooling Stages (1–3)	1

Transformer De-Energized (TRDE)

Transformer heating consists of heating resulting from transformer losses and heating resulting from load. IEEE standard C57.91-1995 assumes the transformer is energized and calculates an increase in oil and winding temperatures resulting from transformer losses.

Relay Word TRDE provides the thermal element a way to distinguish between the de-energized (no magnetizing current flowing) and energized stages (magnetizing current flowing). To achieve this, wire for example, a “52b” (normally closed) circuit breaker auxiliary contact to input IN101 and enter the SELOGIC control equation TRDE = IN101. When IN101 asserts (circuit breaker main contacts open and the 52b auxiliary contacts closed), the thermal element considers the transformer de-energized (no magnetizing current flowing) and the ambient, top-oil, and hot-spot temperatures all have the same value.

Be sure to make up an "effective external contact" from one or more 52a or 52b contacts (from one or more breakers) indicating that all the "source" breakers are open. Failing to assign a properly configured digital input to TRDE causes the relay to consider the transformer as energized, and the top-oil and hot-spot temperatures will increase over the ambient temperature even when the power transformer is actually de-energized (in accordance with the IEEE model).

Label	Prompt	Default
TRDE	Transformer De-energized (SELOGIC control equation)	NA

Default Ambient Temperature (D_AMB)

If the ambient temperature input is unavailable on relay power up, the thermal element calculates the required temperatures using the D_AMB setting. Therefore, select a reasonable value for D_AMB, even if your data acquisition system provides measurement of the ambient temperature (near the power transformer). If your data acquisition system cannot measure ambient temperature, then the thermal element calculations always use the D_AMB value. The D_AMB setting units are degrees Celsius.

Label	Prompt	Default
D_AMB	Default Ambient Temperature (–50.0 to 100.0 C)	25

Number of RTDs Inputs From the SEL-2600 (RTDNUM)

This setting is under the Port Setting Category, but is also included here for the sake of completeness. Connect the temperature devices (ambient and transformer temperatures) to an SEL-2600, and connect the SEL-2600 in turn to any one of the RS-232 ports of the SEL-487E relay. The maximum number of thermal inputs is twelve.

Table 5.10 RTD Configuration (SEL-2600)

Label	Prompt	Default
RTDNUM	RTD Number of Inputs (0–12)	12

RTD Type (RTDxxTY)

These settings are under the Port Setting Category, but are also included here for the sake of completeness. Specify the type of RTD metal for each of the (*xx* = 1 through 12) RTD inputs.

Table 5.11 RTD Configuration (SEL-2600)

Label	Prompt	Default
RTD01TY	RTD01 Type (NA, PT100, NI120, NI100, CU10)	PT100
• • •		
RTD12TY	RTD12 Type (NA, PT100, NI120, NI100, CU10)	PT100

Ambient Temperature Input (AMB_M)

Use this setting to assign one of the selected RTD temperature inputs to the ambient temperature variable in the SEL-487E thermal model.

Label	Prompt	Default
AMB_M	Ambient Temp. Meas. Probe (NA, RTD01–RTD12)	NA

Top-Oil a Temperature Input (Ta_OILM)

Use this setting to assign the selected temperature input to the top-oil temperature variables (*a* = 1–3) in the SEL-487E thermal model.

Label	Prompt	Default
T*a*_OILM[a]	TRFR *a* Top-Oil Temp. Probe (NA, RTD01–RTD12)	NA

[a] a = 1–3.

Default Ambient Temperature if RTD Fails (AMBRTDF)

In most cases, an RTD communication failure is temporary in nature or can be rectified quickly. In general, the thermal element updates the ambient temperature value once a minute, and stores this value in a buffer until the next update. If you set AMBRTDF to BUFF, then the relay uses the stored value in the buffer instead of the D_AMB setting. Because the ambient temperature changes slowly, the temperature calculations will be accurate if the RTD communication is restored quickly. When setting AMBRTDF to SET, the relay uses D_AMB setting instead of the buffered value in the thermal calculations. This setting is not available if AMB_M is set to NA, in which case AMBRTDF = SET.

Label	Prompt	Default
AMBRTDF	Default Temp if Amb Temp RTD Fails (BUFF, SET)	SET

Transformer Cooling Stage Activation (TaCSb)

NOTE: a designates the transformer number and b designates the cooling stage.

The thermal element uses the output of SELOGIC control equations to determine which cooling stage is active, so that thermal element calculations use the correct transformer constants. Settings TRTYPE and NUMCS determine the number of SELOGIC control equations for which the relay prompts the user.

Because the maximum number of cooling stages is three, the relay evaluates a maximum of two SELOGIC control equations to determine the particular cooling stage. Use auxiliary contacts from the fan control devices as inputs to the SEL-487E with the T*x*CSy SELOGIC control equations set to the corresponding digital input. For example, for a single transformer (TRTYPE = 1) with three cooling stages (NUMCS = 3), the relay prompts you to set settings T1CS2S and T1CS3S.

Assume the input from Stage 2 is connected to IN101 and the input from Stage 2 is connected to IN102. Set the two SELOGIC control equations as follows:

T1CS2S := IN101
T1CS3S := IN102

To determine the cooling stage, the relay first evaluates T1CS2S, and then T1CS3S. *Table 5.12* shows the results of the evaluation.

Table 5.12 T1CS2S and T1CS23 Evaluation

Cooling Stage	T1CS2S	T1CS3S
1	0	0
2	1	0
3	1	1

Therefore, the relay uses the values for cooling Stage 1 when both inputs are de-asserted, the values for cooling Stage 2 when T1CS2S is asserted, but T1CS3S is de-asserted, and the values for cooling Stage 3 when both inputs are asserted. Be sure to use contacts that assert in the correct order; if T1CS23 asserts and T1CS2S is not asserted, the relay asserts the CSALRM bit and uses cooling Stage 1 values in the thermal calculations.

Label	Prompt	Default
T*c*CS*b*[a]	TRFR *c* Cooling Stage *b* Activation (SELOGIC control equation)	NA

[a] b = c = 1–3.

Cooling Stage MVA Rating (MVAcCSb)

Range: 0.2–5000 MVA, in 0.1 MVA steps

The MVA rating for all types of transformers (TRTYPE = 1 or 3) is taken as the nameplate MVA (MVA) rating and the line-to-line kilovolt (kV) values.

Label	Prompt	Default
MVA*c*CS*b*[a]	TRFR *c* MVA Rating Cooling Stage *b* (1.0–1000.0 MVA)	100

[a] b = c = 1–3.

Cooling Stage n Constants

Top-Oil Rise Over Ambient Temperature TcHORb

Top-oil rise over ambient temperature is the difference in degrees Celsius of the top-oil temperature of a transformer above the ambient temperature. The default values listed in *Table 5.13* are from IEEE C57.92-1981. If specific values for a particular transformer are known, you can enter values from within a range of 0 to 100°C.

Label	Prompt	Default
T*c*THOR*b*[a]	Top-Oil Rise/Amb (0.1–100.0 C)	See *Table 5.13*

[a] b = c = 1–3.

Hot-Spot Conductor Rise Over Top-Oil Temperature (TcHGRb)

Range: 0.01 to 100°C, in 0.1°C steps

Hot-spot rise over top-oil temperature is the difference in degrees Celsius of the temperature of the hottest spot on the conductor winding over the top-oil temperature. If not provided, THGR can be calculated from the following equation:

$$\mathrm{THgr} = \mathrm{THwr} + \Theta_{\mathrm{hswr}} - \mathrm{THor} \qquad \textbf{Equation 5.24}$$

where:

THwr = average winding rise over ambient at rated load (55°C or 65°C)

Θ_{hswr} = hot-spot winding rise over average winding rise

= (10°C if THwr = 55 or 15°C if THwr = 65)

Label	Prompt	Default
T*c*THGR*b*[a]	Hot-Spot Cond. Rise/Top Oil (0.1–100.0 C)	See *Table 5.13*

[a] b = c = 1–3.

Ratio Losses (TcRATLb)

RATL is the ratio of load loss at rated load to no-load loss. The default values listed in *Table 5.13* are from IEEE C57.92-1981, Tables 2 and 4. If specific values for a particular transformer are known, you can enter values from within a range of 0.1 to 100.

Label	Prompt	Default
T*c*RATL*b*[a]	Ratio Losses (0.1–100.0)	See *Table 5.13*

[a] b = c = 1–3.

Oil Thermal Time Constant (TcOTRb)

The oil thermal time constant is the time it takes the top-oil temperature rise over ambient temperature to reach 63.2 percent of the difference between final rise and initial rise during a load change. If not provided, T*x*OTR can be calculated from the following equation:

$$\mathrm{TcOTR} = \mathrm{C} \bullet \left[\frac{\mathrm{THor}}{\mathrm{P_r}}\right] \qquad \textbf{Equation 5.25}$$

where:

C = transformer thermal capacity (watt-hours/degree)
= 0.06 • (weight of core and coil assembly in pounds)
+ 0.04 • (weight of tank and fitting in pounds)
+ 1.33 • (gallons of oil)

or

C = 0.0272 • (weight of core and coil assembly in kilograms)
+ 0.01814 • (weight of tank and fitting in kilograms)
+ 5.034 • (liters of oil)

Pr = total loss at rated load (watts)

THor = top-oil rise over ambient at rated load

1 kg = 2.2046 pounds

1 gallon = 3.785 liters

Label	Prompt	Default
T*c*OTR*b*[a]	Oil Thermal Time Constant (0.10–20.00 hr)	See *Table 5.13*

[a] b = c = 1–3.

Oil Exponent (TcEXPNb)

This exponent is a constant that the thermal element uses in calculating ultimate top-oil rise over ambient temperature ($\Delta\Theta_{TO}$). The default values listed in *Table 5.13* are from IEEE C57.92-1981, Tables 2 and 4. If specific values for a particular transformer are known, you can enter values from within a range of 0.1 to 5.

Label	Prompt	Default
T*c*EXPN*b*[a]	Oil Exponent (0.1–5.0)	See *Table 5.13*

[a] b = c = 1–3.

Winding Exponent (TcEXPMb)

This exponent is a constant that the thermal unit uses in calculating ultimate hot-spot conductor rise over top-oil temperature ($\Delta\Theta_{H}$). The default values listed in *Table 5.13* are from IEEE C57.92-1981, Tables 2 and 4. If specific values for a particular transformer are known, you can enter values from within a range of 0.1 to 5.

Label	Prompt	Default
T*c*EXPM*b*[a]	Winding Exponent (0.1–5.0)	See *Table 5.13*.

[a] b = c = 1–3.

Hot-Spot Thermal Time Constant (TcTHS)

IEEE C57.91-1995 section 7.2.6 states that the winding time constant, τH (THS), is the time it takes the winding-temperature rise over oil-temperature rise to reach 63.2 percent of the difference between final rise and initial rise during a load change. The winding time constant may be estimated from the resistance cooling curve during thermal tests or calculated by the manufacturer using the mass of the conductor materials.

Label	Prompt	Default
T*c*THS	Hot-Spot Thermal Time Constant (0.01–20.00 hr)	See *Table 5.13*.

Normal Insulation Life (TRLIFE)

IEEE C57.91-1995 suggests that normal transformer insulation life is 20.55 years or 180000 hours. *Table 5.13* lists this default value. You can select other values within a range of 1000–999999 hours.

Label	Prompt	Default
TRLIFE	Normal Insulation Life (1000–999999 hrs)	See *Table 5.13*.

Table 5.13 Default Transformer Constants

IEEE	THwr Setting	55°			65°		
		CS=1	CS=2	CS=3	CS=1	CS=2	CS=3
$\Delta\Theta_{TO,R}$	TH_{or} (°C)	45°	40°	37°	55°	50°	45°
$\Delta\Theta_{H,R}$	TH_{gr} (°C)	20°	25°	28°	25°	30°	35°
R	RATL	3.0	3.5	5.0	3.2	4.5	6.5
n	EXPn	0.8	0.9	1.0	0.8	0.9	1.0
$\tau_{TO,R}$	OTR	3.0	2.0	1.25	3.0	2.0	1.25
m	EXPm	0.8	0.8	1.0	0.8	0.8	1.0
τH	T_{hs}	0.08					
B	BFFA	15000					
Normal Insulation Life	TRLIFE	180000					

Label	Prompt	Default
TRLIFE	Nominal Insulation Life (1000–999999 hrs)	180000

Constant to Calculate FAA (TdBFFA)

IEEE C57.91-1995 section 5.2 states that B (TdBFFA) is an empirical constant equal to 15000. *Table 5.13* lists this value as the default. You can select other values from within a range of 0 to 100000. The thermal element uses this constant to calculate the transformer insulation aging acceleration factor (FAA).

Label	Prompt	Default
T*d*BFFA[a]	Constant to Calc. FAA for TRFR *d* (0–100000)	0

[a] d = 1-3.

Top-Oil Temperature Limit (TOT1, TOT2)

One of the outputs the thermal element provides is top-oil temperature. TOT1 and TOT2 determine limits for top-oil temperature. If the top-oil temperature exceeds either limit, the corresponding TOT1 or TOT2 bit asserts. Using SELOGIC control equations, you can configure the TOT*x* (*x* = 1 or 2) bits to close alarm contacts. When measured temperature inputs are available, the relay compares the TOT1 and TOT2 settings against the measured value.

Should the measured value not be available (communication failure or lack of instrumentation), the relay compares the TOT1 and TOT2 settings against the calculated top-oil value.

With TRTYPE = 3 and top-oil temperatures being measured or calculated for each of the three single-phase transformers, the TOT1 or TOT2 bits assert when any of the three values exceeds a limit, as shown in *Figure 5.16*. The thermal report shows which transformer exceeded the limits.

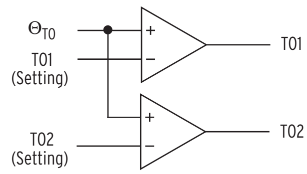


Figure 5.16 Oil Temperature Logic

Label	Prompt	Default
TOT*x*[a]	Top-Oil Temp. Limit *x* (50–150 C)	95

[a] x = 1 or 2.

Hot-Spot Temperature Limit (HST1, HST2)

One of the outputs the thermal element provides is hot-spot temperature. HST1 and HST2 determine limits for hot-spot temperature. If the hot-spot temperature exceeds one of these limits, the corresponding HS1 or HS2 bit asserts, as shown in *Figure 5.17*. Using SELOGIC control equations, you can configure these bits to close alarm contacts.

With TRTYPE = 3 and hot-spot temperatures being calculated for each of the three single-phase transformers, the HST1 or HST2 bits assert when any of the three values exceeds the limits. The thermal report shows which transformer exceeded the limits. *Figure 5.17* shows the oil temperature and hot spot logic.

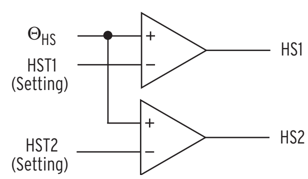


Figure 5.17 Hot-Spot Logic

Label	Prompt	Default
HST*x*[a]	Hot-Spot Limit *x* (80–300 C)	100

[a] x = 1 or 2.

Aging Acceleration Factor Limits (FAAL1, FAAL2)

The insulation of a transformer operating at temperatures higher than the rated temperature ages faster than the same transformer operating at or below rated temperature. One of the outputs the thermal element provides is a transformer insulation aging acceleration factor, which, when multiplied by elapsed time, provides an indication of the how fast the insulation is ageing at the present load and temperature. Should load and temperature be greater than normal, this factor is greater than 1. Should load and temperature be less than normal, the factor is less than 1. FAAL1 and FAAL2 determine limits for the aging acceleration factor. If the aging acceleration factor exceeds the limits, the FAA1 or FAA2 bit asserts, as shown in *Figure 5.18*. Using SELOGIC control equations, you can configure these bits to close alarm contacts.

With TRTYPE = 3 and aging acceleration factors being calculated for each of the three single phase transformers, the FAA1 or FAA2 bit asserts when any of the three values exceeds the limits. The thermal report will show which transformer was above the limits.

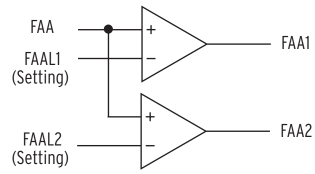


Figure 5.18 Aging Acceleration Factors Logic

Label	Prompt	Default
FAAL*x*	Hot-Spot Limit *x* (80–300 C)	100

Daily Rate of Loss-of-Life Limit (RLOLL)

One of the outputs the thermal element provides is daily rate of loss of life. This output is a measure, in percent, of the life lost from the transformer during a 24-hour period. RLOLL determines a limit for daily rate of loss of life. If the daily rate of loss of life exceeds the limit, a RLLOL bit asserts, as shown in *Figure 5.19*. Using SELOGIC control equations, you can configure the RLOLL bit to close an alarm contact. With TRTYPE = 3 and daily rate of loss of life being calculated for each of the three single-phase transformers, the RLL bit asserts when any of the three values exceeds the limit. The thermal report will show which transformer exceeded the limit.

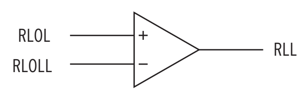


Figure 5.19 Daily Rate of Loss-of-Life Logic

Label	Prompt	Default
RLOLL	Daily Loss-of-Life Limit (0.00–99.99%)	0.00

Total Loss-of-Life Limit (TLOLL)

Range: 0.00–99.99%, in 0.01% steps

One of the outputs the thermal element provides is total loss of life, which is an estimate of the accumulated loss of transformer insulation life as a percentage of normal expected transformer insulation life. TLOLL determines a limit for total loss of life. If the total loss of life exceeds the limit, a TLL bit asserts, as shown in *Figure 5.20*. Using SELOGIC control equations, you can configure the TLL bit to close an alarm contact. With TRTYPE = 3 and aging acceleration factors being calculated for each of the three single phase transformers, the TLL bit asserts when any of the three values exceeds the limit. The thermal report will show which transformer exceeded the limit.

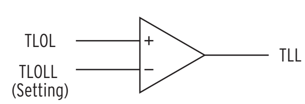


Figure 5.20 Total Loss-of-Life Logic

Label	Prompt	Default
TLOLL	Total Loss-of-Life Limit (0.00–99.99%)	0.00

Preload Total Loss-of-Life Limit (TxTLOL)

Because many transformers have been in service for many years, use the pre-load setting to set an estimated loss-of-life value. This value is usually difficult to estimate because the operating conditions (load current and ambient temperature) for the pre-load time period are not recorded. Do not use current alone as a guideline; temperature as well as current affects insulation aging.

Cooling System Efficiency Pickup (TxCSEP)

When a measured top-oil temperature is available via the serial port, measured currents are used to determine a calculated top-oil temperature. If the measured top-oil temperature is greater than the calculated top-oil temperature by the value of setting T*x*CSEP (*x* = 1–3), then a Cooling System Efficiency, T*x*CSEP, asserts. Using SELOGIC control equations, the T*x*CSEP bit can be configured to any of the relay outputs to perform alarm or tripping functions. Assertion of the T*x*CSEP bit indicates that the cooling system (fans and/or pumps) is operating below expected efficiency and may require maintenance. With TRTYPE = 3 and cooling system efficiency being calculated for each of the three single-phase transformers, the CSE bit is set when any of the three values exceeds the limit. The thermal report will show which transformer was above the setting.

Label	Prompt	Default
T*x*CSEP	TRFR *x* Cooling System Efficiency (5–100 C)	0.00

Thermal Element Condition

Figure 5.21 shows the logic that reports on the overall thermal health of the transformer by generating four status messages in relation to Normal, Warning 1, Warning 2, and Warning 3. These four messages are composed from various Thermal Element Conditions (TEC), and grouped into three alarm categories, in relation to Level 1, Level 2, and Level 3 alarms. *Figure 5.21* shows the reporting process for Transformer 1 (similar logic for Transformers 2 and 3), starting with the three alarm levels, the assessment of these levels, and the generation of the warning messages (see *Table 5.14*).

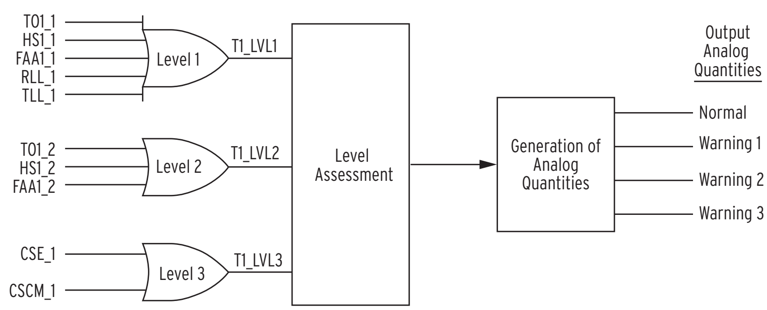


Figure 5.21 Thermal Element Condition (TEC) Logic for Transformer 1

Table 5.14 shows values for analog quantity TEC_1 for various combinations of the three input levels. If all three levels are de-asserted, then the TEC_1 value is 1, and the message is "Normal". If any of the Level 1 alarms assert and no alarms from either Level 2 or Level 3 assert, then the value of TEC_1 is 2, and the message is "Warning 1". Likewise, if only Level 2 alarm(s) assert, TEC_1 has a value of 4, and the message is "Warning 2", and if only Level 3 alarm(s) assert, TEC_1 has a value of 8, and the message is "Warning 3". Should Level 1 and Level 2 alarms assert at the same time, Warning 2 has preference over Warning 1; if Level 2 and Level 3 alarms assert at the same time, then Warning 3 has preference over Warning 2.

Table 5.14 Default Transformer Constants

Level 3	Level 2	Level 1	TEC_1	Message
0	0	0	1	Normal
0	0	1	2	Warning 1
0	1	0	4	Warning 2
0	1	1	4	Warning 2
1	0	0	8	Warning 3
1	0	1	8	Warning 3
1	1	0	8	Warning 3
1	1	1	8	Warning 3

While the SEL-487E relays can communicate directly with the SEL-2600A for gathering temperature readings, some applications may use the SEL-2030 communications processor for retrieving the temperature data from the SEL-2600A.

The SEL-487E obtains temperature information via one of its serial ports. The relay may receive data from as many as four temperature transducers: a single ambient temperature transducer and one transducer for top-oil temperature from each of three single-phase transformers. These data could come from an SEL-2032 or an SEL-2030 Communications Processor, which receives the temperature data from either an SEL-2600A RTD Module or a PLC (see *Figure 5.22*). The SEL communications processor must receive the temperature data in Modbus®, SEL Fast Messaging, or ASCII protocol. The SEL communications processor passes these data on to the SEL-487E in the form of an SEL Fast Message. While the SEL-487E can receive temperature data at any rate, the thermal element uses these data only once a minute.

Please refer to SEL *Application Guide 2000-07, Connection and Configuration of an SEL Communications Processor and SEL-2600A to Obtain Measured Ambient and Top-Oil Temperatures for SEL-387-6 Relay Thermal Element* and *Application Guide 2006-05, SEL Communications Processor and an SEL-2410 I/O Processor to Obtain Measured Ambient and Top-Oil Temperatures for the SEL-387-6 Relay Thermal Element* for information about how to set the SEL communications processor to communicate with the SEL-2600A RTD Module and the SEL-487E.

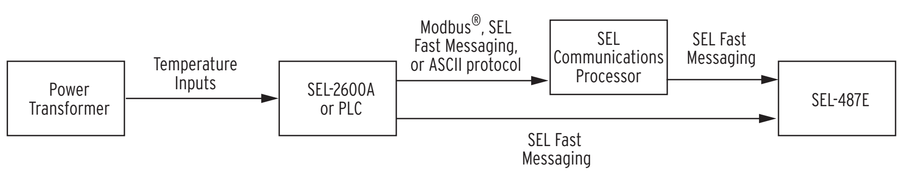


Figure 5.22 Example System Block Diagram

Thermal Monitor Report Function (THE Command)

The **THERM** or **THE** command, with no additional parameters, displays the present thermal status of the transformer(s) monitored by the relay. If an alarm condition is detected (one or more of the thermal Relay Word bits are set), the relay saves a snapshot of the thermal status of the transformer to EEPROM. The format for the **THE** report is as follows:

```
=>>THE <Enter>

Relay 1                                     Date: 03/28/2008  Time: 02:12:44.594
Station A                                   Serial Number: 2008030645

                                  Transformer 1 Transformer 2 Transformer 3
      Thermal Element Condition : NORMAL      NORMAL      NORMAL
                 Load(Per Unit) :0.81        0.83        0.81
       In Service Cooling Stage :1           1           1
               Ambient (deg. C) :20.0        20.0        20.0
    Calculated Top Oil (deg. C) :25.4        26.1        25.7
      Measured Top Oil (deg. C) :46.6        46.9        46.1
      Winding Hot Spot (deg. C) :55.4        56.8        55.1
 Aging Acceleration Factor, FAA :0.00        0.00        0.00
            Rate of LOL (%/day) :0.00        0.00        0.00
      Total Accumulated LOL (%) :0.00        0.00        0.00
          Time-Assert TLL (hrs) :0.00        0.00        0.00
=>>
```

Thermal Event Report Quantities

Thermal Element Conditions

The load condition value can be Normal, Warning 1, Warning 2, or Warning 3. See *Table 5.14* for more information.

Load Current

The load current is reported as a per-unit value based on transformer rating.

In-Service Cooling Stage

The active cooling system value is 1 for Cooling Stage 1, 2 for Cooling Stage 2, and 3 for Cooling Stage 3. Only one of the cooling stages can be active at a time (see *Transformer Cooling Stage Activation (TaCSb) on page 5.29* for more information).

Ambient Temperature

The value displayed (in degrees Celsius) is either the actual ambient temperature received from the serial port or a stored value (see *Default Ambient Temperature (D_AMB)* and *Default Ambient Temperature if RTD Fails (AMBRTDF)* settings for more information).

Calculated Top-Oil Temperature

The value displayed (in degrees Celsius) is the top-oil temperature of the transformer computed using the load current. The maximum value displayed is 3276°C.

Measured Top-Oil Temperature

The value displayed (in degrees Celsius) is the top-oil temperature of the transformer received from the serial port. If no data (or invalid data) are received from the serial port, the value displayed is `-0-`.

Winding Hot-Spot Temperature

The value displayed (in degrees Celsius) is the computed value of the winding hot-spot temperature using the actual ambient and top-oil temperatures or the load current. The maximum value displayed is 3276°C.

Aging Acceleration Factor

The value displayed is the active insulation aging acceleration factor (FAA). The maximum value of FAA is clamped at 9999.0.

Rate of Loss of Life

The value displayed is the computed daily rate of loss of life (percent) accumulated in a 24-hour period. This value is updated at midnight daily.

Total Loss of Life

The value displayed represents the total accumulated loss of life (percent) since last reset.

Time to Assert TLL

The value displayed represents the estimated time (in hours) to assert the total loss-of-life alarm (TLL Relay Word bit).

Thermal Event Report Function (THE n Command)

Whenever a thermal alarm condition is set (load conditions are Warning 1, Warning 2, or Warning 3), the SEL-487E saves a snapshot of the thermal status of the transformer(s) in EEPROM. The five most recent thermal events are saved. If the command for retrieving the nth saved thermal event report is **THE *n***, where *n* is a number from one to five, **THE 1** will display the most recent event report while **THE 5** will display the oldest thermal event report. The format and data for the **THE *n*** report are the same as for the **THE** report.

Thermal Profile Data Report Function (THE H and THE D Commands)

The SEL-487E stores two types of trend data: one set on an hourly basis for the last 24 hours; a second set on a daily basis for the last 31 days. The format of the retrieved data report is suitable for display in Microsoft® Excel®.

Hourly Profile Data Report (THE H Command)

NOTE: When the thermal model is applied on one three-phase transformer (TRTYPE = 1), the SEL-487E displays only the values for Transformer 1; when the thermal model is applied on a set of three single-phase transformers (TRTYPE = 3), the SEL-487E displays the values for Transformer 1, Transformer 2, and Transformer 3.

The SEL-487E stores the following data on an hourly basis for the last 24 hours. The data are stored at the beginning of each hour.

- One-hour average ambient temperature
- One-hour average calculated top-oil temperature
- One-hour average measured top-oil temperature
- One-hour average winding hot-spot temperature
- One-hour average per-unit load current
- One-hour average insulation aging acceleration factor (FAA)

The format for the **THE H** report is as follows:

```
=>>THE H <Enter>

Relay 1                                     Date: 03/28/2008  Time: 02:36:09.634
Station A                                   Serial Number: 2008030645

Transformer 1
                  Ambient   Calc      Measured                Load
Date        Time  Temp      Top-Oil   Top Oil   Hot Spot    Current    FAA
03/16/2008  2300     0.0      25.2     25.0       25.2         0.80    0.99
03/15/2008  2200     0.0      25.1     25.0       25.1         0.70    0.99

Transformer 2
                  Ambient   Calc      Measured                Load
Date        Time  Temp      Top-Oil   Top Oil   Hot Spot    Current    FAA
03/16/2008  2300     0.0      24.2     25.6       25.2         0.80    0.99
03/15/2008  2200     0.0      24.1     25.6       25.1         0.70    0.99

Transformer 3
                  Ambient   Calc      Measured                Load
Date        Time  Temp      Top-Oil   Top Oil   Hot Spot    Current    FAA
03/16/2008  2300     0.0      24.8     25.2       25.2         0.80    0.99
03/15/2008  2200     0.0      24.9     25.3       25.1         0.70    0.99

=>>
```

Daily Profile Data Report Function (THE D Command)

The relay stores the following on a daily basis (at midnight) for the last 30 days:

- Maximum ambient temperature
- Maximum calculated top-oil temperature
- Maximum measured top-oil temperature
- Maximum winding hot-spot temperature
- Maximum per-unit load
- Maximum insulation aging acceleration factor (FAA)
- Daily 24-hour accumulated loss of life (value of accumulated 24-hour loss of life at midnight)
- Total accumulated loss of life (sum of the daily 24-hour accumulated loss of life values)
- * showing a communication failure

The format for the **THE D** report is as follows:

```
=>THE D <Enter>

Relay 1                                     Date: 03/28/2008  Time: 02:43:48.623
Station A                                   Serial Number: 2008030645

Transformer 1
         Max     Max Calc Max Msd  Max
Date     Ambient Top Oil  Top Oil  Hot Spot  Max Load  Max FAA  RLOL   TLOL
03/28/2008  15.0    25.3    26.7    45.3      0.60      0.99    0.00    0.00

Transformer 2
         Max     Max Calc Max Msd  Max
Date     Ambient Top Oil  Top Oil  Hot Spot  Max Load  Max FAA  RLOL   TLOL
03/28/2008  15.0    25.9    27.7    44.3      0.60      0.99    0.00    0.00

Transformer 3
         Max     Max Calc Max Msd  Max
Date     Ambient Top Oil  Top Oil  Hot Spot  Max Load  Max FAA  RLOL   TLOL
03/28/2008  15.0    25.7    26.5    43.4      0.60      0.99    0.00    0.00

=>>
```

Retrieving Thermal Data Reports

Thermal data reports are accessed with the **THE** command in the following different ways:

Table 5.15 Using the THE Command to Access Data Reports

Example THE Serial Port Commands	Format
THE	Enter **THE** command with no additional parameters to display the present status of the monitored transformer.
THE 1	Enter **THE** command followed by a number (1 in this example) to display the latest archived thermal event report.
THE D	Enter **THE** command followed by **D** and no additional parameters to display all available daily profile data records.
THE H	Enter **THE** command followed by an **H** but with no additional parameters to display all available hourly profile data records. The chronological progression through the report is down the page and in descending order.
THE H (or D) 3/30/00	Enter **THE H** (or **D**) followed by the date (**3/30/00** in this example) to display all records (if they exist) starting with that date and ending with the present date. The records display with the latest record at the beginning (top) of the report and the oldest record at the end (bottom) of the report. Chronological progression through the report is down the page and in descending order.
THE D (or H) 2/17/00 3/07/00	Enter **THE D** (or **H**) followed by two dates (**2/17/00** chronologically **precedes 3/07/00** in this example) to display all the records (if they exist) among (and including) those dates. The records display with the latest record (3/07/00) at the beginning (top) of the report and the oldest record (2/17/00) at the end (bottom) of the report.
THE D 3/07/00 2/17/00	Enter **THE D** (or **H**) followed by two dates (**3/07/00** chronologically **follows** date **2/17/00** in this example) to display all records (if they exist) among (and including) those dates. The records display with the latest record (3/07/00) at the beginning (top) of the report and the oldest record (2/17/00) at the end (bottom) of the report.

The date entries in the examples for the **THE H** and **THE D** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, enter the dates as in the above examples (Month/Day/Year). If setting DATE_F = YMD, enter the dates Year/Month/Day.

If the requested **THE** hourly or daily profile records do not exist, the relay responds: Invalid Record. If there are no data in the hourly or daily profile buffers, the relay responds: `No Data Available`.

Thermal Monitor Reset Functions (THE R, THE C, and THE P Commands)

The **THE C** (Clear Thermal Archives Function) command clears the daily profile archives, hourly profile archives, and the thermal event archives. The **THE R** (Reset Thermal Function) command clears all the thermal archives (daily profile data, hourly profile data, and thermal event data) and resets the total accumulated loss-of-life value to its preset value (if it exists) or zero. Using the **THE P *n*** (Load Preset Value of Total Loss of Life) command, the user can preset the initial loss-of-life values for each phase of the monitored transformer. The command must be followed by a value between zero and 100 percent. This command initializes the total loss-of-life value to the preset value entered by the user, clears all the thermal archive data, and restarts the thermal element.

Through-Fault Element

Figure 5.23 shows a fault that occurs outside the area of unit protection of the transformer. Such through faults can last for several cycles, subjecting the transformer windings to mechanical stress and the transformer winding insulation to thermal stress. Because thermal stress and mechanical stress have different effects within the transformer, the SEL-487E provides a separate element for each. To this end, the through-fault element calculates the cumulative mechanical stress on the transformer windings (the thermal element calculates the thermal effects on the insulation).

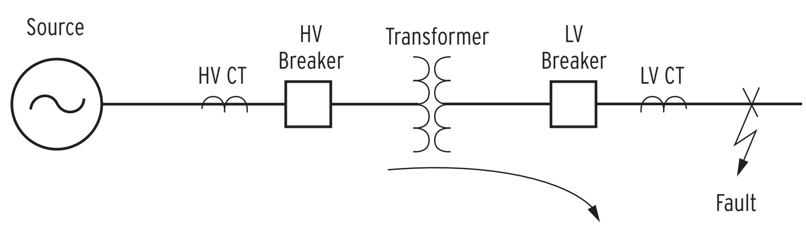


Figure 5.23 Transformer Bank Subjected to Through Fault

Figure 5.24 shows through-fault curves for Category IV transformers as published in IEEE Standard C57 (1994 edition). These curves apply to transformers that are covered by the IEEE standard or, in general, to transformers that were built beginning in the early 1970s. For transformer built prior to 1970, consult the manufacturer to obtain the transformer short-circuit withstand capabilities.

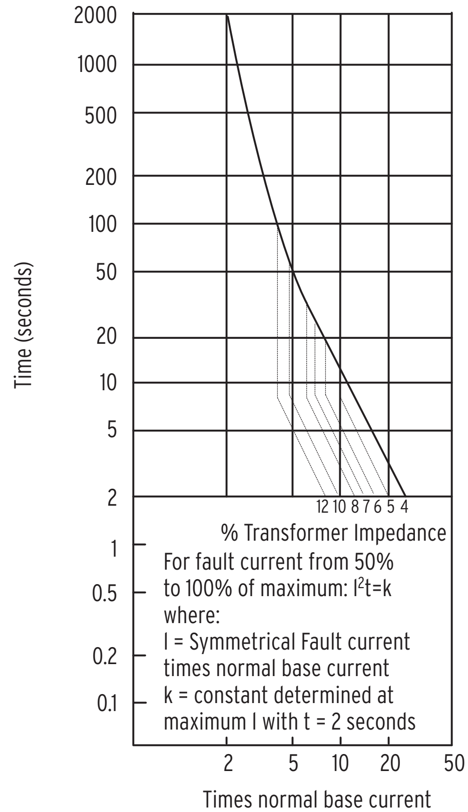


Figure 5.24 Category IV Transformers Through-Fault Protection Curves

The curves in *Figure 5.24* are a function of the transformer short-circuit impedance, and is keyed to the maximum I^2t of the worst-case mechanical duty (maximum fault current for 2 seconds). *Equation 5.26* through *Equation 5.28* shows the three equations that the element uses to evaluate the thermal curve each processing interval. Note that the calculated currents are in primary values. To convert the secondary current to primary current, the element multiplies the secondary current by the CT ratio of the particular winding. For combined windings, the elements uses the highest CT ratio of the two windings. See *Delta-Connected CTs on page 4.28*.

$$I_{RMS\_PU} = \frac{I_{RMS} \bullet \sqrt{3} \bullet kV_{LL}}{S} \quad \textbf{Equation 5.26}$$

$$I_{MAX\_PU} = \frac{100}{Z_{PU}} \quad \textbf{Equation 5.27}$$

$$t(I_{RMS\_PU}) = \frac{K}{(I_{RMS\_PU})^2} \quad \textbf{Equation 5.28}$$

where:

IRMS = Measured current
S = Transformer MVA rating (MVA)
kVLL = Line-to-line voltage (kV)
ZPU = Transformer impedance (per unit)
K = 1250 if $4.5 \le I_{RMS\_PU} \le 0.5 \bullet I_{MAX\_PU}$
$2 \bullet (I_{MAX\_PU})^2$ if $I_{RMS\_PU} > 0.5 \bullet I_{MAX\_PU}$

There are only four settings to set the though-fault element, all under the Monitor category (see *Table 5.16*). Enable the element by setting the SELOGIC control equation ETHRFLT for the conditions under which you want the element to run that you what the element to run. Use Setting THFLTD to select the terminal that you want the element to use when calculating the through-fault current. (Switch S1 in *Figure 5.25* selects one of S, T, U, W, X, ST, TU, UW, or WX). Be sure to select a winding that is included in the ECTTERM setting. Set the through-fault alarm pickup (THFLTPU) to the desired value, and enter the transformer percentage impedance (in percent) at the TRFRZ setting.

Table 5.16 Default Transformer Constants

Setting	Description	Range
ETHRFLT	Enable Through-Fault Monitor (SELOGIC Control Equation)	SELOGIC Control Equation
THFLTD	Identifies the terminal which phase currents will be used in the thermal element	S, T, U, W, X, ST, TU, UW, WX
THFLTPU	Through-Fault Alarm Pickup	50.0–900.0%
TRFRZ	Percentage Transformer Impedance	2.0–40.0%

On the basis that mechanical stress takes effect only at high current values, the through-fault element runs only if the selected phase current is greater than 4.75 times full load current. Allowing a hysteresis of 0.25 of full load, the through-fault element resets when the current falls below 4.5 times the full load current.

Figure 5.25 shows a functional diagram of the thermal element for the A-phase of Terminal S (THFLTD = S), the B-phase and C-phase elements having identical diagrams. When SELOGIC control equation ETHRFLT asserts and the A-phase current exceeds 4.75 times the transformer full-load current, Enable asserts and the 10-cycle Timer starts. When Enable asserts, the following occur:

- The thermal element advances the A-phase fault counter by 1 count
- The thermal element advances the total fault counter by 1 count
- The thermal element records the time when the fault starts (rising edge of Enable)
- The process to determine the maximum through-fault current for the fault duration starts
- The integration process starts, whereby the element sums the values calculated each processing interval (1/8 of a power system cycle)

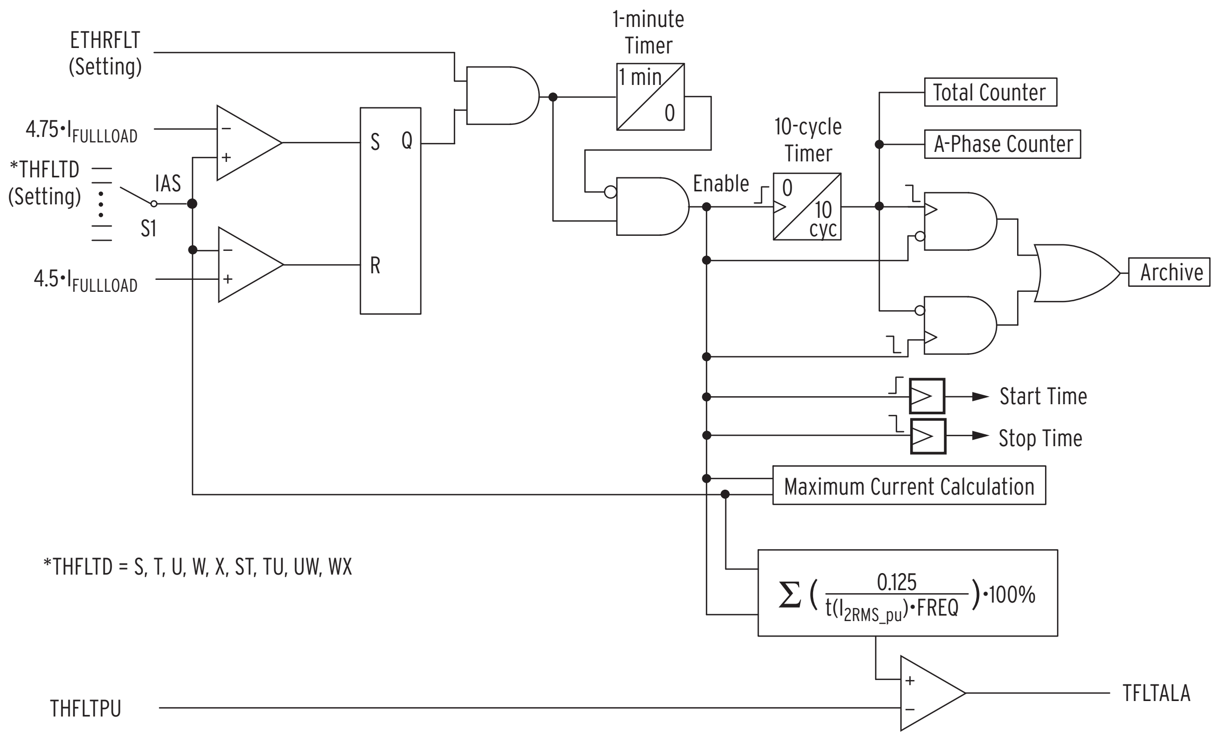


Figure 5.25 Through-Fault Diagram

The 10-cycle Timer avoids the inadvertent increment of the counters or archiving of the data if the fault current momentarily drops below the lower threshold level.

Setting threshold THFLTPU would usually be set to alarm for excessive, cumulative transformer bank stress. When the integration exceeds the value as specified by the THFLTPU setting, Relay Word bit TFLTALA asserts. Assign output Relay Word bit TFLTALA to an output for annunciation or control action such as to modify distribution feeder auto-reclosing (e.g., reduce the number of reclosures from 3 to 2).

When the fault current falls below 4.5 times the full load level, the element deasserts, and the following occurs:

- ➤ The thermal element records the stop time; then calculates (and records) the fault duration.
- ➤ The thermal element records the maximum value of the fault current during the fault.
- ➤ The integration process stops.

The relay can store (archive) the data of 1200 through faults in a first-in-first-out (FIFO) buffer. The element automatically archives the data when one of the following conditions is true:

- ➤ The 10-cycle Timer deasserts and the enable signal is de-asserted.
- ➤ The 10-cycle Timer is de-asserted and the enable signal de-asserts.

Through-Fault Element (TFE) Serial Command

The format of the **TFE** command is as follows: **TFE nnnn A|P|C|R**

where:

nnnn = Specifies number of through faults to display
A = The relay displays all the Through Fault Records in the memory
P = Use to specify pre-loading
C or R = Sets the accumulated values to 0 and deletes the history

Figure 5.26 displays the relay response to the **TFE** (no other parameters) command. Notice that Winding S is the winding whose current inputs the element uses in the calculations (THFLTD = S). The **TFE** command lists up to 20 of the most recent through-faults. "Total Number of Transformer Through Faults:" is the sum of the detected through faults of all three phases since the last reset, with a maximum of 65,535 counts. "Number of *n* Phase Through Faults:" (*n* = A, B, C) refers to the through faults detected for that particular phase since the last reset, also with a maximum of 65,535 counts. The through-fault alarm state is either a 1 (indicating an alarm state), or a 0 (indicating a normal state).

```
=>TFE <Enter>

Winding S
Total Number of Transformer Through Faults: 5
Total Number of A Phase Through Faults:      3
Total Number of B Phase Through Faults:      1
Total Number of C Phase Through Faults:      1

Total Accumulated Percentage of Through Fault Capability:
                                     A-Phase      B-Phase      C-Phase
                                      26.45        12.34        11.78
Through Fault Alarm:   <0>          <0>          <0>

Last Reset: 11/12/07 12:15:23

#      Date          Time               Duration      IA     IB     IC            A     B     C           Alarm
                                                   (seconds)  (max primary kA)      (Increment %)
xxxx mm/dd/yy hh:mm:ss.sss   sss.sss+   xxx.xx  xxx.xx  xxx.xx      xxx.x xxx.x xxx.x      <alarm>
xxxx mm/dd/yy hh:mm:ss.sss   sss.sss+   xxx.xx  xxx.xx  xxx.xx      xxx.x xxx.x xxx.x      <alarm>
xxxx mm/dd/yy hh:mm:ss.sss   sss.sss+   xxx.xx  xxx.xx  xxx.xx      xxx.x xxx.x xxx.x      <alarm>
xxxx mm/dd/yy hh:mm:ss.sss   sss.sss+   xxx.xx  xxx.xx  xxx.xx      xxx.x xxx.x xxx.x      <alarm>
```

Figure 5.26 Result of the TFE Command

Following is a description of each column (#, Date, Time, etc.) of the event report. Through-faults events are numbered (# column) from 1 (the most recent event, at the top) up to a maximum of 1200 through-faults events.

Under the date and time columns, the event shows the date of occurrence and the start time of each event (The date format dependents upon the DATE_F setting).

Although the element processes all values each cycle, event duration (Duration column) is reported in seconds with processing interval resolution. (If the event duration is equal to or greater than 136 seconds (60 Hz) or 163 seconds (50 Hz), the element appends a "+" to the time value).

IA, IB and IC show the maximum primary current for each phase, with a maximum of 100,000 A primary.

A, B and C show the amount (percent increase) of the present fault for each phase. Alarm shows those phase(s) that were in the alarm state at the end of the through-fault event.

Table 5.17 shows events report messages and the reason why these messages may appear in the events report.

Table 5.17 Through-Faults Events Report Messages

Message	Cause
Invalid Data	The accumulated data is corrupt.
Through Fault Event Monitor Disabled	The ETHRFLT setting is NA, or evaluates to logical 0.
Too many events—Data Lost	The memory is full.
Through Fault Event Buffer Empty	There are no event records in the nonvolatile memory
Memory resources are low; check for activity on other ports	There is insufficient memory to display the event records

Use the **TFE A** command to list all the stored through-fault events (not only the last 20 events) since the monitor was last reset. To list a particular number of through-fault events, enter the **TFE *n*** command (*n* = 1 to 1200).

To clear event accumulated data, and all event records, use either the TFE C (clear) or **TFE R** (reset) command. Both commands have the same result, so you can use either of them. Note that when you change the ETHRFLT setting, the relay also clear the data and records, i.e., it has the same effect as the **TFE C** or **TFE R** command.

Use the **TFE P** command to preload or change the values of the through fault event accumulated data, as shown in *Figure 5.27*. Enter these values in percent for each phase, up to a maximum value of 100.0 percent.

```
Winding S Total Accumulated Percentage of Through Fault Capability:
A-Phase = xxx.x? yyy.y
B-Phase = xxx.x? yyy.y
C-Phase = xxx.x? yyy.y
```

Figure 5.27 Preload the Values of the Accumulated Data

Thermal Demand and Rolling Demand

Two methods exist for measuring power system current and power demand. These methods are thermal demand metering and rolling demand metering *Figure 5.28* and *Figure 5.29* illustrate the step input response of the two demand measuring methods with setting DMTC (demand meter time constant) at 15 minutes.

Thermal Demand

Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities. Thermal demand measurement is similar to parallel RC network integration. If current I_S in *Figure 5.28* has been at zero (I_S = 0.0 per unit) for some time, voltage VC across the capacitor is also at zero (VC = 0.0 per unit). If current I_S is suddenly stepped up to some constant value (I_S = 1.0 per unit), voltage VC across the capacitor starts to rise toward the 1.0 per-unit value.

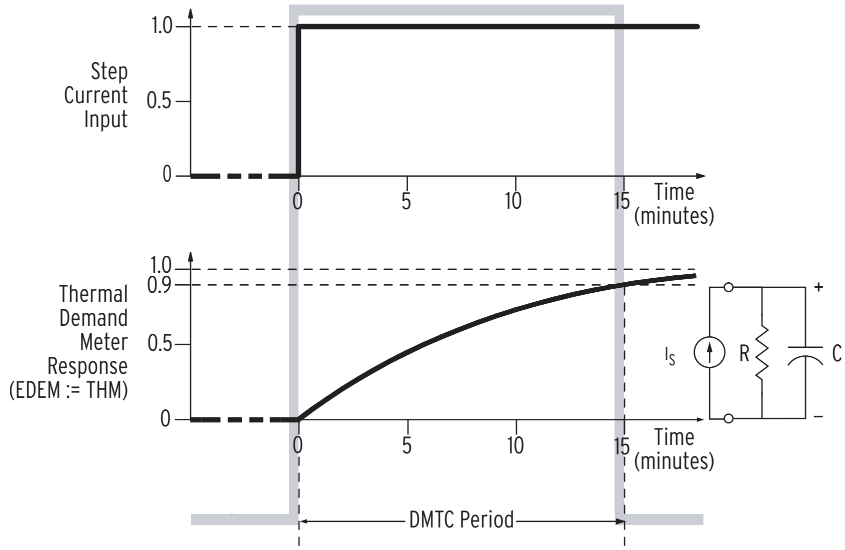


Figure 5.28 Thermal Demand Metering

This voltage rise across the capacitor is analogous to the response of the thermal demand meter to the step current input (top). In general, voltage VC across the capacitor cannot change instantaneously but reacts as a function of the time constant of the circuit. In the same manner, the thermal demand meter response is not immediate either for the increasing or decreasing applied current, but in accordance with the thermal time constant. For the thermal demand meter, the time constant is the DMTC setting.

Thermal demand metering response is at 90 percent (0.9 per unit) of the full-applied value (1.0 per unit) after a period equal to the DMTC setting (15 minutes in *Figure 5.28*).

Rolling Demand

Rolling demand is a sliding time-window arithmetic average. Rolling demand measurement is similar to a step-sampled A/D conversion system. *Figure 5.29* shows the rolling demand response for a step input for a demand meter time constant of 15 minutes (DMTC := 15). The relay divides the DMTC period into three 5-minute intervals and averages the three DMTC sub-interval samples every DMTC period. *Table 5.18* lists the rolling demand response for four DMTC periods shown in *Figure 5.29*.

Table 5.18 Through-Faults Events Report Messages

DMTC Period (see Figure 5.29)	1/3 DMTC Interval (minutes)	Interval Sample (per unit)	Rolling Demand Total	Rolling Demand Calculation	Rolling Demand Response (per unit)
(a)	–5 to 0	0	0	0 / 3	0
(b)	0 to 5	1	1	1 / 3	0.33
(c)	5 to 10	1	2	2 / 3	0.67
(d)	10 to 15	1	3	3 / 3	1.00

Rolling demand metering response is at 100 percent (1.0 per unit) of the full applied value after a time equal to the fourth DMTC period (see (d) in *Figure 5.29*).

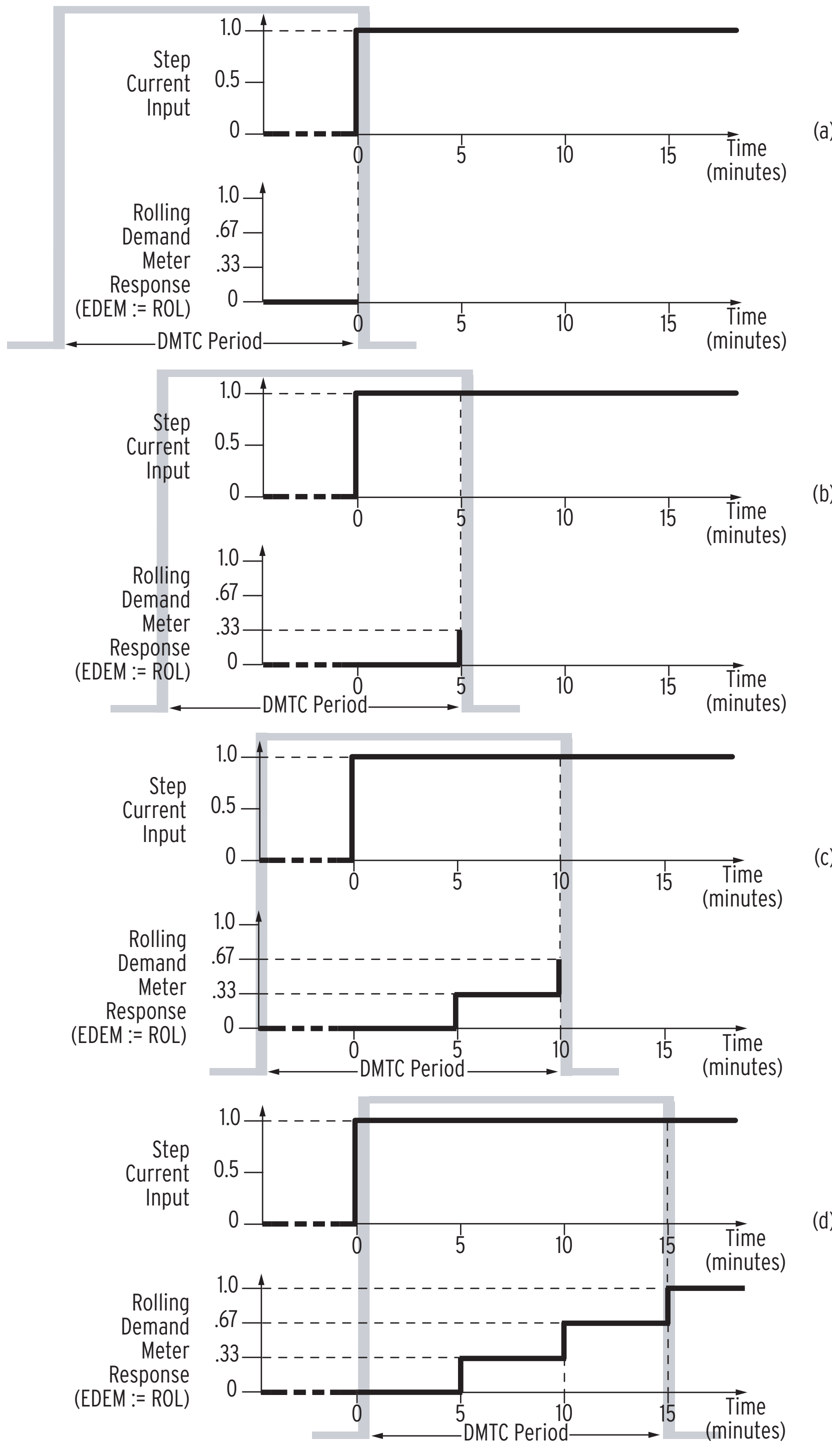


Figure 5.29 Rolling Demand Metering

Figure 5.30 shows the logic for the Thermal and Rolling Demand calculations. To enable the calculations, set the appropriate terminals (CTTERM setting) and enable the number of demand metering elements your application requires. Set EDEM*gg* (*gg* = 01 through 10) to the number of demand meter elements for your application, and use SELOGIC control equation EDM*gg* to state the conditions when those demand meter elements must be active.

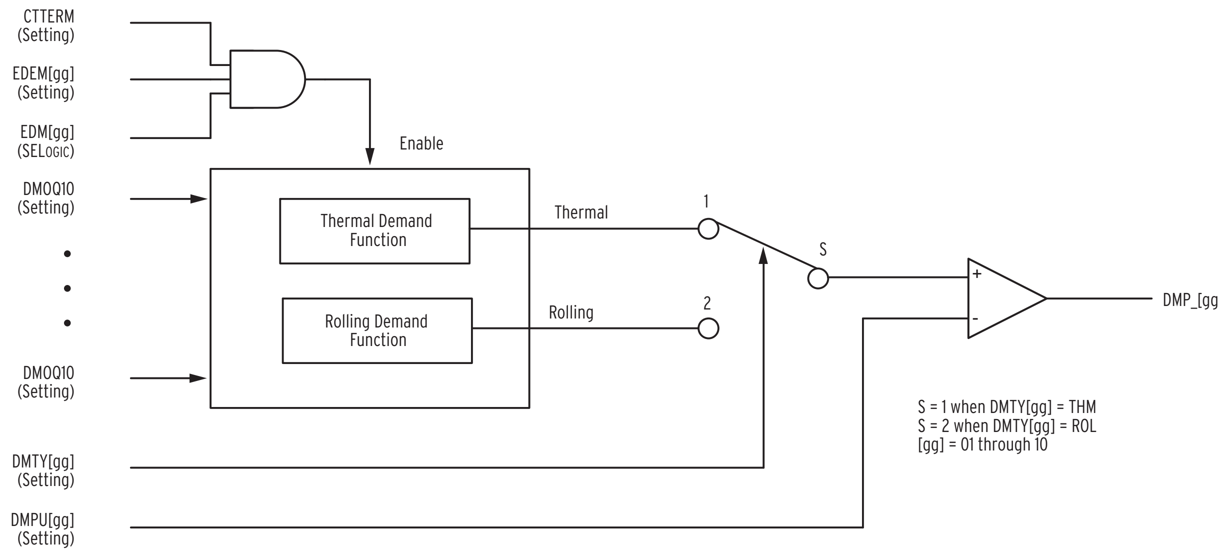


Figure 5.30 Thermal and Rolling Demand Logic for Element gg

Instead of fixed analog input quantities, choose up to10 analog input quantities from the analog quantities listed in *Table 5.19*.

Table 5.19 Demand Metering Operating Quantities

Analog Quantity	Description
Iϕ*m*RS[a,b]	1 second average rms current ϕ phase, Terminal *m*
Iϕ*qp*RS[c]	1 second average rms current ϕ phase, combine Terminal *qp*
IMX*m*RS	1 second average rms maximum phase current, Terminal *m*
IMX*qp*RS	1 second average rms maximum phase current, combined Terminal *qp*
3I2*m*MS	1 second average negative-sequence current angle, Terminal *m*
3I0*m*MS	1 second average zero-sequence current angle, Terminal *m*
3I2*qp*MS	1 second average negative-sequence current, Combined Terminals *qp*
3I0*qp*MS	1 second average zero-sequence current, Combined Terminals *qp*

[a] m = S, T, U, W, X.
[b] ϕ = A, B, C.
[c] qp = ST, TU, UW, WX.

For each analog quantity, use Setting DMTY*gg* to identify the type of demand metering you require. This selection determines the position of Switch S, i.e., if DMTY01 = THM, then Switch S moves to position 1. Likewise, if DMTY01 = ROL, then Switch S moves to position 2. Output DMP_*gg* asserts when the demand meter values exceeds the DMPU*gg* pickup value.

Demand Element Settings

EDEM (Enable Demand Metering Elements)

Set EDEM to the number of demand meter elements for your application. Only terminals that are included in the ECTTERM setting are considered for selection.

Setting	Prompt	Range	Default	Category
EDEM	Enable Demand Metering	N, 1–10	N	Group

DMTYgg (Demand Meter Type Element)

For each enabled analog quantity, use Setting DMTY*gg* (*gg* = 01 through 10) to identify the type of demand metering you require, either Thermal or Rolling.

Setting	Prompt	Range	Default	Category
DMTY*gg*[a]	Demand Met. Type Element *gg*	THM, ROL	THM	Group

[a] gg = 01–10.

DMOQgg (Demand Meter Operating Quantity)

Select the input quantity from the available 1 second average analog quantities (see *Table 5.19*) for each enabled element. Because the analog quantities in *Table 5.14* are in secondary Ampere, you do not need any conversions.

Setting	Prompt	Range	Default	Category
DMOQ*gg*[a]	Demand Met. Op. Qty. Element gg	See *Table 5.14*	IMXSRS	Group

[a] gg = 01–10.

DMPUgg (Demand Meter Pickup)

Use the DMPU*gg* setting to set the pickup value for each enabled element.

Setting	Prompt	Range	Default	Category
DMPU*gg*[a]	Demand Met. P/U. Element *gg* A,sec)	0.50–16.00	5.00	Group

[a] gg = 01–10.

DMTCgg (Demand Meter Time Constant)

Use the DMTC*gg* setting to set the time constant in minutes (5 minute increments) for each enabled element.

Setting	Prompt	Range	Default	Category
DMTC*gg*[a]	Demand Met. Time Const. Elm *gg*	5,10,…300 min	5	Group

[a] gg = 01–10.

EDMgg (Torque Control)

Use the torque-control setting to specify conditions under which the overvoltage elements must be active.

Setting	Prompt	Range	Default	Category
EDM*gg*[a]	Enable Demand Metering Element *gg*	SELOGIC control equation	1	Group

[a] gg = 01–10.

View or Reset Demand Metering Information

The relay shows demand metering quantities and time-stamped peak demand quantities when you use a communications port or ACSELERATOR QuickSet® SEL-5030 Software to view these quantities. In addition, you can read the demand and peak demand quantities on the SEL-487E front-panel LCD screen. To reset the demand metering values use the **MET RD** command from a communications terminal, or use the **RESET** button in the ACSELERATOR QuickSet **HMI > Meter and Control > Demand/Peak** window, or answer Y and press **{ENT}** at the Demand Submenu reset demand prompt on the front panel LCD screen. The relay begins the demand meter sampling period from the time of the demand meter reset. To reset the peak demand metering values, enter the **MET RP** command from a communications terminal, or use the **RESET** button in the ACSELERATOR QuickSet **HMI > Meter and Control > Demand/Peak** window, or answer Y and press **{ENT}** at the Demand Submenu reset peak demand prompt on the front-panel LCD screen. You can also reset demand metering with Global settings RST_DEM and RST_PDM (for demand and peak demand).

Demand Metering Updating and Storage

The SEL-487E updates demand and peak demand values once per second. The relay also stores peak demand values and the date and time these occurred to nonvolatile storage once per day (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it will restore the peak demand information saved at 23:50 hours on the previous day. Demand metering updating and peak recording is suspended during the time that SELOGIC control equation FAULT asserts Relay Word bit DFAULT (Delayed FAULT Suspend).

Analog Signal Profiling

Use the analog signal profiling function to record and track values of up to 20 analog quantities. This function provides data in CASCII that is compatible to import directly into applications like spreadsheets. Specify the specific analog quantities for profiling with the SPAQ Report settings.

At the data acquisition rate of 5 minutes, the SEL-487E stores at least 10 days of all analog signals selected for profiling in nonvolatile memory. The report includes the time of acquisitions and the magnitude of each selected analog quantity. By defining conditions in the signal profiling enable SELOGIC variable setting (SPEN), you can record analog values at particular periods or conditions of interest.

SPAQgg (Analog Quantities for Signal Profiling)

Enter any analog quantity available in the relay from the Analog Quantity list (see *Appendix H: Analog Quantities*). in this free-form setting.

SPAR (Signal Profile Acquisition Rate)

Although you can select up to 20 analog quantities, the signal acquisition rate is the same for all analog quantities. Select an acquisition rate of 1, 5, 15, 30, or 60 minutes.

Setting	Prompt	Range	Default	Category
SPAR	Signal Profile Acq Rate	1, 5, 15, 30, 60	5	Report

SPEN (Signal Profile Enable)

Use this SELOGIC control equation to specify conditions under which the profiling must take place. If there are no conditions, be sure to set SPEN = 1, else no data is recorded (default value of NA disables the function).

Setting	Prompt	Range	Default	Category
SPEN	Signal Profile Enable	SV	NA	Report

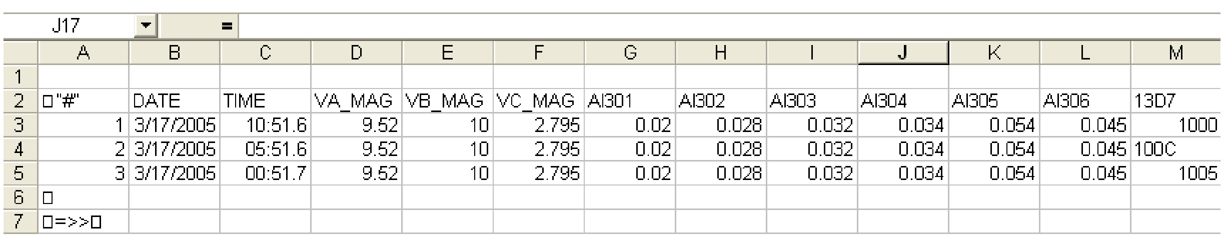
Use the compressed ASCII **CMR** command to view the profile data, as shown in *Figure 5.31*.

```
=>>CPR<Enter>
"#","DATE","TIME","VA_MAG","VB_MAG","VC_MAG","AI301","AI302","AI303","AI304","AI
305","AI306","13D7"
1,"03/17/2005","04:20:51.603",20.000,25.769,15.811,0.020,0.027,0.032,0.034,0.054
,0.045,"1066"

=>>
```

Figure 5.31 Compressed ASCII Data Display

Because the data is optimally formatted for machine-to-machine compatibility, use software such as Excel to display the profile data. *Figure 5.32* shows the data from *Figure 5.31* after importing the data (comma-delimited) into an Excel spreadsheet.


J17 =

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2	□"#"	DATE	TIME	VA_MAG	VB_MAG	VC_MAG	AI301	AI302	AI303	AI304	AI305	AI306	13D7
3	1	3/17/2005	10:51.6	9.52	10	2.795	0.02	0.028	0.032	0.034	0.054	0.045	1000
4	2	3/17/2005	05:51.6	9.52	10	2.795	0.02	0.028	0.032	0.034	0.054	0.045	100C
5	3	3/17/2005	00:51.7	9.52	10	2.795	0.02	0.028	0.032	0.034	0.054	0.045	1005
6	□												
7	□=>>□												

Figure 5.32 Profile Data in Excel Spreadsheet

Use the **PRO C**(lear) command to clear all profile data, as shown in *Figure 5.33*.

```
=>>PRO C<Enter>
Reset All Profile Data (Y,N)? Y<Enter>
Reset Complete

=>>
```

Figure 5.33 Profile Data Reset

Metering

The SEL-487E provides one-cycle average metering for measuring power system conditions and differential protection values. Each SEL-487E processes 18 currents, 6 voltages, and 1 battery monitor.

Table 5.20 shows all the **MET** commands available in the relay.

NOTE: The relay compensates for delta-connected CTs when reporting primary values. (See *Delta-Connected CTs on page 4.28*.)

Table 5.20 MET Command

Command	Description
MET RMS *w n*[a, b]	Display rms metering quantities (current and voltage only)
MET F *w n* N/Y[c]	Display fundamental metering quantities
MET SEC *w n*	Display secondary metering quantities
MET D *n*	Display demand and peak demand metering quantities
MET D R|C	Reset demand meter data
MET RD	Alternative syntax for **MET D R**
MET P R|C	Reset peak demand data
MET RP	Alternative syntax for **MET P R**
MET DIF *n*	Display differential data
MET E *n*	Display energy import and export metering quantities
MET E R|C	Reset energy data
MET RE	Alternative syntax for **MET E R**
MET PM *n*	Display synchrophasor data
MET PM	Triggers a synchrophasor measurement
MET RTD *n*	SEL-2600 Temperature quantities
MET PMV *n*	Display protection math variables
MET AMV *n*	Display automation math variables
MET BAT *n*	Display battery data
MET RBM	Reset station battery max/min measurements
MET BAT R|C[d]	Alternative syntax for MET RBM
MET ANA *n*	Display analog values from MIRRORED BITS analog, and Remote analogs

[a] w = S, T, U, W, X, ST, TU, UW, WX.
[b] n = the number of times the relay repeats the response.
[c] N/Y = displays primary currents from the Y-Winding
[d] | = either (e.g., R|C = either R or C).

Because of the large number of analog channels, not all analog channels are required for every application. Furthermore, when the Torque Control settings (of those analog quantities that have Torque Control settings) de-assert, those analog quantities are not shown in the meter report.

There are thus two different instances for not displaying analog quantities in the meter report: you either did not select the analog quantity, or the analog quantity is temporary not calculated when the Torque Control equation de-asserts. To distinguish between these two conditions, the relay display dashes (-----) when the analog quantity was not selected, and zeros (000.00) when the Torque Equation de-asserts.

Fundamental Meter

Use the **MET (FUN)** ***k*** command (*k* = S, T, U, W, X, ST, TU, UW, WX) to view the fundamental (60 or 50 Hz) metering values. When you type **MET** without an argument, the report defaults to Winding S. For each winding, the fundamental meter report provides the quantities shown in *Table 5.22*.

Table 5.21 shows the order of valid reference quantities that the relay uses to display the angular relationship among the metering values.

Table 5.21 Valid Reference Quantities

Reference Quantity	Source	Valid Value
Positive-sequence voltage	PT V	Positive-sequence voltage > 0.1 • VNOMV
Positive-sequence voltage	PT Z	Positive-sequence voltage > 0.1 • VNOMZ
Positive-sequence current	Winding S	Positive-sequence current > 0.05 • INOMS
Positive-sequence current	Winding T	Positive-sequence current > 0.05 • INOMT
Positive-sequence current	Winding U	Positive-sequence current > 0.05 • INOMU
Positive-sequence current	Winding W	Positive-sequence current > 0.05 • INOMW
Positive-sequence current	Winding X	Positive-sequence current > 0.05 • INOMX

For example, the positive-sequence voltage calculated from the PT V voltage inputs is reference for all metering quantities, provided that this positive-sequence voltage exceeds 10 percent of the VNOMV setting. If PT V is not available, then the positive-sequence voltage calculated from the PT Z voltage inputs is reference for all metering quantities, provided that this positive-sequence voltage exceeds 10 percent of the VNOMV settings. This sequence continues for all other reference quantities.

Table 5.22 Quantities in the Fundamental Meter Report (Sheet 1 of 2)

Quantity	Description
IA, IB, IC	Winding *k* A-phase, B-phase, and C-phase primary current. The reference is independent of the VREF*k* settings, and is determined as follows: 1. A-phase of PT V (if available) 2. A-phase of PT Z (if available, and PT V is not available) 3. A-phase of Winding *k* current (if no PTs are available)
I1, 3I2, 3I0	Positive-, negative-, and zero-sequence components for Winding *k*. 3I0 is not available when the CTs are connected in delta (CTCON = D)
VA, VB, VC	Primary voltage of the PT specified in the VREF*n* setting (A-phase as reference)
V1, 3V2, 3V0	Positive-, negative-, and zero-sequence components of the PT specified in the VREF*n* setting. 3V0 is not available when the PTs are connected in delta (PTCON = D)
PA, PB, PC, 3P	A-phase, B-phase, C-phase and 3-phase active (real) power for Winding *k*. Only 3-phase real power is available when either CTs or PTs (or both) are delta-connected. Not calculated if setting VREF*k* does not include a reference PT and/or setting EPCAL does not include the winding.
QA, QB, QC, 3Q	A-phase, B-phase, C-phase and 3-phase reactive power for Winding *k*. Only 3-phase reactive power is available when either CTs or PTs (or both) are delta-connected. Not calculated if setting VREF*k* does not include a reference PT and/or setting EPCAL does not include the winding.

Table 5.22 Quantities in the Fundamental Meter Report (Sheet 2 of 2)

Quantity	Description
SA, SB, SC, 3S	A-phase, B-phase, C-phase and 3-phase apparent power for Winding *k* Only 3-phase power apparent is available when either CTs or PTs (or both) are delta-connected. Not calculated if setting VREF*k* does not include the winding and/or setting EPCAL does not include the winding.
Power factor	A-phase, B-phase, C-phase and 3-phase power factor for Winding *k* Not calculated if setting VREF*k* does not include a reference PT and/or setting EPCAL does not include the winding.
VAB, VBC, CA	AB, BC, and CA line-to-line voltages for PT V.
VAB, VBC, CA	AB, BC, and CA line-to-line voltages for PT Z.
Frequency	Measured system frequency
Frequency Tracking	When the relay tracks the frequency, the report display "Y", and "N" when the relay does not track the frequency
Battery Voltage	Measured battery voltage
Volts/Hertz	Percentage V/Hz

Enable current, voltage, and power meter quantities with the following settings:

- Current: include the Winding(s) in the ECTTERM Group setting
- Voltage: include the PT in the EPTTERM Group setting
- Power (Fundamental power only):
  - In addition to being included in the EPTTERM setting, also select the reference PT for each winding (VREF*k*) setting. *Table 5.23* summarizes the settings for Winding S and PT V.
  - Include Winding S in the EPCAL setting

Table 5.23 Report Settings Summary

I in Report	V in Report	S, P, Q in Report
ECTTERM = S	EPTTERM = V	VREFS = V EPCAL = S

Figure 5.34 shows the report with the following settings:

- ECTTERM: includes S (ECTTERM = S,…)
- EPTTERM: does not includes V or Z (EPTTERM = OFF)
- VREFS: no reference voltage specified (VREFS = OFF)
- EPCAL = OFF
- E24 = N

With these settings, the report shows only the current values for Winding S. Notice that there is no indication of the reference PT in the Phase Voltages – PT – heading (VREFS = OFF). Also, the A-phase current is the reference because there is no PT available.

```
=>>MET <Enter>

Relay 1                                     Date: 04/20/2008  Time: 02:03:30.014
Station A                                   Serial Number: 2008030645


Fundamental Meter: Winding S

               Phase Currents                  Sequence Currents
           IA         IB         IC            I1         3I2        3I0
MAG(A,pri)  219.26     219.47     219.96        219.55       1.52       1.92
ANG(deg)     -0.13    -120.14     120.28          0.00     -51.86    -170.31

            Phase Voltages - PT -              Sequence Voltages
           VA         VB         VC            V1         3V2        3V0
MAG (kV)   -------    -------    -------       -------    -------    -------
ANG(deg)   ------     ------     ------        ------     ------     ------

Power Quantities
Active Power P (MW,pri)
     PA          PB          PC          3P
------    ------    ------   ------

Reactive Power Q (MVAr,pri)
     QA          QB          QC          3Q
------    ------    ------   ------

Apparent Power  S (MVA,pri)
     SA          SB          SC          3S
------    ------    ------   ------

Power factor
 Phase A     Phase B     Phase C     3-Phase
----        ----        ----        ----

Line-to-Line Voltage
                   PT - V                                PT - Z
           VAB        VBC        VCA           VAB        VBC        VCA
MAG (kV)   -------    -------    -------       -------    -------    -------
ANG(deg)   ------     ------     ------        ------     ------     ------

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   115.81          V/Hz      -----%

=>>
```

Figure 5.34 Fundamental Quantities Report with VREFS = OFF and EPTTERM = OFF

In the report shows in *Figure 5.34*, the EPTTERM includes both V and Z PTs, but PT Z is connected to a dead busbar.

Figure 5.34 shows the report with the following settings:

- ➤ ECTTERM: includes S (ECTTERM = S,….)
- ➤ EPTTERM: includes both V or Z (EPTTERM = V, Z), but PT Z is de-energized
- ➤ VREFS: no reference voltage specified (VREFS = OFF)
- ➤ EPCAL = OFF
- ➤ E24 = N

With these settings, Winding S current is available, as well as the two PTs. Although there is no reference voltage selected (VREFS = OFF), the phase currents are referenced to the A-phase of PT V.

```
=>>MET <Enter>

Relay 1                                     Date: 04/20/2008  Time: 02:08:46.920
Station A                                   Serial Number: 2008030645


Fundamental Meter: Winding S

               Phase Currents                  Sequence Currents
           IA         IB         IC          I1         3I2        3I0
MAG(A,pri)  219.81     219.28     219.23      219.44      1.20       1.39
ANG(deg)    -16.17    -135.86     104.10      -15.97    -85.85     -76.74

            Phase Voltages - PT -              Sequence Voltages
           VA         VB         VC          V1         3V2        3V0
MAG (kV)   -------    -------    -------     -------    -------    -------
ANG(deg)   ------     ------     ------      ------     ------     ------

Power Quantities
Active Power P (MW,pri)
     PA          PB          PC          3P
------    ------    ------    ------

Reactive Power Q (MVAr,pri)
     QA          QB          QC          3Q
------    ------    ------    ------

Apparent Power  S (MVA,pri)
     SA          SB          SC          3S
------    ------    ------    ------

Power factor
 Phase A     Phase B     Phase C     3-Phase
----        ----        ----        ----

Line-to-Line Voltage
                   PT - V                              PT - Z
           VAB        VBC        VCA           VAB        VBC        VCA
MAG (kV)   217.888    217.704    218.330        0.005      0.007      0.005
ANG(deg)    29.89     -89.93     150.02       -166.32      61.99     -75.31

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   115.82          V/Hz      -----%

=>>
```

Figure 5.35 Fundamental Quantities Report With VREFS = OFF and EPTTERM = V, Z

In the report shows in *Figure 5.36*, the EPTTERM includes both V and Z PTs (PT Z is hot), and the VREFS setting include Winding S. The Phase Voltages heading now indicates the reference PT (V), and the voltage values are shown. Because EPCAL = OFF there are no power values shown in the report.

Figure 5.36 shows the report with the following settings:

- ECTTERM: includes S (ECTTERM = S,…)
- EPTTERM: includes both V or Z (EPTTERM = V, Z)
- VREFS: PT V as reference voltage (VREFS = S…)
- EPCAL = OFF
- E24 = Y

```
=>>MET S <Enter>

Relay 1                                     Date: 04/20/2008  Time: 02:23:31.610
Station A                                   Serial Number: 2008030645


Fundamental Meter: Winding S

               Phase Currents                  Sequence Currents
           IA        IB        IC           I1        3I2       3I0
MAG(A,pri)  219.56    219.68    219.24       219.49      0.96      1.60
ANG(deg)    -16.16   -135.90    104.21       -15.95    -77.23   -117.62

            Phase Voltages - PT V              Sequence Voltages
           VA        VB        VC           V1        3V2       3V0
MAG (kV)   125.839   125.873   125.853      125.854     0.647     0.710
ANG(deg)    -0.14   -120.06    120.21         0.00    -41.95   -138.62

Power Quantities
Active Power P (MW,pri)
     PA          PB          PC          3P
------    ------    ------    ------

Reactive Power Q (MVAr,pri)
     QA          QB          QC          3Q
------    ------    ------    ------

Apparent Power  S (MVA,pri)
     SA          SB          SC          3S
------    ------    ------    ------

Power factor
 Phase A     Phase B     Phase C     3-Phase
----        ----        ----        ----

Line-to-Line Voltage
                  PT - V                            PT - Z
           VAB       VBC       VCA          VAB       VBC       VCA
MAG (kV)   217.911   217.710   218.363      130.809   130.743   130.966
ANG(deg)    29.90    -89.93    150.03        29.96    -89.95    150.03

FREQ (Hz) 59.992          Frequency Tracking = Y
VDC (V)   115.81          V/Hz      99.87%

=>>
```

Figure 5.36 Fundamental Quantities Report With EPCAL = OFF

In the report shows in *Figure 5.37*, the EPTTERM includes both V and Z PTs, and the EPCAL setting include Winding S.

Figure 5.37 shows the report with the following settings:

- ECTTERM: includes S (ECTTERM = S,…)
- EPTTERM: includes both V or Z (EPTTERM = V, Z)
- VREFS: PT V as reference voltage (VREFS = V.…)
- EPCAL: includes Winding S (EPCAL = S.…)
- E24 = Y

With these settings, all functions are enabled and all values are shown.

```
=>>MET <Enter>

Relay 1                                      Date: 04/20/2008  Time: 05:28:37.595
Station A                                    Serial Number: 2008030645


Fundamental Meter: Winding S

               Phase Currents                  Sequence Currents
           IA        IB        IC            I1        3I2       3I0
MAG(A,pri)  219.78    219.58    219.29       219.54      1.19      1.37
ANG(deg)    -16.15   -135.94    104.22       -15.96    -59.31   -112.78

            Phase Voltages - PT V              Sequence Voltages
           VA        VB        VC            V1        3V2       3V0
MAG (kV)   125.845   125.866   125.852      125.854     0.662     0.703
ANG(deg)    -0.14   -120.07    120.21         0.00    -41.11   -139.10

Power Quantities
Active Power P (MW,pri)
     PA          PB          PC          3P
    26.58       26.58       26.53       79.70

Reactive Power Q (MVAr,pri)
     QA          QB          QC          3Q
     7.63        7.56        7.60       22.79

Apparent Power  S (MVA,pri)
     SA          SB          SC          3S
    27.66       27.64       27.60       82.89

Power factor
Phase A     Phase B     Phase C     3-Phase
 0.96 Lag    0.96 Lag    0.96 Lag    0.96 Lag

Line-to-Line Voltage
                   PT - V                            PT - Z
           VAB       VBC       VCA           VAB       VBC       VCA
MAG (kV)   217.912   217.694   218.347      130.807   130.728   130.953
ANG(deg)    29.90    -89.93    150.03        29.96    -89.95    150.03

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   115.21          V/Hz      99.01%

=>>
```

Figure 5.37 Fundamental Quantities Report

RMS Meter

Use the **MET RMS *k*** command (*k* = S, T, U, W, X, ST, TU, UW, WX) to view the root-mean-square (rms) current and voltage values; the relay does not calculate rms power values. Setting conditions (EPCAL, VREF*k*, EPTTERM and ECTTERM) are the same for rms metering as for fundamental metering. *Table 5.20* shows the quantities in the rms report.

Table 5.24 Quantities in the RMS Meter Report (Sheet 1 of 2)

Quantity	Description
IA, IB, IC	Winding *k* A-phase, B-phase, and C-phase primary current. The reference is independent of the VREF*k* settings, and is determined as follows: 1. A-phase of PT V (if available) 2. A-phase of PT Z (if available, and PT V is not available) 3. A-phase of Winding *k* current (if no PTs are available)
VA, VB, VC	Primary voltage of the PT specified in the VREF*n* setting (A-phase as reference)
VAB, VBC, CA	Primary voltage AB, BC, and CA line-to-line voltages for PT V.
VAB, VBC, CA	Primary voltage AB, BC, and CA line-to-line voltages for PT Z.
Frequency	Measured system frequency
Frequency Tracking	When the relay tracks the frequency, the report display “Y”, and “N” when the relay does not track the frequency

Table 5.24 Quantities in the RMS Meter Report (Sheet 2 of 2)

Quantity	Description
Battery Voltage	Measured battery voltage
Volts/Hertz	Percentage V/Hz

Figure 5.38 shows rms report for Winding S; other windings have similar reports.

```
=>>MET RMS <Enter>

Relay 1                                     Date: 04/20/2008  Time: 06:21:32.214
Station A                                   Serial Number: 2008030645


        RMS Meter: Winding S

Phase Currents, I (A,pri)
IA        IB        IC
  219.73    218.97    219.79

Phase Voltages (kV,pri)  - PT V
VA        VB        VC
125.841   125.847   125.855

Line-to-Line Voltage V (kV,pri)
PT - V                           PT - Z
VAB       VBC       VCA          VAB       VBC       VCA
217.889   217.696   218.336      130.796   130.731   130.945

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   115.81          V/Hz      99.78%

=>>
```

Figure 5.38 RMS Report for Winding S

Secondary Meter

Use the **MET SEC** command to see the secondary fundamental current and voltage values. Setting conditions (EPCAL, VREF*k*, EPTTER and ECTTERM) are the same for rms metering as for fundamental metering. *Figure 5.39* shows the report for Winding T; other windings have similar reports. *Table 5.25* shows the quantities in the secondary quantities report.

Table 5.25 Quantities in the MET SEC Report

Quantity	Description
IA, IB, IC	Winding *k* A-phase, B-phase, and C-phase in secondary current. The reference is independent of the VREF*k* settings, and is determined as follows: 1. A-phase of PT V (if available) 2. A-phase of PT Z (if available, and PT V is not available) 3. A-phase of Winding *k* current (if no PTs are available)
VA, VB, VC	Secondary voltage of the PT specified in the VREF*n* setting (A-phase as reference)
VAB, VBC, CA	Secondary voltage AB, BC, and CA line-to-line voltages for PT V.
VAB, VBC, CA	Secondary voltage AB, BC, and CA line-to-line voltages for PT Z.
Frequency	Measured system frequency
Frequency Tracking	When the relay tracks the frequency, the report display “Y”, and “N” when the relay does not track the frequency
Battery Voltage	Measured battery voltage
Volts/Hertz	Percentage V/Hz

```
=>>MET SEC T <Enter>

Relay 1                                          Date: 04/20/2008  Time: 06:47:23.494
Station A                                        Serial Number: 2008030645


  Secondary Meter: Winding T

                Phase Currents                     Sequence Currents
           IA         IB         IC           I1         3I2        3I0
MAG(A,sec)    4.37       4.37       4.36        4.37       0.01       0.01
ANG(deg)    164.23      44.32     -75.60       164.32     118.41      63.71

             Phase Voltages - PT V                 Sequence Voltages
           VA         VB         VC           V1         3V2        3V0
MAG(V,sec)  62.922     62.937     62.924       62.928      0.324      0.353
ANG(deg)     -0.13    -120.07     120.19        0.00     -40.24    -138.95

Line-to-Line Voltage
                   PT - V                                 PT - Z
           VAB        VBC        VCA          VAB        VBC        VCA
Mag(V,sec) 108.962    108.850    109.171      109.014    108.946    109.126
ANG(deg)    29.89     -89.94     150.03        29.95     -89.95     150.03

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   115.81          V/Hz      99.56%

=>>
```

Figure 5.39 MET SEC Report for Winding T

Demand Meter

Figure 5.40 shows the Demand report with four of the available ten elements enabled (see *Thermal Demand and Rolling Demand* for more information). *Table 5.26* shows the quantities in the demand metering report.

Table 5.26 Quantities in the Demand Metering Report

Quantity	Description
DM01–DM04	Four of the available ten elements (DM01–DM10 available)
Op_Qty	Displays the analog quantities selected for each enabled element. (see *Table 5.19* for a list of available analog quantities).
Type	Displays the selected type (rolling demand or thermal) of demand meter for each element. (see *Thermal Demand and Rolling Demand* for more information).
Demand	Displays the accumulated demand and the time and date of the recording.
Peak	Displays the peak demand and the time and date of the recording.

```
=>>MET D <Enter>

Relay 1                                          Date: 04/20/2008  Time: 20:30:08.674
Station A                                        Serial Number: 2008030645


        Op_Qty     Type      Demand       Peak     Date        Time

DM01    IMXSRS     THERM       1.864       2.580 04/18/2008 23:17:10.635
DM02    IMXTRS     ROLL        2.184       2.184 04/20/2008 20:29:14.898
DM03    IMXURS     THERM       0.004       7.664 01/02/1792 03:32:27.834
DM04    IMXXRS     THERM       3.243       3.243 04/20/2008 20:30:08.536

LAST DEMAND RESET: 04/20/2008 20:24:14.615
LAST MAX DEMAND RESET: 04/15/2008 22:51:50.456

=>>
```

Figure 5.40 Demand Report With Four Elements Enabled

Demand/Peak Meter Reset

Use the **MET D R** or the **MET D C** command to reset/clear the demand (only) values. Use the **MET P R** or the **MET P C** command to reset/clear the peak (only) values. *Figure 5.41* shows the use of the **MET D R** to reset the demand values, and *Figure 5.42* the result of the reset. Peak reset has a similar result.

```
=>>MET D R <Enter>

Reset Demands   (Y/N)? Y <Enter>

Demands Reset
```

Figure 5.41 MET D R Command

```
=>>MET D <Enter>

Relay 1                                     Date: 04/20/2008  Time: 21:00:57.166
Station A                                   Serial Number: 2008030645


        Op_Qty     Type     Demand       Peak     Date       Time

DM01    IMXSRS     THERM      0.067      2.580 04/18/2008 23:17:10.635
DM02    IMXTRS     ROLL       0.000      3.028 04/20/2008 20:34:17.497
DM03    IMXURS     THERM      0.000      7.664 01/02/1792 03:32:27.834
DM04    IMXXRS     THERM      0.133      4.369 04/20/2008 20:59:52.541

LAST DEMAND RESET: 04/20/2008 21:00:51.134
LAST MAX DEMAND RESET: 04/15/2008 22:51:50.456

=>>
```

Figure 5.42 Result of Demand Reset

Differential Meter

Use the **MET DIF** command to see the differential operate, restraint and percentage harmonic values. *Table 5.27* summarizes the quantities in the differential report, and *Figure 5.43* shows the differential element report.

Table 5.27 Quantities in the MET SEC Report

Quantity	Description
IOPA, IOPB, IOPC	Per-unit operating current for Differential Element A, Differential Element B, and Differential Element C
IRTA, IRTB, IRTC	Per-unit restraint current for Differential Element A, Differential Element B, and Differential Element C
IOPAF2, IOPBF2, IOPCF2	Second Harmonic Currents, expressed as a percentage of the operating current.
IOPAF4, IOPBF4 IOPCF4	Fourth Harmonic Currents, expressed as a percentage of the operating current.
IOPAF5, IOPBF5 IOPCF5	Fifth Harmonic Currents, expressed as a percentage of the operating current.
Enabled Windings	Displays the windings included in the differential calculations (based on the E87T setting)

```
=>>MET DIF <Enter>

Relay 1                                      Date: 04/12/2008  Time: 06:06:31.366
Station A                                    Serial Number: 2008030645


Operate Currents (per unit)       Restraint Currents (per unit)
IOPA      IOPB      IOPC          IRTA      IRTB      IRTC
 1.32      1.32      1.32          3.91      3.91      3.91

2nd Harmonic Currents (percentage of IOPA, IOPB, IOPC)
IOPAF2    IOPBF2    IOPCF2
 0.08      0.09      0.01

4th Harmonic Currents (percentage of IOPA, IOPB, IOPC)
IOPAF4    IOPBF4    IOPCF4
 0.05      0.10      0.06

5th Harmonic Currents (percentage of IOPA, IOPB, IOPC)
IOPAF5    IOPBF5    IOPCF5
 0.06      0.11      0.04

Enabled Windings:  S, T


=>>
```

Figure 5.43 Differential Element Report

Synchrophasor Meter

Use the **MET PM** command to display the synchrophasor values, as shown in *Figure 5.44* (see *Section 11: Synchrophasors* for more information).

```
=>>MET PM <Enter>

Relay 1                                      Date: 05/28/2008  Time: 12:29:09.000
Station A                                    Serial Number: 0000000000

Time Quality   Maximum time synchronization error:  >999.999 (ms)  TSOK = 0

Synchrophasors
                     VV Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)          0.003     0.007     0.010             0.005
ANG (DEG)       -84.721   147.645   125.695           -42.686

                     VZ Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)          0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IS Phase Currents         IS Pos. Sequence Current
                 IA        IB        IC                I1S
MAG (A)           0.178     0.371     0.462             0.042
ANG (DEG)       150.260   116.837   136.352           -47.019

                     IT Phase Currents         IT Pos. Sequence Current
                 IA        IB        IC                I1T
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IU Phase Currents         IU Pos. Sequence Current
                 IA        IB        IC                I1U
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IW Phase Currents         IW Pos. Sequence Current
                 IA        IB        IC                I1W
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IX Phase Currents         IX Pos. Sequence Current
                 IA        IB        IC                I1X
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IY Phase Currents         IY Pos. Sequence Current
                 IA        IB        IC                I1X
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)        0.000     0.000     0.000           0.000
```

(Continued on next page)

```
                                                    (Continued from previous page)
FREQ (Hz) 60.000          Frequency Tracking = N
Rate-of-change of FREQ (Hz/s)    0.00

Digitals

PSV08  PSV07  PSV06  PSV05  PSV04  PSV03  PSV02  PSV01
  0      0      0      0      0      0      0      0
PSV16  PSV15  PSV14  PSV13  PSV12  PSV11  PSV10  PSV09
  0      0      0      0      0      0      0      0
PSV24  PSV23  PSV22  PSV21  PSV20  PSV19  PSV18  PSV17
  0      0      0      0      0      0      0      0
PSV32  PSV31  PSV30  PSV29  PSV28  PSV27  PSV26  PSV25
  0      0      0      0      0      0      0      0
PSV40  PSV39  PSV38  PSV37  PSV36  PSV35  PSV34  PSV33
  0      0      0      0      0      0      0      0
PSV48  PSV47  PSV46  PSV45  PSV44  PSV43  PSV42  PSV41
  0      0      0      0      0      0      0      0
PSV56  PSV55  PSV54  PSV53  PSV52  PSV51  PSV50  PSV49
  0      0      0      0      0      0      0      0
PSV64  PSV63  PSV62  PSV61  PSV60  PSV59  PSV58  PSV57
  0      0      0      0      0      0      0      0

Analogs

PMV49      0.000  PMV50      0.000  PMV51      0.000  PMV52      0.000
PMV53      0.000  PMV54      0.000  PMV55      0.000  PMV56      0.000
PMV57      0.000  PMV58      0.000  PMV59      0.000  PMV60      0.000
PMV61      0.000  PMV62      0.000  PMV63      0.000  PMV64      0.000


=>>
```

Figure 5.44 Synchrophasor Report

RTD Meter

Use the **MET RTD** command to display the RTD values, as shown in *Figure 5.45*.

```
=>>MET RTD <Enter>

Relay 1                                    Date: 04/12/2008  Time: 06:06:31.366
Station A                                  Serial Number: 2008030645


RTD Input Temperature Data (deg. C)
RTD   1 = -50
RTD   2 = 250
RTD   3 = 0
RTD   4 = 45
RTD   5 = 34
RTD   6 = 65
RTD   7 = -23
RTD   8 = 39
RTD   9 = 23
RTD  10 = 11
RTD  11 = 54
RTD  12 = 78

=>>
```

Figure 5.45 RTD Report

Protection Math Variable Meter

Use the **MET PMV** command to display all 64 PMV values, as shown in *Figure 5.46*.

```
=>>MET PMV <Enter>

Relay 1                                     Date: 04/07/2008  Time: 21:03:40.451
Station A                                   Serial Number: 2008030645

Protection Analog Quantities
  PMV01 =       0.000       PMV02 =       0.000       PMV03 =       0.000
  PMV04 =       0.000       PMV05 =       0.000       PMV06 =       0.000
  PMV07 =       0.000       PMV08 =       0.000       PMV09 =       0.000
  PMV10 =       0.000       PMV11 =       0.000       PMV12 =       0.000
  PMV13 =       0.000       PMV14 =       0.000       PMV15 =       0.000
  PMV16 =       0.000       PMV17 =       0.000       PMV18 =       0.000
  PMV19 =       0.000       PMV20 =       0.000       PMV21 =       0.000
  PMV22 =       0.000       PMV23 =       0.000       PMV24 =       0.000
  PMV25 =       0.000       PMV26 =       0.000       PMV27 =       0.000
  PMV28 =       0.000       PMV29 =       0.000       PMV30 =       0.000
  PMV31 =       0.000       PMV32 =       0.000       PMV33 =       0.000
  PMV34 =       0.000       PMV35 =       0.000       PMV36 =       0.000
  PMV37 =       0.000       PMV38 =       0.000       PMV39 =       0.000
  PMV40 =       0.000       PMV41 =       0.000       PMV42 =       0.000
  PMV43 =       0.000       PMV44 =       0.000       PMV45 =       0.000
  PMV46 =       0.000       PMV47 =       0.000       PMV48 =       0.000
  PMV49 =       0.000       PMV50 =       0.000       PMV51 =       0.000
  PMV52 =       0.000       PMV53 =       0.000       PMV54 =       0.000
  PMV55 =       0.000       PMV56 =       0.000       PMV57 =       0.000
  PMV58 =       0.000       PMV59 =       0.000       PMV60 =       0.000
  PMV61 =       0.000       PMV62 =       0.000       PMV63 =       0.000
  PMV64 =       0.000
=>>
```

Figure 5.46 PMV Report

Automation Math Variable Meter

Use the **MET AMV** command to display all 256 PMV values, as shown in *Figure 5.47*.

```
=>>MET AMV <Enter>

Relay 1                                     Date: 04/07/2008  Time: 21:04:33.579
Station A                                   Serial Number: 2008030645

Automation Analog Quantities
 AMV001 =       0.000      AMV002 =       0.000      AMV003 =       0.000
 AMV004 =       0.000      AMV005 =       0.000      AMV006 =       0.000
 AMV007 =       0.000      AMV008 =       0.000      AMV009 =       0.000
 AMV010 =       0.000      AMV011 =       0.000      AMV012 =       0.000
 AMV013 =       0.000      AMV014 =       0.000      AMV015 =       0.000
.
.
.

 AMV238 =       0.000      AMV239 =       0.000      AMV240 =       0.000
 AMV241 =       0.000      AMV242 =       0.000      AMV243 =       0.000
 AMV244 =       0.000      AMV245 =       0.000      AMV246 =       0.000
 AMV247 =       0.000      AMV248 =       0.000      AMV249 =       0.000
 AMV250 =       0.000      AMV251 =       0.000      AMV252 =       0.000
 AMV253 =       0.000      AMV254 =       0.000      AMV255 =       0.000
 AMV256 =       0.000
=>>
```

Figure 5.47 AMV Report

Battery Meter

See *Figure 5.13* for more information.

Section 6
Settings

Overview

This section contains tables of relay settings for the SEL-487E Relay that have not been described in other sections. The relay hides some settings based upon the state of other settings. For example, if you set an enable setting to OFF (disabling the function), then the relay hides all settings associated with that function.

The settings prompts in this section are similar to the ASCII terminal and ACSELERATOR QuickSet® SEL-5030 Software prompts. Prompts in this section are unabbreviated and show all possible setting options.

Table 6.1 shows the settings categories in the SEL-487E and the sections where these settings are described in the instruction manual.

Table 6.1 Setting Categories and Appropriate Section

Setting category	Section
Alias (SET T)	*Section 6: Settings*
Automation (SET A)	*Section 12: SELOGIC Control Equations*
DNP (SET D)	*Appendix E: DNP3 Communications Protocol*
Front Panel (SET F)	*Section 8: Front-Panel Operations*
Global (SET G)	*Section 6: Settings*
Group (SET)	*Section 4: Protection and Logic Functions*
Logic (Protection) (SET L)	*Section 6: Settings* / *Section 12: SELOGIC Control Equations*
MIMIC (Bay Control) (SET B)	*Making Text-Edit Mode Settings Changes on page 14.11*
Monitor (SET M)	*Section 5: Monitoring and Metering*
Notes (SET N)	*Section 14: Testing and Troubleshooting*
Output (SET O)	*Section 4: Protection and Logic Functions*
Port (SET P*n*)	*Section 6: Settings* / *Appendix E: DNP3 Communications Protocol* / *Appendix D: High-Accuracy Timekeeping* / *Section 11: Synchrophasors* / *Section 5: Monitoring and Metering* / *Section 7: Communications, Interfaces, and Protocols*
Report (SET R)	*Section 10: Event Reports and SER*

Alias Settings

Assign a valid seven-character alias name to any of the following:

- Relay Word bit (except target LEDs)
- Analog Quantity

Alias names are valid when the following are true:

- They consist of a maximum of seven characters.
- They are constructed using characters 0–9, uppercase A–Z, or the underscore (_).

For example, the default name for contact output OUT101 is OUT101. You could change the default name to an alias, BKS Trip, for example. BKS Trip (including the space) consists of eight characters, one more than the allowable number of seven. Changing the name to BK1 Tr reduces the character count to six, but the alias contains two elements not permitted, a space and one lowercase letter (r). One possible alias for the existing name of OUT101 could be BKS_TR, entered using the following syntax:

primitive name, alias name,

e.g., OUT101, BK1_TR

Figure 6.1 shows the steps using the **SET T** command, and Table 10.1 shows the default settings.

```
=>>SET T <Enter>
Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
?  <Enter>
2:
?  OUT101, BK1_TR
3:
?  END <Enter>
Alias
Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"RLY_EN"
2: OUT101, "BKS_TR"
..
.


Save settings (Y,N)  ?Y <Enter>

Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 6.1 Changing a Default Name to an Alias

Table 6.2 Default Alias Settings

Label	Default Value
EN	RLY_EN

Invalid alias names are those keywords used by settings and SELOGIC control equations such as:

- END
- INSERT
- DELETE
- LIST
- NA
- OFF

Also, SELOGIC control equation operators (e.g., NOT, AND, OR, COS) cannot be used as alias names (see *Section 12: SELOGIC Control Equations* for a complete list of the operators).

Global Settings

SID, RID, NFREQ, PHROT

Enter the station name (SID) and the relay name (RID) to identify where the relay is installed. These names appear in all reports for easy analysis and reporting. NFREQ is the nominal system frequency and is either 50 or 60 Hz. PHROT is the system phase rotation and influences functions such as sequence calculations (directional element) and the matrix selection for the differential element.

Label	Prompt	Default Value
SID	Station Identifier (40 characters)	Station A
RID	Relay Identifier (40 characters)	Relay 1
NFREQ	Nominal System Frequency (50, 60 Hz)	60
PHROT	System Phase Rotation (ABC, ACB)	ABC

EICIS (Enable Independent Control Input Settings)

Set Enable Independent Control Input Settings = Y to set the de-bounce time of inputs on an individual basis. When EICIS = N, all inputs have the same de-bounce setting.

Label	Prompt	Default Value
EICIS	Independent Control Input Settings (Y, N)	N

EMPU (Enable Synchrophasor)

See *Section 11: Synchrophasors*.

Power Transformer Data (MVA, VTERM[k], TAP[k])

See *Section 4: Protection and Logic Functions*.

FRQST (Primary Frequency Source Terminal)

Use the FRQST setting to select which PT (V or Z) the relay will use for the functions that uses the system frequency, such as V/Hz, synchrophasors, etc.

Label	Prompt	Default Value
FRQST	Primary Frequency Source Terminal (OFF, V, Z)	V

IN1XXD, IN2XXD, IN3XXD (Debounce Time)

Control input settings are only available if EICIS = N, i.e.,when all inputs have the same de-bounce setting. Furthermore, IN2XXD (first I/O board) and IN3XXD (second I/O board) are available only when those interface boards are installed. Although you can set the three boards independently, the setting applies to both pickup and drop-off times of that particular board, i.e., a setting of 10 ms delays the input by 10 ms and also maintains the output for 10 ms after de-assertion.

Label	Prompt	Default Value
IN1XXD	Mainboard Debounce Time (0.0–30.0 ms)	2.0
IN2XXD	Int Board # 1 Debounce Time (0.0–30.0 ms)	2.0
IN3XXD	Int Board # 2 Debounce Time (0.0–30.0 ms)	2.0

IN1XXD (Individual Debounce Time)

If you want to separately set the de-bounce time for each input, then set EICIS = Y. With EICIS = Y, the three individual setting categories (main board, interface board #1 and interface board #2) become available for setting the individual inputs. These settings are not available if EICIS = N.

Label	Prompt	Default Value
IN1[*xx*]PU[a]	Input IN1[*xx*] Pickup Delay (0.0–30.0 ms)	2.0
IN1[*xx*]DO	Input IN1[*xx*] Dropout Delay (0.0–30.0 ms)	2.0

[a] [xx] = 01, 02, 03, 04, 05, 06, 07.

IN2XXD (Individual Debounce Time)

Set the individual settings of Interface board #1. These settings are available only if EICIS = Y and if the interface board is installed.

Label	Prompt	Default Value
IN2[*yy*]PU[a]	Input IN2[*yy*] Pickup Delay (0.0–30.0 ms)	2.0
IN2[*yy*]DO	Input IN2[*yy*] Dropout Delay (0.0–30.0 ms)	2.0

[a] [yy] = 01-24.

IN3XXD (Individual Debounce Time)

Set the individual settings of Interface board #2. These settings are available only if EICIS = Y and if the interface board is installed.

Label	Prompt	Default Value
IN3[*yy*]PU[a]	Input IN3[*yy*] Pickup Delay (0.0–30.0 ms)	2.0
IN3[*yy*]DO	Input IN3[*yy*] Dropout Delay (0.0–30.0 ms)	2.0

[a] [yy] = 01-24.

SGR, TGR (Settings Group Selection)

Use the SS[*c*] (*c* = 1 through 6) to change the Group settings to another Group settings setting group. Default setting shown applies to SS1, i.e., all other default = NA. The Group Change Delay timer setting, TGR, defines the amount of time that must pass before a new group of settings takes effect. This function prevents the relay from jumping around from group to group in response to spurious fulfillment of the SS1 setting conditions and ensures that a request for change is real and justified.

Label	Prompt	Default Value
SS[*c*][a]	Select Setting Group [*c*] (SELOGIC Control Equation)	NA
TGR	Group Change Delay (1–54000 cyc)	180

[a] [c] = 1, 2 . . . 6.

DATE_F, IRIGC (Date and Synchrophasor Time Format)

The DATE_F setting permits you to define either a Month-Day-Year (MDY) format or a Year-Month-Day (YMD) format for all relay date reporting, with the default setting of MDY.

Use the IRIGC setting to set the time format to the synchrophasor C37.118 standard. If IRIGC = NONE then all control field extensions are ignored. Furthermore, if EPMU=Y and MFRMT = C37.118 (see *Section 11: Synchrophasors*), then the relay automatically sets the IRIGC setting to C37.118.

Label	Prompt	Default Value
DATE_F	Date Format (MDY, YMD, DMY)	MDY
IRIGC	IRIG-B Control Bits Definition (NONE, C37.118)	NONE

RST_DEM, RST_PDM, RST_ENE, RSTTRGT, RSTDNPE (Reset Functions)

Use the SELOGIC control equations to reset the demand quantities (RST_DEM), the peak demand quantities (RST_PDM) and the DNP fault summary data after it is read. Resetting the demand and peak demand values resets all the enabled peak demand values.

Label	Prompt	Default Value
RST_DEM	Reset Demand Metering (SELOGIC Control Equation)	NA
RST_PDM	Reset Max Demand Metering (SELOGIC Control Equation)	NA
RST_ENE	Reset Energy Metering (SELOGIC Control Equation)	NA
RSTTRGT	Target Reset	NA
RSTDNPE	Reset DNP Fault Summary Data (SELOGIC Control Equation)	TRGTR

Group Settings

Current Transformer Data (CTR, CTCON, CTRY)

Always enter the CTR[*k*] (*k* = S, T, U, W, X) setting with reference to a 1 A secondary. For example if the S-winding CT ratio is 600/5 CT, then enter CTRS = 120. Use the CTCON[*k*] setting to indicate the CT connection, either Y for wye (star), or D for delta-connected CTs. When entering D (delta-connected CTs) the relay scales the TAP[*k*] value by $\sqrt{3}$ for the differential element, so always enter the phase CT ratio regardless of the CT connection. CTRYA, CTRYB, and CTRYC are single-phase (neutral) CTs, primarily used for restricted earth-fault protection.

Label	Prompt	Default Value
CTR[*k*][a]	Current Trans. Ratio Terminal [*k*] (1–50000)	100
CTCON[*k*]	Current Trans. Connection Terminal [*k*] (Y, D)	Y
CTRY[Ø][b]	Current Trans. Ratio Terminal Y[Ø] (1–50000)	100

[a] [k] = S, T, U, W, X.
[b] [Ø] = 1, 2, 3.

Voltage Transformer Data (PTR, PTCON, PTCOMP, VNOM)

The relay uses the potential transformer ratio (PTR) to convert measured secondary phase-to-neutral voltages into primary phase-phase voltages for display in the meter report. For example, a 230 kV line-to-line voltage has a primary phase-to-neutral voltage of 230 kV/$\sqrt{3}$ = 132.8 kV. Since the secondary line-to-line voltage is 110 V (VNOM), the PTR = 230 kV/110 V ≈ 2000.

Use the PTCOMP[*n*] setting to adjust the PT angle if either the CTs or the PTs are connected in delta. This angular adjustment is available only when CTCON[*k*] = D or when PTCON[*n*] = D (see *Figure 2.28*), and applies to the real (P) and reactive (Q) power calculations only. You cannot adjust the current/voltage angular relationship for any other element or metering values in this way, including the directional elements.

VNOM is the nominal system line-to-line voltage in secondary volts.

Label	Prompt	Default Value
PTR[*n*][a]	Potential Trans. Ratio Terminal [*n*] (1–10000)	2000
PTCON[*n*]	Potential Trans. Connection Terminal [*n*] (Y, D)	Y
PTCOMP[*n*]	PT Comp. Angle Terminal [*n*] (–179.99 to +180 deg)	0
VNOM[*n*]	PT Nominal Voltage (L–L) Term. *n*] (30–300 V, sec)	110

[a] [n] = V, Z.

VREF[k] (Voltage Reference for Terminal [k])

Use the VREF setting to tell the relay which of the two PT values (V or Z) to associate with each current terminal (S, T, U, W, X) when calculating power values. There are no setting to enable power calculations (EPCAL) for combined windings. For combined windings, set the two windings in question to the same VREF setting. For example, if Winding S and Winding T are a combined winding, then set VREFS = V and VREFT = V (or both equal to Z). This causes the relay to calculate power for a combined ST winding.

Label	Prompt	Default Value
VREF[*k*][a]	Voltage Reference For Terminal [*k*] (OFF, V, Z)	OFF

[a] [k] = S, T, U, W, X.

Protection Logic: Default Settings

The SEL-487E provides 250 lines of Free-Form SELOGIC control equations. Following are the protection logic default settings.

1: # BREAKER S OPEN AND CLOSE CMD
2: PCT01IN := PB1 AND 52CLS #CMD TO OPEN BKR S
3: PCT01PU := 60
4: PCT01DO := 0
5: PCT02IN := PB7 AND NOT 52CLS #CMD TO CLOSE BKR S
6: PCT02PU := 60
7: PCT02DO := 0
8: # BREAKER T OPEN AND CLOSE CMD
9: PCT03IN := PB2 AND 52CLT #CMD TO OPEN BKR T
10: PCT03PU := 60
11: PCT03DO := 0
12: PCT04IN := PB8 AND NOT 52CLT #CMD TO CLOSE BKR T
13: PCT04PU := 60
14: PCT04DO := 0
15: PLT03S := PB3_PUL AND NOT PLT03 # DIRECTIONAL OVERCURRENT ENABLED
16: PLT03R := PB3_PUL AND PLT03
17: PLT04S := PB4_PUL AND NOT PLT04 # BREAKER WEAR LEVELS RESET
18: PLT04R := (PB4_PUL AND PLT04) OR RST_BKS OR RST_BKT
19: PLT09S := PB9_PUL AND NOT PLT09 # ADAPTIVE OVERCURRENT ENABLED
20: PLT09R := PB9_PUL AND PLT09

Port Settings

PROTO (Protocol)

Select the desired protocol for each port. To communicate with SEL relays, select PROTO = SEL. On virtual ports, the PROTO setting is hidden and forced to SEL. DNP, MBA and MBB can each be set to one port only. If the relay doesn't support DNP, then the DNP option is hidden.

Label	Prompt	Default Value
EPORT	Enable Port (Y, N)	Y
MAXACC	Maximum Access Level (1, B, P, A, 0, 2, C)	C
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	SEL

MBT (Pulsar 9600 Modem)

Setting MBT = Y enables the Pulsar 9600 modem. When the Pulsar modem is enabled, the SPEED setting is not available, and the baud is fixed at 9600. This setting is hidden and forced to N when PROTO = SEL, RTD, PMU and DNP.

Label	Prompt	Default Value
MBT	Using Pulsar 9600 modem? (Y, N)	N

Communication Settings

Set the baud to 300, 1200, 2400, 4800, 9600, 19200, 38400, or 57600. Setting SPEED:= SYNC (available only on the rear-panel serial ports for which PROTO:= MBA or MBB) places the serial port in synchronous (or externally-clocked) mode. The serial port hardware will synchronize transmit and receive data (TX/RX) to a clock signal applied to the Pin 8 input at any effective baud rate up to 64000. This setting choice will suit certain synchronous communications networks. (See *Section 7: Communications, Interfaces, and Protocols* for more information). Also, the maximum baud is 38400 for PROTO:= MBA or MBB.

When RTDs are used (PROTO = RTD), the speed is fixed at 2400 baud.

Label	Prompt	Default Value
SPEED	Data Speed (300 to 57600, SYNC)	9600

DATABIT

Use the DATABIT setting to select the number of data bits. Table 7.3 shows the permitted data bits for the different protocol settings

Table 6.3 Permitted Data Bit Settings

Protocol Setting	Permitted Data bit Setting
SEL	7 or 8
DNP	8
MBA and MBB	6
RTD	8

Label	Prompt	Default Value
DATABIT	Data Bits (7, 8 bits)	8

PARITY

Use the PARITY setting to set the parity of each port. *Table 6.4* shows the permitted parity settings for the different protocol settings

Table 6.4 Permitted Parity Settings

Protocol Setting	Permitted Parity Setting
PMU	None
DNP	None
MBA and MBB	Odd
RTD	None

Label	Prompt	Default Value
PARITY	Parity (Odd, Even, None)	N

STOPBIT

Use the STOPBIT setting to set the number of stop bits on each port. For PROTO = DNP (also hidden) or RTD, or if MBT = Y (also hidden), the STOPBIT is set to 1.

Label	Prompt	Default Value
STOPBIT	Stop Bits (1, 2 bits)	1

RTSCTS (Hardware handshaking)

Setting RTSCTS = Y enables hardware handshaking (only if PROTO = SEL). This setting is hidden and set to N when PROTO = DNP, MBA, MBB, and RTD.

Label	Prompt	Default Value
RTSCTS	Enable Hardware Handshaking (Y, N)	N

TIMEOUT (Port Time-Out)

The port inactivity time-out can be set 0 through 30 minutes. When setting TIMEOUT = 0, the port will never time-out. This setting is set to OFF when PROTO = MBA, MBB, PMU (also hidden), and RTD.

Label	Prompt	Default Value
TIMEOUT	Port Time-Out (OFF, 1–60 mins)	5

AUTO

The SEL-487E Relay generates automatic messages and sends these messages out the serial port(s) with the SET P setting AUTO = Y. This setting is set to N when PROTO = DNP (also hidden), MBA, MBB, RTD, and PMU (also hidden).

Label	Prompt	Default Value
AUTO	Send Auto-Messages to Port (Y, N)	Y

FASTOP (Enable Fast operate)

Use the FASTOP setting to enable the Fast Operate messages. This setting is not available when PROTO = DNP (also hidden) or RTD.

Label	Prompt	Default Value
FASTOP	Enable Fast Operate Messages (Y, N)	N

TERTIM1, TERSTRN, TERTIM2 (Protocol Settings)

TERTIM1 is the length of time the channel must be idle before checking for the termination string in seconds. TERSTRN is the transparent communication termination string. TERTIM2 is the length of time the channel must be idle before accepting the termination string in seconds. This setting is not available when PROTO = PMU.

Label	Prompt	Default Value
TERTIM1	Initial Delay-Disconnect Sequence (0–600 seconds)	1
TERSTRN	Termination String-Disconn. Sequence (9 char max)	Node: “\005” (CTRL-E)Hub: “\006” (CTRL-F)
TERTIM2	Final Delay-Disconnect Sequence (0–600 seconds)	0

RTDNUM, RTD01TY–RTD12TY

Enter the number of RTDs (RTDNUM) and the type (RTDxxTY) for each selected RTD.

RTD Configuration (SEL-2600)

Label	Prompt	Default Value
RTDNUM	RTD Number of Inputs (0–12)	0
RTD01TY... RTD12TY	RTD1 Type (NA, PT100, NI100, NI120, CU10)	PT100

Section 7

Communications, Interfaces, and Protocols

Overview

This section provides information on communications interface options for the SEL-487E Relay. The following topics are discussed:

Communications Interfaces

A communications interface is the physical connection on the relay that you use to communicate with the relay. Communication with the relay comprises collecting data from the relay, setting the relay, and performing relay test and diagnostic functions. You can establish communication with the SEL-487E either by serial port or through an optional communications card (including Ethernet).

This section describes the serial port connections and protocols; see *Appendix I: Communications Card* for the communications card details.

EIA-232

The SEL-487E has three rear-panel serial ports and one front-panel serial port. These serial ports conform to the EIA/TIA-232 standard (often called RS-232). While these ports are all EIA-232, you can add transceivers or converters to operate on different physical media including EIA-485 and fiber-optic cable.

Figure 7.1 (front-panel serial port) and *Figure 7.2* (rear-panel serial ports) show the serial port locations for the SEL-487E relay. *Figure 7.1* shows the 6U chassis, but the ports are the same on the 7U chassis. The port on the front panel is **PORT F** and the three rear-panel ports are **PORT 1**, **PORT 2**, and **PORT 3**.

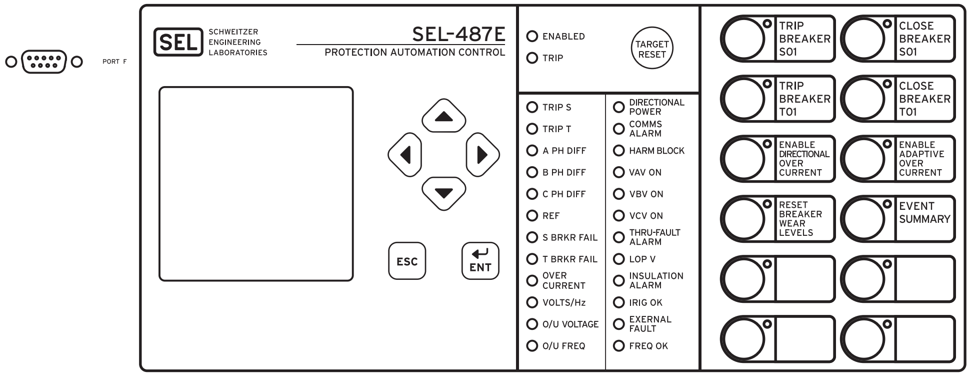


Figure 7.1 SEL-487E 6U Chassis Front-Panel Layout

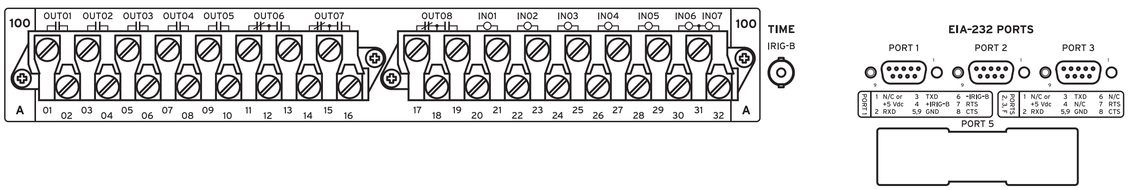


Figure 7.2 SEL-487E 6U Rear-Panel Layout

The EIA-232 ports are standard female 9-pin connectors with the pin numbering shown in *Figure 7.3*.

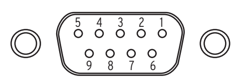


Figure 7.3 EIA-232 Connector Pin Numbers

Table 7.1 lists the pin functions for the EIA-232 standard. Pin 1 can provide power to an external device. See *Serial Port Jumpers on page 2.16* for more information on installing the jumper to provide voltage on Pin 1.

NOTE: Pins 5 and 9 are not intended to provide a chassis ground connection.

Table 7.1 EIA-232 Pin Assignments

Pin	Signal Name	Description	Comments
1	5 Vdc	Modem power	Jumper selectable on PORT 1–PORT 3. No connection on PORT F.
2	RXD	Receive data	
3	TXD	Transmit data	
4	+IRIG-B	Time code signal positive	PORT 1 only. No connection on PORT F, PORT 2, and PORT 3.
5	GND	Signal ground	Also connected to chassis ground.
6	–IRIG-B	Time code signal negative	PORT 1 only. No connection on PORT F, PORT 2, and PORT 3.
7	RTS	Request to send	
8	CTS	Clear to send (input)	
8	TX/RX CLK (for SPEED := SYNC, only available when PROTO := MBA or MBB)	Transmit and receive clock (input)	Rear-panel serial ports only.
9	GND	Chassis ground	

EIA-232 Communications Cables

For most installations, you can obtain information on the proper EIA-232 cable configuration from the SEL-5801 Cable Selector Program. Using the SEL-5801 software, you can choose a cable by application. The software provides the SEL cable number with wiring and construction information, so you can order the appropriate cable from SEL or construct one. If you do not see information for your application, please contact SEL and we will assist you. You can obtain a copy of the SEL-5801 software by contacting SEL or from the SEL website www.selinc.com.

⚠CAUTION
Severe power and ground problems can occur on the communications ports of this equipment as a result of using non-SEL cables. Never use standard null-modem cables with this equipment.

You can connect to a standard 9-pin computer port with the SEL cable C234A for relay configuration and programming with a terminal program or with the ACSELERATOR QuickSet® SEL-5030 Software. See *Figure 2.21* for the construction of SEL cable C234A.

Fiber-Optic Interface

You can add transceivers to the EIA-232 ports to use fiber-optic cables to connect devices. We strongly recommend that you use fiber-optic cables to connect devices within a substation. Power equipment and control circuit switching can cause substantial interference with communications circuits. You can also experience significant ground potential differences during fault conditions that can interfere with communications and damage equipment. Fiber-optic cables provide electrical isolation that increases safety and equipment protection.

Use the SEL-2800 product family transceivers for multimode or single-mode fiber-optic communications. All of these transceivers are port powered, require no settings, and operate automatically over a broad range of data rates. SEL-2800 series transceivers operate over the same wide temperature ranges as SEL relays, providing reliable operations in extreme conditions.

EIA-485

There is no EIA-485 port integral to the SEL-487E. You can install an SEL-2885 or SEL-2886 transceiver to convert one of the rear-panel EIA-232 ports (PORT 1 or PORT 3) on the relay to an EIA-485 port. The SEL-2885 and SEL-2884 are powered by the +5 Vdc output on Pin 1. These transceivers offer transformer isolation not found on most EIA-232-to-EIA-485 transceivers. See the transceiver product flyers for more information. The SEL-2885 offers the SEL distributed port switch (LMD) protocol. With this protocol you can selectively communicate with multiple devices on an EIA-485 network. You can communicate with other network nodes including EIA-232 devices with an SEL-2885 and SEL devices having integral EIA-485 ports.

Hardware Protocol (Serial Port)

The serial ports comply with the EIA/TIA-232 Standard, commonly referred to as EIA-232 (formerly known as RS-232), and supports RTS/CTS hardware flow control.

Hardware Flow Control

Hardware handshaking is one form of flow control that two serial devices use to prevent input buffer information overflow and loss of characters. To support hardware handshaking, connect the RTS output pin of each device to the CTS input pin of the other device. To enable hardware handshaking, use the **SET P** command (or front-panel {SET} pushbutton sequence) to set RTSCTS := Y. Disable hardware handshaking by setting RTSCTS := N. *Table 7.2* shows actions the relay takes for the RTSCTS setting values and the conditions relevant to hardware flow control.

Table 7.2 Hardware Handshaking

Setting RTSCTS Value	Condition	Relay Action
N	All	Assert RTS output pin and ignore CTS input pin.
Y	Normal input reception	Assert RTS output pin.
Y	Local input buffer is close to full	Deassert RTS pin to signal remote device to stop transmitting.
Y	Normal transmission	Sense CTS input is asserted, transmit normally.
Y	Remote device buffer is close to full, so remote device deasserts RTS	Sense CTS input is deasserted, stop transmitting,

Note that the relay must assert the RTS pin to provide power for some modems, fiber-optic transceivers, and hardware protocol converters that are port powered. Check the documentation for any port-powered device to determine if the device supports hardware handshaking or if you must always assert RTS (RTSCTS := N) for proper operation.

Data Frame

The relay ports use asynchronous data frames to represent each character of data. Four port settings influence the framing: SPEED, DATABIT, PARITY, and STOPBIT. The time allocated for one bit is the reciprocal of the SPEED. For example, at 9600 bits per second, one bit-time is 0.104 milliseconds (ms).

The default port framing uses one start bit, 8 data bits, no parity bit, and one stop bit. The transmitter asserts the TXD line for one data frame, as described in the following steps:

- ➤ The TXD pin is normally in a deasserted state.
- ➤ To send a character, the transmitter first asserts the TXD pin for one bit time (start bit).
- ➤ For each data bit, if the bit is set, the transmitter asserts TXD for one bit time. If the bit is not set, it deasserts the pin for one bit time (data bits).
- ➤ If the PARITY setting is E, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an even number. If the PARITY setting is O, the transmitter asserts or deasserts the parity bit so that the number of asserted data bits plus the parity bit is an odd number. If the PARITY setting is N, the data frame does not include a parity bit.
- ➤ At the completion of the data bits and parity bit (if any), the transmitter deasserts the line for one bit time (stop bit). If STOPBIT is set to 2, the transmitter deasserts the line for one more bit time (stop bit).
- ➤ Until the relay transmits another character, the TXD pin will remain in the unasserted state.

Software Protocol Selections

Table 7.3 shows the protocols and command sets that the SEL-487E supports with serial communications.

Table 7.3 Supported Serial Command Sets

PROTO Setting Value	Command Set	Description
SEL	SEL ASCII	Commands and responses
SEL	SEL Compressed ASCII	Commands and comma-delimited responses
SEL	SEL Fast Meter	Binary meter and digital element commands and responses
SEL	SEL Fast Operate	Operate Binary operation commands
SEL	SEL Fast SER	Binary SER commands and responses
SEL	SEL Fast Message Data Access	Binary data (Relay Word bit) transfer
MBA or MBB	SEL MIRRORED BITS® communications	Binary high-speed control commands
PMU	Phasor Measurement Unit	Binary synchrophasor protocol, as selected by Global Setting MFRMT and Port Setting PMUMODE
PMU	SEL Fast Operate	Binary operation commands
RTD	SEL Fast Message protocol for Resistance Temperature Detector (RTD) data	Up to 12 analog temperature readings from the SEL-2600A or SEL-2600D
DNP	DNP3 Level 2	Slave Binary commands and responses

Virtual Serial Ports

In addition to actual serial ports, the SEL-487E supports several virtual serial ports. A virtual serial port does the following:

- Transmits and receives characters through a different mechanism than the physical serial port
- "Encapsulates" characters in virtual terminal messages of a different protocol
- Simulates an actual serial port with setting PROTO := SEL
- May have restrictions imposed by the protocol that encapsulates the virtual serial data

You can set the SEL-487E to use virtual serial ports encapsulated in SEL MIRRORED BITS communications links, DNP3 links, and through the Telnet mechanism of an installed Ethernet card.

Active Protocol When Setting PROTO := SEL

This subsection describes the command sets that are active when the port setting PROTO := SEL. You can also access these protocols through virtual serial ports that simulate ports with PROTO := SEL.

SEL ASCII Commands

SEL originally designed the SEL ASCII commands for communication between the relay and a human operator via a keyboard and monitor or a printing terminal. A computer with a serial port can also use the SEL ASCII protocol to communicate with the relay, collect data, and issue commands. The ASCII character set specifies numeric codes that represent printing characters and control characters. *Table 7.4* shows the subset of the ASCII control characters used in this section.

Table 7.4 Selected ASCII Control Characters

Decimal Code	Name	Usage	Keystroke(s)
13	CR	Carriage return	**<Enter>** or **<RETURN>** or **<Ctrl+M>**
10	LF	Line feed	**<Ctrl+J>**
02	STX	Start of transmission	**<Ctrl+B>**
03	ETX	End of transmission	**<Ctrl+C>**
24	CAN	Cancel	**<Ctrl+X>**
17	XON	Flow control on	**<Ctrl+Q>**
19	XOFF	Flow control off	**<Ctrl+S>**

The **<Enter>** key on standard keyboards sends the ASCII character CR for a carriage return. This manual instructs you to press the **<Enter>** key after commands to send the proper ASCII code to the relay. A correctly formatted command transmitted to the relay consists of the command, including optional parameters, followed by either a CR character (carriage return) or CR and LF characters (carriage return and line feed). The following line contains this information in the format this manual uses to describe user input:

<command> <Enter> or **<command> <CR> <LF>** or **<Enter> <LF>**

You may truncate commands to the first three characters. For example, **EVENT 1 <Enter>** is equivalent to **EVE 1 <Enter>**. You may use upper- and lowercase characters without distinction, except in passwords.

In response to a command, the relay may respond with an additional message. The relay transmits dialog lines in the following format:

```
<DIALOG LINE ><CR><LF>
```

The relay transmits messages in the following format:

```
<STX><MESSAGE LINE 1><CR><LF>
<MESSAGE LINE 2><CR><LF>
...
<LAST MESSAGE LINE><CR><LF>< ETX>
```

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX. Each line of the message ends with a carriage return, CR, and line feed, LF.

Send the CAN character to the relay to abort a transmission in progress. For example, if you request a long report and want to terminate transmission of this report, depress the **<Ctrl>** and **<X>** keys (**<Ctrl+X>**) to terminate the report.

SEL Compressed ASCII Commands

The relay supports a subset of SEL ASCII commands identified as Compressed ASCII commands. Each of these commands results in a comma-delimited message that includes a checksum field. Most spreadsheet and database programs can directly import comma-delimited files. Devices with embedded processors connected to the relay can execute software to parse and interpret comma-delimited messages without expending the customization and maintenance labor needed to interpret nondelimited messages. The relay calculates a checksum for each line by numerically summing all of the bytes that precede the checksum field in the message. The program that uses the data can detect transmission errors in the message by summing the characters of the received message and comparing this sum to the received checksum.

Most commands are available only in SEL ASCII or Compressed ASCII format. Selected commands have versions in both standard SEL ASCII and Compressed ASCII formats. Compressed ASCII reports generally have fewer characters than conventional SEL ASCII reports, because the compressed reports reduce blanks, tabs, and other white space among data fields to a single comma.

Compressed ASCII Message Format

Each message begins with the start-of-transmission character, STX, and ends with the end-of-transmission character, ETX:

```
<STX><MESSAGE LINE 1><CR><LF>
<MESSAGE LINE 2><CR><LF>
...
<LAST MESSAGE LINE><CR><LF><ETX>
```

Each line in the message consists of one or more data fields, a checksum field, and a CRLF. Commas separate adjacent fields. Each field is either a number or a string. Number fields contain base-10 numbers using the ASCII characters 0–9, plus (+), minus (-), and period (.). String fields begin and end with quote marks and contain standard ASCII characters. Hexadecimal numbers are contained in string fields.

The checksum consists of four ASCII characters that are the hexadecimal representation of the two-byte binary checksum. The checksum value is the sum of the first byte on a line (first byte following <STX>, <CR>, or <CR><LF>) through the comma preceding the checksum.

If you request data with a Compressed ASCII command and these data are not available, (in the case of an empty history buffer or invalid event request), the relay responds with the following Compressed ASCII format message:

```
<STX>“No Data Available”“0668”<CR><ETX>
```

where:

`No Data Available`	is a text string field.
`0668`	is the checksum field, which is a hexadecimal number represented by a character string.

Table 7.5 lists the Compressed ASCII commands and contents of the command responses. The Compressed ASCII commands are described in *Section 13: ASCII Command Reference*.

Table 7.5 Compressed ASCII Commands

Command	Response	Access Level[a]
BNAME	ASCII names of Fast Meter status bits	0
CASCII	Configuration data of all Compressed ASCII commands available at access levels > 0	0
CBREAKER	Circuit breaker data	1
CEVENT	Event report	1
CHISTORY	List of events	1
CSER	Sequential Events Recorder report	1
CSTATUS	Self-diagnostic status	1
CSUMMARY	Summary of an event report	1
DNAME	ASCII names of digital I/O reported in Fast Meter	0
ID	Relay identification	0
SNS	ASCII names for SER data reported in Fast Meter	0

[a] For more information on access levels, see Table 13.1 and Access Levels on page 14.7.

CASCII Configuration Message for Compressed Level 0 ASCII Commands

The CASCII message provides a block of data for each of the Compressed ASCII commands supported by an SEL device. The block of data for each command provides message description information to allow automatic data extraction. The relay arranges items in the Compressed ASCII configuration message in a predefined order. For the purpose of improving products and services, SEL sometimes changes the items and item order. The information presented below explains the message and serves as a guide to the items in Compressed ASCII configuration messages.

NOTE: Compressed ASCII is self-describing and may vary with the firmware version of your relay. Before you program a master device to send and parse Compressed ASCII commands and responses, you should perform a **CASCII** command on your relay or contact SEL for more detailed information.

A Compressed ASCII command can require multiple header and data configuration lines. The general format of a Compressed ASCII configuration message is the following:

```
<STX>"CAS",n,"yyyy"<CR><LF>
"COMMAND 1",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF>
.
.
.
"COMMAND n",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><LF><ETX>
```

Definitions for the items and fields in a Compressed ASCII configuration message are the following:

- `n` is the number of Compressed ASCII command descriptions to follow.
- `COMMAND` is the ASCII name for the Compressed ASCII command that the requesting device (terminal or external software) sends. The naming convention for the Compressed

ASCII commands is a C character preceding the typical command. For example, **CSTATUS**, abbreviated to **CST**, is the Compressed ASCII **STATUS** command.

- `#H` identifies a header line to precede one or more data lines; the # character represents the number of subsequent ASCII names. For example, 21H identifies a header line with 21 ASCII labels.
- `xxxxx` is an ASCII name for corresponding data on following data lines. Maximum ASCII name width is 10 characters.
- #`D` identifies a data format line; the # character represents the maximum number of data lines in command response.
- `ddd` identifies a format field containing one of the following type designators:
  - I—Integer data
  - F—Floating point data
  - *z*S—String of maximum *z* characters (for example, enter 10S for a 10-character string)
- `yyyy` is the 4-byte hex ASCII representation of the checksum. Every checksum is followed by a new line indication (<CR><LF>).

Software Flow Control

Software handshaking is a form of flow control that two serial devices use to prevent input buffer overflow and loss of characters. The relay uses XON and XOFF control characters to implement software flow control for ASCII commands.

The relay transmits the XOFF character when the input buffer is more than 75 percent full. The connected device should monitor the data it receives for the XOFF character to prevent relay input buffer overflow. The external device should suspend transmission at the end of a message in progress when it receives the XOFF character. When the relay has processed the input buffer so that the buffer is less than 25 percent full, the relay transmits an XON character. The external device should resume normal transmission after receiving the XON character.

The relay also uses XON/XOFF flow control to delay data transmission to avoid overflow of the input buffer in a connected device. When the relay receives an XOFF character during transmission, it pauses transmission at the end of the message in progress. If there is no message in progress when the relay receives the XOFF character, it blocks transmission of any subsequent message. Normal transmission resumes after the relay receives an XON character.

Interleaved ASCII and Binary Messages

SEL relays have two separate data streams that share the same physical serial port. Human data communications with the relay consist of ASCII character commands and reports that you view using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information; the ASCII data stream continues after the interruption. This mechanism uses a single communications channel for ASCII communication (transmission of an event report, for example) interleaved with short bursts of binary data to support fast acquisition of metering data.

The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. However, you do not need a device to interleave data streams in order to use the binary or ASCII commands. Note that XON, XOFF, and CAN operations operate on only the ASCII data stream.

An example of using these interleaved data streams is when the SEL-487E communicates with an SEL Communications Processor. The communications processor performs auto-configuration by using a single data stream and SEL Compressed ASCII and binary messages. In subsequent operations, the communications processor uses the binary data stream for Fast Meter, Fast Operate, and Fast SER messages to populate a local database and to perform SCADA operations. At the same time, you can use the ASCII data stream to connect transparently to the SEL-487E and use the ASCII data stream for commands and responses.

Automatic Messages

If you enable automatic messages, AUTO = Y, the SEL-487E issues a message any time the relay powers up, asserts a self-test, changes to another settings group, or triggers an event. For virtual ports, the relay issues automatic messages only if the connection is active. Automatic messages contain the following information:

- Power up: On power up, the message provides the terminal ID and the present date and time.
- Self-test failure: When the relay detects an internal failure, the automatic message is the same as the relay response to the **STATUS** command.
- Group switch: Whenever a settings group change occurs, the message contains the relay ID, terminal ID, present date, and time, and the selected settings group.
- Events: When the relay triggers an event, the automatic message is the same as the relay response to the **SUMMARY** command.

Timeout

Use the TIMEOUT setting to set the idle time for each port. Idle time is the period when no ASCII characters are transmitted and received (interleaved fast messages do not affect the idle time). When the idle time exceeds the TIMEOUT setting, the following takes place:

- The access level changes to Access Level 0.
- The front-panel targets reset to TAR 0 if the port had previously remapped the targets.
- Virtual connections are disconnected.
- The software flow control state changes to XON. When set to OFF, the port never times out.

SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access

SEL Fast Meter is a binary message that you solicit with binary commands. Fast Operate is a binary message for control. The relay can also send unsolicited Fast SER messages automatically. If the relay is connected to an SEL communications processor, these messages provide the mechanism that the communications processor uses for SCADA or DCS functions that occur simultaneously with ASCII interaction (see *Table C.6* for the settings).

This section summarizes the binary commands and messages and includes our recommendation for using Fast Commands and Compressed ASCII configuration information to communicate with the relay. You need this information to develop or specify the software an external device uses to communicate using Fast Messages with the SEL-487E. To support this type of development, you will also need to contact SEL for Fast Message protocol details.

Table 7.6 lists the two-byte Fast Commands and the actions the relay takes in response to each command.

Table 7.6 Fast Commands and Response Descriptions

Command (Hex)	Name	Description
A5B9h	Status acknowledge message	Clears Fast Meter status byte and sends current status.
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information.
A5C1h	Fast Meter configuration block	Defines contents of Fast Meter data message.
A5C2h	Demand Fast Meter configuration block	Defines contents of demand Fast Meter data message.
A5C3h	Peak demand Fast Meter configuration block	Defines contents of peak demand Fast Meter data message.
A5CEh	Fast Operate configuration block	Defines available circuit breaker, remote bits, and associated commands, if setting FASTOP :=Y for this port.
A5D1h	Fast Meter data message	Defines present values of analog and digital data.
A5D2h	Demand Fast Meter data message	Defines values of most recently completed demand period.
A5D3h	Peak demand Fast Meter data message	Defines values for peak demands as of end of most recently completed demand periods.

Fast Operate commands use one of the two-byte command types shown in *Table 7.7*. Each Fast Operate command also includes additional bytes that specify a remote bit or circuit breaker bit.

Table 7.7 Fast Operate Command Types

Command (Hex)	Name	Description
A5E0h	Fast Operate command for remote bits	Sends command code that will change the state of a remote bit, if setting FASTOP := Y for this port.
A5E3h	Fast Operate command for circuit breaker bits	Sends command code that will change the state of a circuit breaker control bit, if setting FASTOP :=Y for this port.

The Fast Operate messages transfer control commands through the binary data stream. You must enable Fast Operate messages for a port before the relay accepts these messages on that port. In the port settings, when the protocol is set to SEL, the FASTOP setting is visible. Set FASTOP :=Y to enable Fast Operate commands or to N to disable Fast Operate commands.

General Fast Messages have a two byte identifier (A546h) and a function code. Fast SER messages are general Fast Messages that transport Sequential Event Recorder report information. The Fast SER messages include function codes to accomplish different tasks. *Table 7.8* lists the Fast SER function codes and the actions the relay takes in response to each command.

Table 7.8 Fast Message Command Function Codes Used With Fast SER (A546 Message) and Relay Response Descriptions

Function Code (Hex)	Function	Relay Action
00h	Fast message definition block request	Relay transmits Fast Message definition request acknowledge (Function Code 80).
01h	Enable unsolicited transfers	Relay transmits Fast SER command acknowledged message (Function Code 81) and sets relay element bit FSERx. Relay will transmit subsequent SER events (Unsolicited SER broadcast, Function Code 18).
02h	Disable unsolicited transfers	Relay sends Fast SER command acknowledged message (Function Code 82) and clears relay element bit FSERx. Relay will not transmit subsequent SER messages.
05h	Ping; determine channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85).
98h	Fast SER message acknowledge	Relay completes dialog processing for unsolicited message sequence.
30h	Device description request	Relay sends summary of data blocks available (Function Code B0h).
31h	Data format request	Relay sends description of requested data block, including data labels and types (Function Code B1h).
33h	Bit label request	Relay sends set of bit labels for specific data item (Function Code B3h).
10h	Data request	Relay responds with set of requested data (Function Code 90h).

The SEL Fast Message Synchrophasor protocol is covered in *Section 11: Synchrophasors*.

Recommended Use of Relay Self-Description Messages for Automatic Configuration

Compressed ASCII and Fast Message commands provide information to allow an external computer-based device to adapt to the special messages for each relay. The SEL Communications Processors use the self-description messages to configure a database and name the elements in the database.

Table 7.9 lists commands and command usage in the recommended order of execution for automatic configuration.

Table 7.9 Commands in Recommended Sequence for Automatic Configuration

Command ASCII or hexadecimal (h suffix)	Response	Usage
ID	Relay identification	ID and FID
A5C0h	Relay Fast Meter definition block	Defines available Fast Meter messages and general relay configuration information
A5C1h, A5C2h, A5C3h	Fast Meter configuration blocks	Defines contents of Fast Meter data messages
A546h, function code 0	Fast message definition block request	Supported fast message information
BNAME	Binary names	ASCII names of status bits
DNAME	Digital I/O name	ASCII names of digital I/O points
SNS	SER names	ASCII names for SER data points
CASCII	Compressed ASCII configuration block	Configuration data for Compressed ASCII commands with access levels > 0
A5CEh	Fast Operate configuration block	Defines available circuit breaker and remote bits, and associated commands, if setting FASTOP := Y for this port

Virtual File Interface

You can retrieve and send data as files through the SEL-487E virtual file interface. Devices with embedded computers can also use the virtual file interface. When using serial ports or virtual terminal links, use the **FILE DIR** command. When you use a communications card, the file transfer protocol(s) supported by the card can present the file structure and send and receive files.

The SEL-487E has a two-level file structure. There is one file at the root level and three subdirectories or folders. *Table 7.10* shows the directories and the contents of each directory.

Table 7.10 Virtual File Structure

Directory	Usage	Access Level
root	CFG.TXT file, and the SETTINGS, REPORTS, and EVENTS directories (below)	1
SETTINGS	Relay settings	1
REPORTS	SER, circuit breaker, and history reports	1
EVENTS	EVE, CEV, COMTRADE, and history reports	1
Synchrophasors	Synchrophasor reports	1

System Data Format (SDF)

Settings files and the CFG.TXT file use the SDF (System Data Format) unless otherwise specified. The files may contain keywords to aid external support software parsing. A keyword is defined as a string surrounded by the open and close bracket characters, followed by a carriage return and line feed. Only one keyword is allowed per line in the file. For example, the keyword INFO would look like this in the file: [INFO]<CR><LF>.

Records are defined as comma-delimited text followed by a carriage return and line feed. One line in a text file equals one record. Fields are defined as comma-delimited text strings.

Comma-Delimited Text Rules

Field strings are separated by commas or spaces and may be enclosed in optional double quotation marks. Double quotes within the field string are repeated to distinguish these double quotes from the quotes that surround the field string. Delimiters are spaces and commas that are not contained within double quotes. Two adjacent commas indicate an empty string, but spaces that appear next to another delimiter are ignored.

Consider the following examples for converting a list of fields to comma-delimited text. Consider the following list of fields:

Stri,ng 1

Stri”ng 2

String 3

String4

The translation to comma-delimited text is as follows:

“Stri,ng 1”,“Stri”“ng 2”,“String 3”,“String4”

Root Directory

The root directory contains three subdirectories and one file, CFG.TXT.

CFG.TXT File (Read-Only)

The CFG.TXT file contains general configuration information about the relay and each setting class. External support software retrieves the CFG.TXT file to interact automatically with the connected relay.

Settings Directory

You can access the relay settings through files in the SETTINGS directory. We recommend that you use support software to access the settings files, rather than directly accessing the text files. External settings support software functions by reading settings from all of these files. The relay only allows you to write to the individual SET_*cn* files, where *c* is the settings class code and *n* is the settings instance. Changing settings with external support software involves the following steps:

Step 1. The PC software reads the CFG.TXT and SET_ALL.TXT files from the relay.

Step 2. You modify the settings at the PC.

For each settings class that you modify, the software sends a SET_*cn*.TXT file to the SEL-487E.

Step 3. The PC software reads the ERR.TXT file.

If it is not empty, the relay detects errors in the SET_*cn*.TXT file.

Step 4. For any detected errors, modify the settings and send the settings until the relay accepts your settings.

Step 5. Repeat *Step 2* through *Step 4* for each settings class that you want to modify.

Step 6. Test and commission the relay.

SET_ALL.TXT File (Read-Only)

The SET_ALL.TXT file contains all of the settings for all of the settings classes in the relay.

SET_cn.TXT Files (Read and Write)

There is a file for each instance of each setting class. *Table 7.11* summarizes the settings files. The settings class is designated by *c*, and the settings instance number is *n*.

ERR.TXT (Read-Only)

The ERR.TXT file contents are based on the most recent SET_*cn*.TXT file you wrote to the relay. If there were no errors, the file is empty. If errors occurred, the relay logs these errors in the ERR.TXT file.

Table 7.11 Settings Directory Files

Settings Class	Filename	Settings Description	Read Access Level	Write Access Level
S	SET_S*n*.TXT	Group *n*; *n* in range 1–6	1, B, P, A, O, 2	P, 2
G	SET_G1.TXT	Global	1, B, P, A, O, 2	P, A, O, 2
R	SET_R1.TXT	Report	1, B, P, A, O, 2	P, A, O, 2
P	SET_P*n*.TXT	Port; *n* in range 1, 2, 3, 5, F	1, B, P, A, O, 2	P, A, O, 2
D	SET_D1.TXT	DNP remapping (serial)	1, B, P, A, O, 2	P, A, O, 2
F	SET_F1.TXT	Front panel	1, B, P, A, O, 2	P, A, O, 2
O	SET_O1.TXT	Contact outputs	1, B, P, A, O, 2	O, 2
A	SET_A*n*.TXT	Automation; *n* in range 1–10	1, B, P, A, O, 2	A, 2
L	SET_L*n*.TXT	Protection logic; *n* in range 1–6	1, B, P, A, O, 2	P, 2
T	SET_T1.TXT	Alias settings	1, B, P, A, O, 2	P, A, O, 2
M	SET_M1.TXT	Monitor settings	1, B, P, A, O, 2	P, 2
All	SET_ALL.TXT	All instances of all settings classes	1, B, P, A, O, 2	NA
All	ERR.TXT	Error log for most recently written settings file	1, B, P, A, O, 2	NA
N	N1.TXT	Notes settings	1, B, P, A, O, 2	
B	B1.TXT	Bay Control (mimic) settings	1, B, P, A, O, 2	

Ethernet Card Subdirectory

If an Ethernet card with the DNP3 protocol is installed into an SEL-487E, the card settings subdirectory (CARD) is accessible as a subdirectory of the SETTINGS directory, as shown in *Table 7.12*.

Table 7.12 CARD Subdirectory

Path and Filename	File Description	Read Access Level	Write Access Level
\SETTINGS\CARD\SET_DNP*n*.TXT	DNP custom remapping (Ethernet); *n* in range 1–5	1, B, P, A, O, 2	P, A, O, 2
\SETTINGS\CARD\ERR.TXT	List of all error messages from the last write of a settings file (SET_CC1.TXT or SET_DNP*n*.TXT)	1, B, P, A, O, 2	NA

Reports Directory

Use the REPORTS directory to retrieve files that contain the reports shown in *Table 7.13*. Note that the relay provides a report file that contains the latest information each time you request the file. You can use the **FILE DIR REPORTS** command to display the contents of the REPORTS directory.

Table 7.13 REPORTS Directory Files

File	Usage: All are read-only files
BRE_S.TXT	BRE S H report (Circuit breaker S)
BRE_SS.TXT	BRE S report (Circuit breaker S)
BRE_ST.TXT	BRE T report (Circuit breaker T)
BRE_SU.TXT	BRE U report (Circuit breaker U)
BRE_SW.TXT	BRE W report (Circuit breaker W)
BRE_SX.TXT	BRE X report (Circuit breaker X)
BRE_T.TXT	BRE T H report (Circuit breaker T)
BRE_U.TXT	BRE U H report (Circuit breaker U)
BRE_W.TXT	BRE W H report (Circuit breaker W)
BRE_X.TXT	BRE X H report (Circuit breaker X)
CBRE.TXT	Compressed ASCII CBR report for all circuit breakers
CHISTORY.TXT	Compressed ASCII history file
CPRO.TXT	Compressed ASCII signal profile file
CSER.TXT	Compressed ASCII SER report file
HISTORY.TXT	History file
PRO.TXT	Signal profile file
SER.TXT	SER report file
TFE.TXT	Through-fault report file
THE.TXT	Thermal element report file
THE_D.TXT	Thermal element daily report file
THE_H.TXT	Thermal element hourly report file

Events Directory

The relay provides history, event reports, and oscillography files in the EVENTS directory. Event reports are available in the following formats: SEL ASCII 4- or 8-samples/cycle reports and Compressed ASCII 4- or 8-samples/cycle reports. The size of each event report file is determined by the LER setting in effect at the time the event is triggered. Higher resolution oscillography is available in binary COMTRADE (IEEE C37.111-1999) format at the sample rate (SRATE) and length (LER) settings in effect at the time the event is triggered. You can use the **FILE DIR EVENTS** command to display the contents of the EVENTS directory.

The 4- and 8-samples/cycle report files (files with names that begin with E or C) are text files with the same format as the **EVENT** and **CEVENT** command responses. Event file names start with the prefix E4_, E8_, C4_, C8_, or HR_, followed by a unique event serial number. For example, if one event is triggered, with serial number of "10001," the EVENTS directory contains the files shown in *Table 7.14*. Event oscillography in COMTRADE format consists of three files (.CFG, .DAT, and .HDR) that conform to the COMTRADE standard.

Table 7.14 EVENTS Directory Files (for event 10001)

File	Usage
HISTORY.TXT	History file; read-only
CHISTORY.TXT	Compressed ASCII History file; read-only
C4_10001.TXT	4-samples/cycle Compressed ASCII event report; read-only
C8_10001.TXT	8-samples/cycle Compressed ASCII event report; read-only
E4_10001.TXT	4-samples/cycle event report; read-only
E8_10001.TXT	8-samples/cycle event report; read-only
HR_10001.CFG	Sample/second COMTRADE configuration file; read-only
HR_10001.DAT	Sample/second COMTRADE binary data file; read-only
HR_10001.HDR	Sample/second COMTRADE header file; read-only

Table 7.15 shows the synchrophasor directory. The data in the record conforms to the C37.118 data format.

Table 7.15 Synchrophasor Directory

File	Description
080528,160910,0,ONA,1,ABC.PMU	080528 = date 160910 = time 0 = GMT (no time offset) ONA = Last three letter (spaces removed) of the PMSTN setting 1 = PMID setting ABC = CONAM setting (company name) PMU = file extension indicating synchrophasor recording file

SEL-2600A RTD Module Operation

The SEL-2600A RTD Module Protocol (RTD) enables communication with an SEL-2600A via an SEL-2800 (EIA-232 to Fiber-Optic) Transceiver. *Figure 7.4* shows two RTDs connected to an SEL-2600A, which in turn connects to an SEL-487E through an SEL-2800 transceiver.

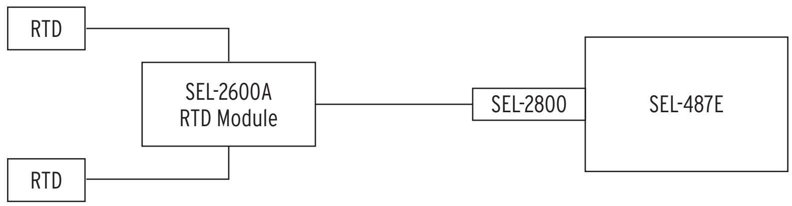


Figure 7.4 SEL-2600A RTD Module and the SEL-487E

This protocol supports data acquisition of up to 12 temperature channels and places the results directly into predefined analog quantities (RTD01–RTD12) inside the relay for use in free-form SELOGIC applications. For more information on the SEL-2600A or SEL-2800, contact your local technical service center, the SEL factory, or visit the SEL website (www.selinc.com) for a copy of the SEL-2600A and SEL-2800 product flyers.

Initialization

Perform the following steps to prepare the SEL-487E for communicating with an SEL-2600A RTD module:

Step 1. Set the desired port to RTD protocol.

Step 2. Set the port setting RTDNUM to the number of RTDs attached to the SEL-2600A.

Step 3. Set the RTD type settings (RTD*nn*TY) to the appropriate RTD type.

Step 4. Connect the SEL-2600A RTD Module to the port via the SEL-2800 (EIA-232 to Fiber-Optic) Transceiver.

Operational Overview

NOTE: When a channel status bit is not asserted, the data in the respective analog quantity is the last valid temperature, not the current temperature.

The SEL-2600A RTD module sends all temperature measurements to the relay every 0.5 seconds. The relay places the received temperature measurements into analog quantities RTD01 through RTD12 for use in free-form SELOGIC applications. The data range is from –50 to +250°C.

If the relay stops receiving valid analog quantities from a certain channel, the temperature stored in the relay freezes at the last received value. Fifteen status bits help supervise decisions based on temperature measurements. *Table 7.16* describes how to interpret the status bits.

Table 7.16 RTD Status Bits

RTD Status Bit	Description
RTDFL	Asserts if the SEL-2600A experiences an internal problem.
RTDCOMF	Asserts if the relay does not receive a valid measurement from the SEL-2600A for 1.25 seconds.
RTD01ST–RTD12ST	Assert when an RTD is attached to a channel and the SEL-2600A is able to read RTD.

To view the temperature measurements received from the SEL-2600A, issue the **MET RTD** command, as depicted in *Figure 7.5*.

```
=>>MET RTD <Enter>
Relay 1                                     Date: 05/17/2003  Time: 13:42:13.220
Station A                                   Serial Number: 2008030645
RTD Input Temperature Data (deg. C)
RTD  1 = -48
RTD  2 = Channel Failure
RTD  3 =   0
RTD  4 =  24
RTD  5 = Channel Not Used
RTD  6 =  72
RTD  7 = Channel Failure
RTD  8 = 120
RTD  9 = Channel Not Used
RTD 10 = 168
RTD 11 = 192
RTD 12 = 216
```

Figure 7.5 MET RTD Command Response

The **MET RTD** command displays the following messages:

- `Channel Failure`: This message is displayed for each channel whose channel status bit is not asserted.
- `Channel Not Used`: This message is displayed for each channel whose channel type is set to NA.

When there is a status problem with the SEL-2600A RTD module, the **MET RTD** command will respond with an informational message, as shown in *Figure 7.6*.

```
=>>MET RTD
SEL-2600 Failure
```

Figure 7.6 MET RTD Command Response for Status Problem

The three possible messages for status problems, with their interpretation, are indicated in *Table 7.17*.

Table 7.17 MET RTD Command Status Messages

Message	Interpretation
SEL-2600 Failure	RTDFL status bit asserted
Communication Failure	RTDCOMF status bit asserted
No data available	Port Protocol not set to RTD
Channel Failure	RTD*xx*ST status bit asserted

SEL MIRRORED BITS Communications

With SEL-patented MIRRORED BITS communications protocol, protective relays and other devices can directly exchange information quickly, securely, and with minimal cost. Use MIRRORED BITS communications for remote control or remote sensing. SEL products support several variations of MIRRORED BITS communications protocols. Through port settings, you can set the SEL-487E for compatible operation with SEL-300 series relays, the SEL-2505 Remote I/O Modules, and the SEL-2100 Logic Processors. These devices use MIRRORED BITS communications to exchange the states of eight logic bits. You can also use settings to select extensions of the MIRRORED BITS communications protocols, available only in SEL-400 series relays, to exchange analog values, synchronize clocks, and engage in virtual terminal dialogs. *Table 7.18* summarizes MIRRORED BITS communications features.

Table 7.18 MIRRORED BITS Communications Features

Feature	Compatibility
Transmit and receive logic bits	SEL-300 series relays, SEL-2505, SEL-2100, SEL-400 series relays
Transmit and receive analog values	SEL-400 series relays
Synchronize time	SEL-400 series relays
Send and receive virtual serial port characters	SEL-400 series relays
Support synchronous communications channel	SEL-400 series relays

Communications Channels and Logical Data Channels

NOTE: Complete all of the port settings for a port that you use for MIRRORED BITS communications before you connect an external MIRRORED BITS communications device. If you connect a MIRRORED BITS communications device to a port that is not set for MIRRORED BITS communications operation, the port will be continuously busy.

The SEL-487E supports two MIRRORED BITS communications channels, designated A and B. Use the port setting PROTO to assign one of the MIRRORED BITS communications channels to a serial port; PROTO := MBA for MIRRORED BITS communications Channel A or PROTO := MBB for MIRRORED BITS communications Channel B. Transmitted bits include TMB1A–TMB8A and TMB1B–TMB8B. The last letter (A or B) designates the channel with which the bits are associated. These bits are controlled by SELOGIC control equations. Received bits include RMB1A–RMB8A and RMB1B–RMB8B. You can use received bits as arguments in SELOGIC control equations.

The channel status bits are ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, DOKA, ANOKA, DOKB, and ANOKB. You can also use these bits as arguments in SELOGIC control equations. Use the **COM** command for additional channel status information. Within each MIRRORED BITS communications message for a given channel (A or B), there are eight logical data channels (1–8). In operation compatible with other SEL products, you can use the eight logical data channels for TMB1 through TMB8. If you use fewer than eight transmit bits, Data Channel 8 is reserved to support data framing and time synchronization features. You can assign the eight logical data channels as follows:

- ➤ Logic Bits. Setting MBNUM controls the number of channels used for logic bits, TMB1–TMB8, inclusive.
  - ➢ If you set MBNUM to 8, then you cannot use channels for any of the following features.
  - ➢ If you set MBNUM less than 8, you can use the remaining channels (up to a total of eight) for the following features.
- ➤ Message and Time Synchronization. If MBNUM is less than 8, the relay dedicates a logical data channel to message framing and time synchronization.

- Analog Channels. Setting MBNUMAN controls the number of Analog Channels.
  - If MBNUM := 8, all channels are used for logic bits and MBNUMAN is forced to 0.
  - If MBNUM := 7, seven channels are used for logic bits and one channel is used for message and time synchronization, and MBNUMAN is forced to 0.
  - If MBNUM is less than 7, you can use the remaining channels for analog channels by setting the desired number of channels in MBNUMAN (1 to 7 – MBNUM).
- Virtual Terminal Sessions. Setting MBNUMVT controls the number of additional channels available for the virtual terminal session.
  - If MBNUMVT := OFF, the relay does not dedicate any additional channels to the virtual terminal session.
  - If there are spare channels (7 – MBNUM – MBNUMAN > 0), you can use MBNUMVT to dedicate these additional channels to the virtual terminal session.
  - With MBNUM = 7 or less and MBNUMVT = 0, virtual terminal is still possible, because the relay uses the eighth element for time synchronization and virtual terminal.

The virtual terminal session uses channels differently than other data exchange mechanisms. There can only be one active virtual terminal session across a MIRRORED BITS link. One channel, included in the synchronization data, is always dedicated to this virtual terminal session. If you assign additional channels to the virtual terminal session (set MBNUMVT > 0), you will improve the performance of the virtual terminal session. The relay uses the additional channels to exchange data more quickly.

Operation

Message Transmission

MIRRORED BITS communications messages are transmitted as a function of the transmission mode and modem settings, as shown in *Table 7.21*. Each message contains the most recent values of the transmit bits. If you enabled any of the extended features through the settings, note that the relay transmits a portion of the extended data in each message.

If you have specified virtual terminal data channels for this port, the designated data channels are normally idle. If you use the **PORT** command to open a virtual terminal session for this port and type characters, the relay transmits these characters through the virtual terminal logical data channels.

Message Reception Overview

When the devices are synchronized and the MIRRORED BITS communications channel is in a normal state, the relay decodes and checks each received message. If the message is valid, the relay performs the following operations:

- Sends each received logic bit (RMB*n*) to the corresponding pickup and dropout security counters, that in turn set or clear the RMB*nc* relay element bits.
- For 16 out of 18 messages, builds the analog datum for each analog data point; on the 18th message, processes the analog data.
- For 16 out of 18 messages, buffers the received characters for each MIRRORED BITS communications virtual serial logical channel; on receiving the 18th message, treats the character exactly as a character from an actual serial port.

Message Decoding and Integrity Checks

The relay provides indication of the status of each MIRRORED BITS communications channel, with element bits ROKA and ROKB. During normal operation, the relay sets the ROK*c* bit. The relay clears the bit upon detecting any of the following conditions:

- Parity, framing, or overrun errors
- Receive data redundancy error
- Receive message identification error
- No message received in the time three messages have been sent

The relay will assert ROK*c* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*c* is reasserted, received data may be delayed while passing through the security counters described below. While ROK*c* is not set, the relay does not transfer new RMB data to the pickup-dropout security counters described below. Instead, the relay sends one of the user-definable default values to the security counter inputs. For each RMB*n*, specify the default value with setting RMB*n*FL, as follows:

- 1
- 0
- P (to use last valid value)

Individual pickup and dropout security counters supervise the movement of each received data bit into the corresponding RMBn element. You can set each pickup/dropout security counter from 1 to 8. A setting of 1 causes a security counter to pass every occurrence, while a setting of 8 causes a counter to wait for eight consecutive occurrences in the received data before updating the data bits. The pickup and dropout security count settings are separate. Control the security count settings with the settings RMB*n*PU and RMB*n*DO.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that the counter uses units of counted received messages instead of time. An SEL-487E communicating with another SEL-487E typically sends and receives MIRRORED BITS communications messages eight times per power system cycle. Therefore, a security counter set to two counts will delay a bit by approximately 1/4 of a power system cycle. Reference *Table 7.22* for the message rates based on the transmission mode and modem settings. You must consider the impact of the security counter settings in the receiving device to determine the channel timing performance.

Channel Synchronization

When an SEL-487E detects a communications error, it deasserts ROKA or ROKB. The relay transmits an attention message until it receives an attention message that includes a match to the TX_ID setting value. If the attention message is successful, the relay has properly synchronized and data transmission will resume. If the attention message is not successful, the relay will repeat the attention message until it is successful.

Loopback Testing

Use the **LOOP** command to verify the communications channel. In this mode, the relay expects the transmitted data to be looped back to the relay to test the data transmissions, including communication data. At the remote end, jumper the send and receive communications channels to complete the path for the test. While in loopback mode, ROK*c* is deasserted, and LBOK*c* asserts and deasserts based on the received data checks.

Channel Monitoring

Based on the results of data checks (described above), the relay collects information regarding the 255 most recent communications errors. Each record contains at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout

Use the **COM** command to generate a long or summary report of the communications errors.

NOTE: Combine error conditions including RBADA, RBADB, CBADA, and CBADB with other alarm conditions using SELOGIC control equations. You can use these alarm conditions to program the relay to take appropriate action when it detects a communications channel failure.

There is a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but framing errors can extend the outage. If the channel is presently down, the COMM record will only show the initial cause, but the COMM summary will display the present cause of failure.

When the duration of an outage on Channel A or B exceeds a user-definable threshold, the relay will assert a user-accessible flag, RBADA or RBADB. When channel unavailability exceeds a user-definable threshold for Channel A or B, the relay asserts a user-accessible flag, CBADA or CBADB.

MIRRORED BITS Communications Protocol for the Pulsar 9600-BPS Modem

NOTE: You must consider the idle time in calculations of data transfer latency through a Pulsar MBT modem system.

To use a Pulsar MBT modem, set setting MBT := Y. Setting MBT := Y hides setting SPEED and forces it to 9600, hides setting PARITY and forces it to a value of O, and hides setting RTSCTS and forces it to a value of N. The relay also injects a delay (idle time) of 3 ms among messages.

The relay sets RTS to a negative voltage at the EIA-232 connector to signify that MIRRORED BITS communications matches this specification.

Settings

The SEL-487E Port settings associated with MIRRORED BITS communications are shown in *Table 7.19* and *Table 7.21*. Set PROTO := MBA to enable the MIRRORED BITS communications protocol

Channel A on this port. Set PROTO := MBB to enable the MIRRORED BITS communications protocol Channel B on this port.

Table 7.19 General Port Settings Used With MIRRORED BITS Communications

Name	Description	Range	Default
PROTO	Protocol.	None, SEL, DNP[a], MBA, MBB	SEL
MBT	Enable Pulsar 9600 modem.	Y, N	N
SPEED	Data speed. Hidden and set to 9600 if MBT := Y.	300, 600, 1200, 2400, 4800, 9600, 19200, 38400, SYNC	9600
STOPBIT	Stop bits. Hidden and set to 1 if MBT := Y.	1, 2	1
RTSCTS	Hardware handshaking enable.	Y, N	N

[a] Optional relay feature.

The relay uses the RBADPU setting to determine how long a channel error must persist before the relay asserts RBADA or RBADB. The relay deasserts RBADA and RBADB immediately when it no longer detects a channel error. The relay uses the CBADPU setting to determine when to assert CBADA and CBADB. If the short-term channel down time ratio exceeds CBADPU, the relay asserts the appropriate CBAD bit.

SEL-300 Series Relays and SEL-2100 Compatibility

NOTE: You must use paced transmission mode (set TXMODE := P) when connecting to an SEL product that is not an SEL-400 series relay.

The TXMODE setting provides compatibility with SEL devices that are not SEL-400 series relays. The SEL-487E can send messages quicker than the SEL-300 series relays and other SEL devices can process these messages. This could lead to loss of data and a failure to communicate properly. When you set TXMODE to P, the relay sends new MIRRORED BITS messages no faster than every 3 ms even if the selected data speed (SPEED setting) would allow more frequent messages. As a function of the settings for SPEED, TXMODE, and MBT, the message transmission periods are shown in *Table 7.22*. In addition to the normal MIRRORED BITS settings, ensure the 400-series relay has the settings as shown in *Table 7.20*.

Table 7.20 400-Series Relay Prerequisite Settings

Name	Setting
TXMODE	P
MBNUM	8

Table 7.21 MIRRORED BITS Communications Protocol Settings

Name	Description	Range	Default
TX_ID	MIRRORED BITS communications ID of this device	1–4	2
RX_ID	MIRRORED BITS communications ID of device connected to this port	1–4; must be different than TX_ID	1
RBADPU	Outage duration to set RBAD	1–10000 seconds	10
CBADPU	Channel unavailability to set CBAD	1–100000 parts per million	20000
TXMODE	Transmission mode[a]	N (normal), P (paced)	N
MBNUM	Number of MIRRORED BITS communications data channels used for logic bits	0–8	8
RMB1FL[b]	RMB1 channel fail state	0, 1, P	P
RMB1PU[b]	RMB1 pickup message count	1–8	1
RMB1DO[b]	RMB1 dropout message count	1–8	1
. . .			
RMB8FL[b]	RMB8 channel fail state	0, 1, P	P
RMB8PU[b]	RMB8 pickup message count	1–8	1
RMB8DO[b]	RMB8 dropout message count	1–8	1
MBTIME	MIRRORED BITS time synchronize enable	Y, N	N
MBNUMAN	Number of analog data channels. Hidden and set to 0 if MBNUM := 7 or 8.	0–n, n = 7–MBNUM	0
MBANA1[c]	Selection for Analog Channel 1	Analog quantity label	PMV58
MBANA2[c]	Selection for Analog Channel 2	Analog quantity label	PMV59
MBANA3[c]	Selection for Analog Channel 3	Analog quantity label	PMV60
MBANA4[c]	Selection for Analog Channel 4	Analog quantity label	PMV61
MBANA5[c]	Selection for Analog Channel 5	Analog quantity label	PMV62
MBANA6[c]	Selection for Analog Channel 6	Analog quantity label	PMV63
MBANA7[c]	Selection for Analog Channel 7	Analog quantity label	PMV64
MBNUMVT	Number of virtual terminal channels	OFF,0–n, n = 7–MBNUM–MBNUMAN	OFF

[a] Must be P for connections to devices that are not SEL-400 series relays.
[b] Hidden based on MBNUM setting.
[c] Hidden based on MBNUMAN setting.

Table 7.22 MIRRORED BITS Communications Message Transmission Period

Speed in Bits per Second	TXMODE := NORMAL MBT := N	TXMODE := PACED MBT := N	MBT := Y
38400	1.0 ms	3.0 ms	n/a
19200	2.0 ms	3.0 ms	n/a
9600	4.0 ms	4.0 ms	7.0 ms
4800	8.0 ms	8.0 ms	n/a

Set the RX_ID of the local relay to match the TX_ID of the remote relay. In a three-terminal case, Relay X transmits to Relay Y, Relay Y transmits to Relay Z, and Relay Z transmits to Relay X. *Table 7.23* lists the MIRRORED BITS communications ID settings for Relays X, Y, and Z.

Table 7.23 MIRRORED BITS Communications ID Settings for Three-Terminal Application

Relay	TX_ID	RX_ID
X	1	3
Y	2	1
Z	3	2

Section 8
Front-Panel Operations

Overview

There are two prominent functions of the front panel, i.e., front panel operations and the bay controller. This section describes the front panel operations, and *Section 9: Bay Control* describes the bay controller. Using the front panel, you can analyze power system operating information, view and change relay settings, collect power system data, and perform relay control functions. For ease of navigation, the front panel menu is a straightforward menu driven control structure presented on the front-panel liquid crystal display (LCD). Front-panel targets and other LED indicators give a quick look at SEL-487E operation status. You can perform often-used control actions rapidly by using the large direct-action pushbuttons. All of these features help you operate the relay from the front panel and include:

- ➤ Reading metering
- ➤ Inspecting targets
- ➤ Accessing settings
- ➤ Controlling relay operations

This section includes the following:

Front-Panel Layout

Figure 8.1 shows the front-panel pocket areas and openings for slide-in labels (dashed lines denote the pocket areas): one pocket for the target LED label, and two pockets for the operator control labels. Refer to the instructions included in the Configurable Label kit for information on reconfiguring front-panel LED and pushbutton labels.

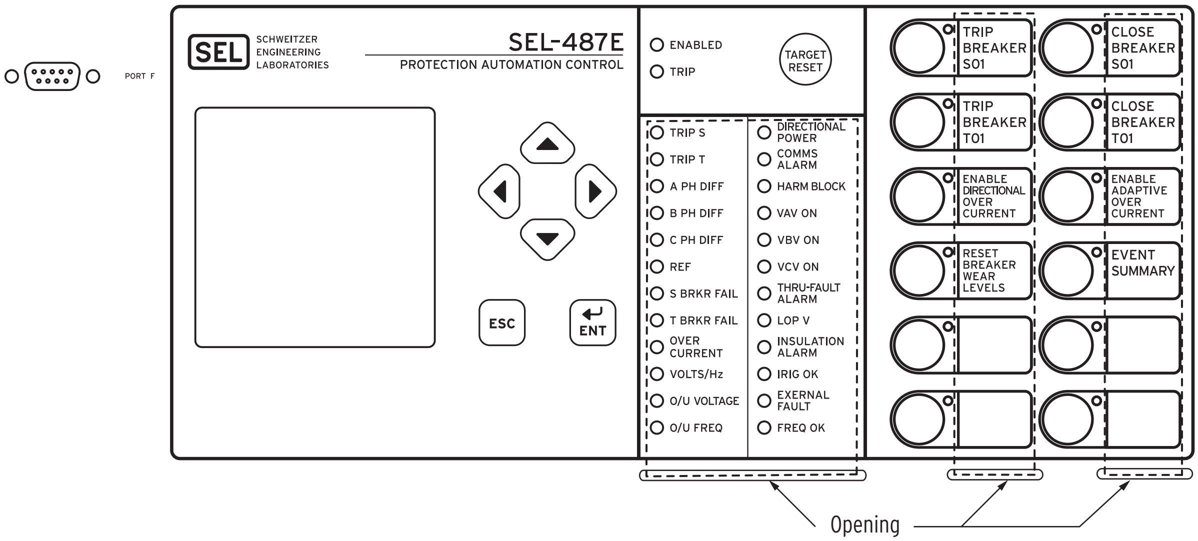


Figure 8.1 SEL-487E Front Panel

A 128 x 128 pixel LCD shows relay operating data including event summaries, metering, settings, and relay self-test information. Six navigation pushbuttons adjacent to the LCD window control the relay menus and information screens. Sequentially rotating display screens relate important power system metering parameters; you can easily change this ROTATING DISPLAY to suit your particular on-site monitoring needs. Use a simple and efficient menu structure to operate the relay from the front panel. With these menus you can quickly access SEL-487E metering, control, and settings.

Front-panel LEDs indicate the relay operating status. You can confirm that the SEL-487E is operational by viewing the **ENABLED** LED. The relay illuminates the **TRIP** LED target to indicate a tripping incident. The other 24 LEDs are factory programmed for particular relay elements to illuminate the other target LEDs. You can re-program these 24 target LEDs to show the results of the most recent relay trip event. The asserted and de asserted colors for the LEDs are programmable.

The SEL-487E front panel features large operator control pushbutton switches with annunciator LEDs that facilitate local control. Factory default settings associate specific relay functions with these direct-action pushbuttons and LEDs. Using SELOGIC® control equations or front-panel settings PB*n*_HMI, you can readily change the default direct-action pushbutton functions and LED indications to fit your specific control and operational needs. Change the pushbutton and pushbutton LED labels with the slide-in labels adjacent to the pushbuttons.

The SEL-487E front panel includes an EIA-232 serial port (labeled **PORT F**) for connecting a communications terminal or using the ACSELERATOR QuickSet® SEL-5030 Software program. Use the common EIA-232 open ASCII communications protocol to communicate with the relay via front panel PORT

F. Other communications protocols available with the front-panel port are MIRRORED BITS® communications, and DNP3, as well as RTD and PMU functions.

Front-Panel LCD

The LCD is the prominent feature of the SEL-487E front panel. *Figure 8.2* shows the areas contained in the LCD:

- Title area
- Main area
- Message area
- Scroll bars

The scroll bars are present only when a display has multiple screens.

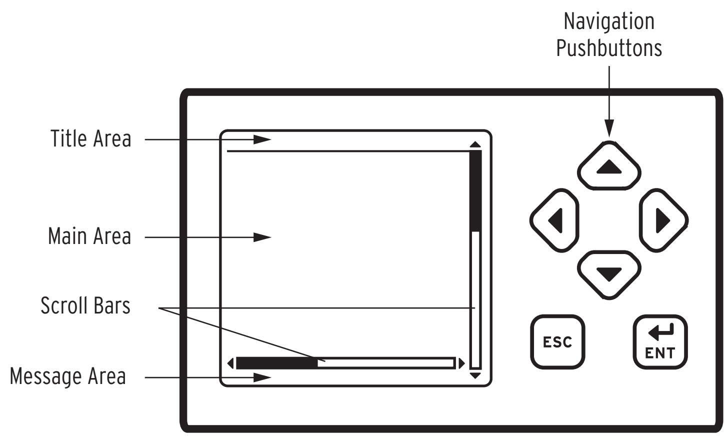


Figure 8.2 LCD Display and Navigation Pushbuttons

Front-Panel Inactivity Time-Out

An LCD backlight illuminates the screen when you press any front-panel pushbutton. This backlight extinguishes after a front-panel inactivity time-out. You can control the duration of the time-out with relay setting FP_TO, listed in *Table 8.1*.

To set FP_TO, use the **SET F** (set front panel) settings from any communications port or use the **Front Panel** branch of the ACSELERATOR QuickSet software settings tree view. The maximum backlight time is one hour. Obtain this 60-minute maximum backlight time by setting FP_TO to 60. When the front-panel times out, the relay displays an automatic ROTATING DISPLAY, described later in this section under *Screen Scrolling*.

Table 8.1 Front-Panel Inactivity Time-Out Setting

Name	Description	Range	Default
FP_TO	Front-panel display time-out	OFF, 1–60 minutes	15 minutes

Navigating the Menus

The SEL-487E front panel presents a menu system for accessing port settings and control functions. Use the LCD and the six pushbuttons adjacent to the display (see *Figure 8.2*) to navigate these front-panel menus.

The SEL-487E front panel presents a menu system for accessing metering, settings, and control functions. Use the LCD and the six pushbuttons adjacent to the display (see *Figure 8.2*) to navigate these front-panel menus.

The navigation pushbutton names and functions are the following:

- **{ESC}**—Escape pushbutton
- **{ENT}**—Enter pushbutton
- **{Left Arrow}**, **{Right Arrow}**, **{Up Arrow}**, and **{Down Arrow}**—Navigation pushbuttons

Menus show lists of items that display information or control the relay. A rectangular box around an action or choice indicates the menu item you have selected. This rectangular box is the menu item highlight. *Figure 8.3* shows an example of the highlighted item RELAY ELEMENTS in the MAIN MENU. When you highlight a menu item, pressing the **{ENT}** pushbutton selects the highlighted item.

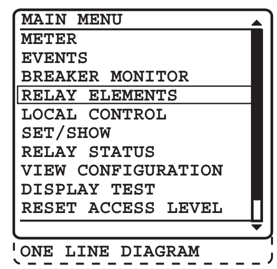


Figure 8.3 RELAY ELEMENTS Highlighted in MAIN MENU

The **{Up Arrow}** pushbutton and **{Down Arrow}** pushbutton scroll the highlight box to the previous or next menu selection, respectively. When there is more than one screen of menu items, pressing **{Up Arrow}** while at the first menu item causes the display to show the previous set of full-screen menu items, with the last menu item highlighted. Pressing **{Down Arrow}** while at the bottom menu item causes the display to show the next set of full-screen menu items, with the first menu item highlighted. Pressing the **{ESC}** pushbutton reverts the LCD display to the previous screen. Pressing **{ESC}** repeatedly returns you to the MAIN MENU. If a status warning, alarm condition, or event condition is active (not acknowledged or reset), the relay displays the full-screen status warning, alarm screen, or trip event screen in place of the MAIN MENU.

Screen Scrolling

The SEL-487E has two screen scrolling modes: autoscrolling and manual scrolling. After front-panel time-out, the relay enters the auto scrolling mode, and the LCD presents each of the display screens in this sequence:

- Any active (filled) alarm points screens
- Any active (filled) display points screens
- Enabled metering screens
- One-line diagrams

Autoscrolling Mode

Auto scrolling mode shows each screen for a user-settable period of time. Front-panel setting SCROLD defines the period of time each screen is shown. When you first apply power to the relay, the LCD shows the auto scrolling ROTATING DISPLAY. With SCROLD := OFF the screen remains on the first screen in the rotating display order, automatic rotation of additional screens is disabled.

The auto scrolling ROTATING DISPLAY also appears after a front-panel inactivity time-out. The relay retrieves data prior to displaying each new screen, and does not update screen information during the display interval. Pressing **{ENT}** at any time during auto scrolling mode takes you to the MAIN MENU. Pressing any of the four navigation pushbuttons switches the display to manual-scrolling mode.

Table 8.2 shows the high voltage and low voltage side screen selection, and *Table 8.3* through *Table 8.6* show the meter screen available for display on the front panel in the auto scrolling mode. This sequence comprises the ROTATING (DEFAULT) DISPLAY.

Table 8.2 Metering Screens Enable Settings

Screen	Description
HV_BAY	HV side one-line diagram
LV_BAY	LV side one-line diagram

Table 8.3 RMS Values

Screen	Description
Individual Windings (Values)	
RMS_VLL	Line-to-line RMS voltage
RMSW*k*VI[a]	Winding *k* RMS current and voltage screens
Combined Windings	
STRMSVI	Combined windings S and T current and voltage screens
TURMSVI	Combined windings T and U current and voltage screens
UWRMSVI	Combined windings U and W current and voltage screens
WXRMSVI	Combined windings W and X current and voltage screens

[a] k = S, T, U, W, X.

Table 8.4 Fundamental Values (Sheet 1 of 2)

Screen	Description
Individual Windings (Values)	
FUN_VLL	Fundamental Line-Line Voltage, Frequency and VDC Screen
FUNW*k*[a]VI	Winding *k* Fundamental Phase current and voltage screen
FUNW*k*SQ	Winding *k* Fundamental Sequence voltage and current screens
FUNW*k*PQ	Winding *k* Fundamental real (P) and reactive (Q) screen
FUNW*k*VA	Winding *k* Fundamental Apparent Power and pf Screen
Combined Windings	
STFUNVI	Combined windings S and T current and voltage screen
TUFUNVI	Combined windings T and U current and voltage screen
UWFUNVI	Combined windings U and W current and voltage screen
WXFUNVI	Combined windings W and X current and voltage screen
STFUNSQ	Combined windings S and T Fundamental Sequence voltage and current screen
TUFUNSQ	Combined windings T and U Fundamental Sequence voltage and current screen
UWFUNSQ	Combined windings U and W Fundamental Sequence voltage and current screen

Table 8.4 Fundamental Values (Sheet 2 of 2)

Screen	Description
WXFUNSQ	Combined windings W and X Fundamental Sequence voltage and current screen
STFUNPQ	Combined windings S and T real (P) and reactive (Q) screen
TUFUNPQ	Combined windings T and U real (P) and reactive (Q) screen
UWFUNPQ	Combined windings U and W real (P) and reactive (Q) screen
WXFUNPQ	Combined windings W and X real (P) and reactive (Q) screen
STFUNVA	Combined windings S and T Apparent Power and pf Screen
TUFUNVA	Combined windings T and U Apparent Power and pf Screen
UWFUNVA	Combined windings U and W Apparent Power and pf Screen
WXFUNVA	Combined windings W and X Apparent Power and pf Screen

[a] k = S, T, U, W, X.

Table 8.5 Energy Quantities

Screen	Description
ENRMET*k*[a]	Winding K energy screen
STENERM	Combined windings W and X energy screen
TUENERM	Combined windings W and X energy screen
UWENERM	Combined windings W and X energy screen
WXENERM	Combined windings W and X energy screen

[a] k = S, T, U, W, X.

Table 8.6 Differential Quantities

Screen	Description
DIFFMET	Differential quantities screen

Use the front-panel settings (the **SET F** command from a communications port or the **Front Panel** settings in the ACSELERATOR QuickSet software) to access the metering screen enables. Entering a **Y** (Yes) for a metering screen enables setting results in the corresponding metering screen appearing in the ROTATING DISPLAY. Entering an **N** (No) hides the metering screen from presentation in the ROTATING DISPLAY. *Figure 8.4* shows a ROTATING DISPLAY example consisting of a display points screen and one of the factory-default metering screens (the screen values in *Figure 8.4* are representative values).

Use the front-panel settings (the **SET F RDD** command from a communications port or the **Front Panel** settings in ACSELERATOR QuickSet software) to access the metering screen enables. Enter each of the desired screens on a separate line and the relay displays the screens in the sequence that you enter. *Figure 8.4* shows a sample ROTATING DISPLAY consisting of an example alarm points screen (see *Alarm Points*), an example display points screen (see *Display Points*), and a factory-default metering screen RMSWSVI (see *Table 8.3*).

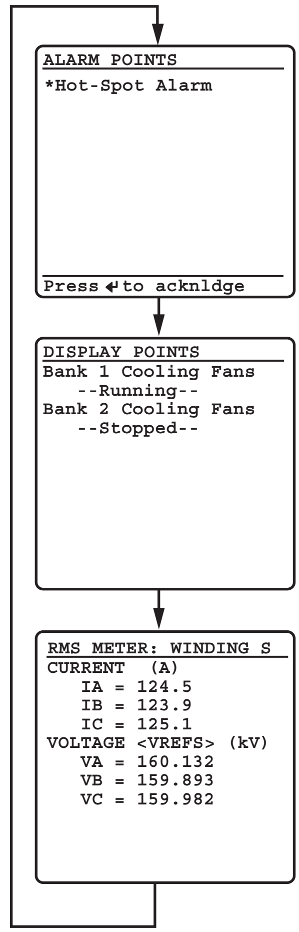


Figure 8.4 Sample ROTATING DISPLAY

Manual-Scrolling Mode

In the manual-scrolling mode you can use the directional navigation arrow pushbuttons to select the next or previous screen. Pressing the {Down Arrow} or {Right Arrow} pushbuttons switches the display to the next screen; pressing the {Up Arrow} or {Left Arrow} pushbuttons switches the display to the previous screen. In manual-scrolling mode, the display shows arrows at the top and bottom of the vertical scroll bar. The screen arrows indicate that you can navigate among the different screens at will. The relay retrieves data prior to displaying each new screen. Unlike the auto scrolling mode, the relay continues to update screen information while you view it in the manual-scrolling mode. To return to auto scrolling mode, press {ESC} or wait for a front-panel time-out.

Front-Panel Menus and Screens

Operate the SEL-487E front panel through a sequence of menus that you view on the front-panel display. The MAIN MENU is the introductory menu for other front-panel menus. These additional menus allow you on-site access to metering, control, and settings for configuring the SEL-487E to your specific application needs. Use the following menus and screens to set the relay, perform local control actions, and read metering:

- Support Screens
  - Contrast
  - Password
- MAIN MENU
  - METER
  - EVENTS
  - BREAKER MONITOR
  - RELAY ELEMENTS
  - LOCAL CONTROL
  - SET/SHOW
  - RELAY STATUS
  - VIEW CONFIGURATION
  - DISPLAY TEST
  - RESET ACCESS LEVEL
  - ONE LINE DIAGRAM

Support Screens

The relay displays special screens over the top of the menu or screen that you are using to control the relay or view data. These screens are the contrast adjustment screen and the Password Required screen.

Contrast

You can adjust the LCD screen contrast to suit your viewing angle and lighting conditions. To change screen contrast, press and hold the **{ESC}** pushbutton for one second. The relay displays a contrast adjustment box superimposed over the display. *Figure 8.5* shows the contrast adjustment box with the MAIN MENU screen in the background. Pressing the **{Right Arrow}** pushbutton increases the contrast. Pressing the **{Left Arrow}** pushbutton decreases the screen contrast. When finished adjusting the screen contrast, press the **{ENT}** pushbutton.

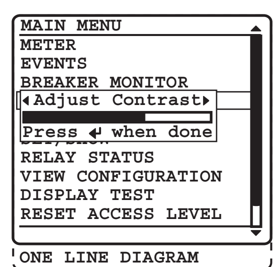


Figure 8.5 Contrast Adjustment

Password

The SEL-487E uses passwords to control access to settings and control menus. The relay has six access-level passwords. See *Changing the Default Passwords: Terminal on page 14.9* for more information on access levels and setting passwords. The SEL-487E front panel is at Access Level 1 upon initial powerup and after front-panel time-out.

Password validation occurs only when you request a menu function that is at a higher access level than the presently authorized level. At this point, the relay displays a password entry screen, shown in *Figure 8.6*. This screen has a blank password field and an area containing alphabetic, numeric, and special password characters with a movable highlight box.

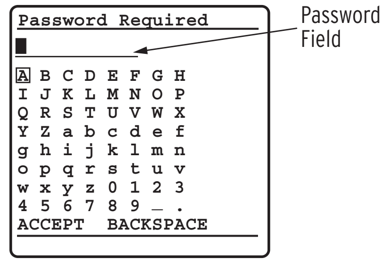


Figure 8.6 Enter Password Screen

Enter the password by pressing the navigation pushbuttons to move the highlight box through the alphanumeric field. When at the desired character, press **{ENT}**. The relay enters the selected character in the password field and moves the dark box cursor one space to the right. You can backspace at any time by highlighting the BACKSPACE character and then pressing **{ENT}**. When finished, enter the password by highlighting the ACCEPT option and then pressing **{ENT}**.

If you entered a valid password for an access level greater than or equal to the required access level, the relay authorizes front-panel access to the combination of access levels (new level and all lower levels) for which the password is valid. The relay replaces the password screen with the menu screen that was active before the password validation routine. When you enter Access Levels B, P, A, O, and 2, the Relay Word bit SALARM pulses for one second.

If you did not enter a valid password, the relay displays the error screen shown in *Figure 8.7*. Entering a valid password for an access level below the required access level also causes the relay to generate the error screen. In both password failure cases, the relay does not change the front-panel access level (it does not reset to Access Level 1 if at a higher access level). The relay displays the Password Invalid screen for five seconds. If you do not want to wait for the relay to remove the message, press any of the six navigational pushbuttons during the five-second error message to return to the previous screen in which you were working.

Figure 8.7 Invalid Password Screen

MAIN MENU

The MAIN MENU is the starting point for all other front-panel menus. The relay MAIN MENU is shown in *Figure 8.8*. When the front-panel LCD is in the ROTATING DISPLAY, press the **{ENT}** pushbutton to show the MAIN MENU.

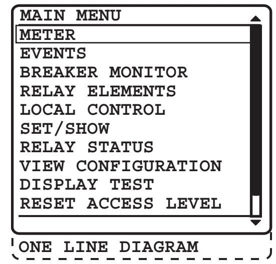


Figure 8.8 MAIN MENU

METER

From the `MAIN MENU` shown in *Figure 8.8*, press the **{ESC}** key to return to the auto-scrolling rotating display. In the manual-scrolling mode, press the **{Up Arrow}** or **{Down Arrow}** keys repeatedly to get to and move between the metering screens. Factory-enabled metering screens scroll through the following metering screens:

- Differential quantities
- Zone configuration (when active)
- Fundamental Current
- Fundamental Voltage

The SEL-487E displays metering screens on the LCD. Highlight `METER` on the `MAIN MENU` screen to select these screens. The `METER MENU`, shown in *Figure 8.8*, allows you to choose the following metering screens corresponding to the relay metering modes:

- RMS METER
- FUNDAMENTAL METER
- DEMAND METER
- ENERGY METER
- DIFFERENTIAL METER

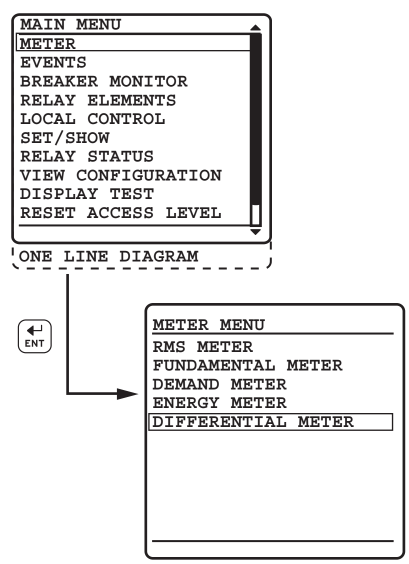


Figure 8.9 METER Menus

Figure 8.9 shows the five categories of meter screens available in the SEL-487E relay, as well as the prerequisite(s) for each screen. *Table 8.3* summarizes these prerequisite(s) and also states how the VREF, PTCON*n* (*n* = V, Z), and CTCON*k* (*k* = S, T, U, W, X) settings influence the displays. *Table 8.7* also shows the sequence in which the screens appear on the front panel.

Table 8.7 Meter Availability Conditions

Meter	Prerequisite
RMS Meter	Neither ECTTERM nor EPTTERM is to be set to OFF
Fundamental Meter	Neither ECTTERM nor EPTTERM is to be set to OFF
Demand Meter	EDEM is not set to OFF
Energy Meter	None of EPCAL, VREFV or VREZ is set to OFF
Differential Meter	E87 is not set to OFF
VREF*k*[a] setting	Power screens (apparent, real, and reactive) are displayed only for those windings that specified a PT in the VREF*k* settings
PTCON*n*[b]	If PTCON*n* = D (delta connected PTs), then 3V0 is not displayed
CTCON*k*	If CTCON*k* = D (delta connected CTs), then 3I0 is not displayed

[a] k = S, T, U, W, X.
[b] n = V, Z.

RMS Meter

To view the rms meter values, select `METER` from the main menu and press **{ENT}**, then press **{ENT}** with `RMS METER` highlighted, as shown in *Figure 8.10*(a). *Figure 8.10*(b) shows the screen with the `LINE VOLTAGES`, `SINGLE WINDING`, and `COMBINED WINDING` options. With the `LINE VOLTAGES` highlighted, press **{ENT}** to see the line-to-line voltages of the enabled PTs, as shown in *Figure 8.10*(c). In this example, both PT V and PT Z are enabled (included in the EPTTERM Group setting), and values from both PTs are available. If no PTs are enabled (EPTTERM = OFF), then this screen is not displayed.

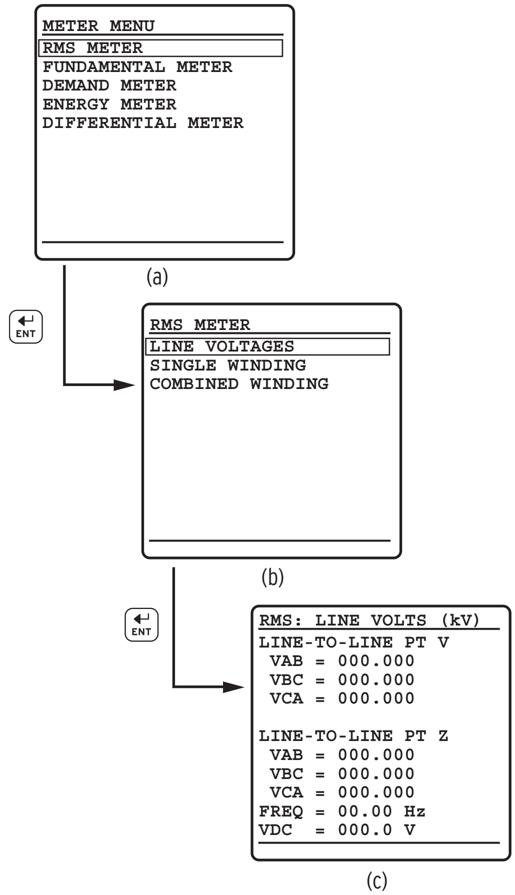


Figure 8.10 Line Voltages, Single Winding, and Combined Winding Options

With the SINGLE WINDING highlighted, press **{ENT}** to go to screen (a) in *Figure 8.11*, showing the single windings. Only windings that are included in the ECTTERM Group setting appear on this screen. In this example, all five windings are included in the ECTTERM setting (ECTTERM = S T U W X). With WINDING S highlighted, press **{ENT}** to move to the WINDING S CURENT and VOLTAGE screen (screen (b)) in *Figure 8.11*. If no voltages are enabled, then only current values are shown. Press **{Down Arrow}** to move to the active and reactive power screen (screen (c)).

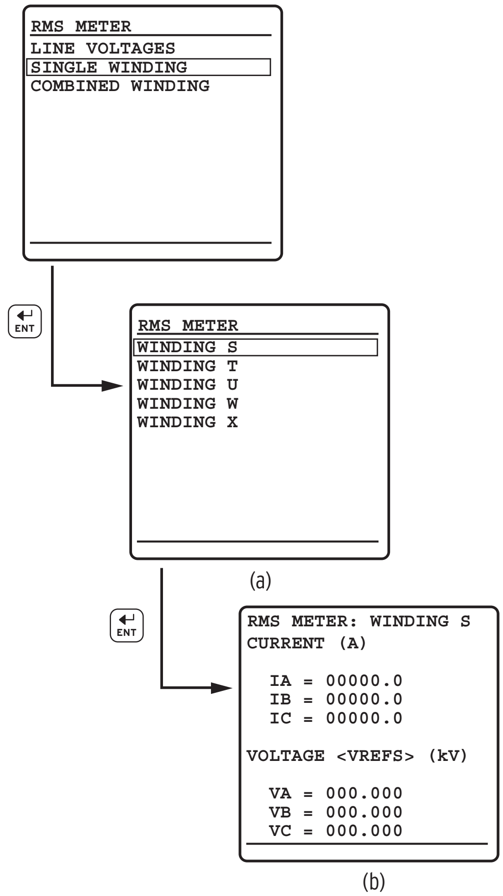


Figure 8.11 RMS Meter Screens

In screen (b) `<VREF S>` displays the value of the PT specified (VREFS = V or Z) for Winding S. If no PT is specified for Winding S, (VREFS = OFF), then neither screen (a) nor screen (b) is displayed. Winding T through Winding X have similar screens.

Combined winding screens are similar to the winding specific screens, as shown in *Figure 8.12* (combined Winding ST). Valid combinations are ST, TU, UW, and WX, and the content of *Table 8.3* also applies to the combined windings.

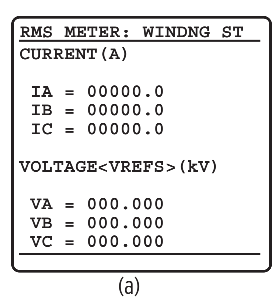


Figure 8.12 RMS Combined Windings

Fundamental Meter

The fundamental voltage and single winding screens provides similar information as shown in *Figure 8.10* and *Figure 8.11*. However, the fundamental meter also includes active, reactive, and apparent power screens, as well as sequence component screens, as shown in *Figure 8.13*.

Figure 8.13(a) shows the last of the five windings (on the assumption that all five are enabled). Notice that the fundamental meter includes the angular relationships, using V1V as reference. Press **{Down Arrow}** to move to the Winding S sequence screen. This screen shows the positive, negative, and zero-sequence voltage and currents for Winding S. Zero-sequence values are not shown when the CTs or PTs are connected in delta. Press **{Down Arrow}** repeatedly to move through the remaining enabled winding, until screen (c). Screens (c) and (d) shows the fundamental real, reactive and apparent power, and the power factors.

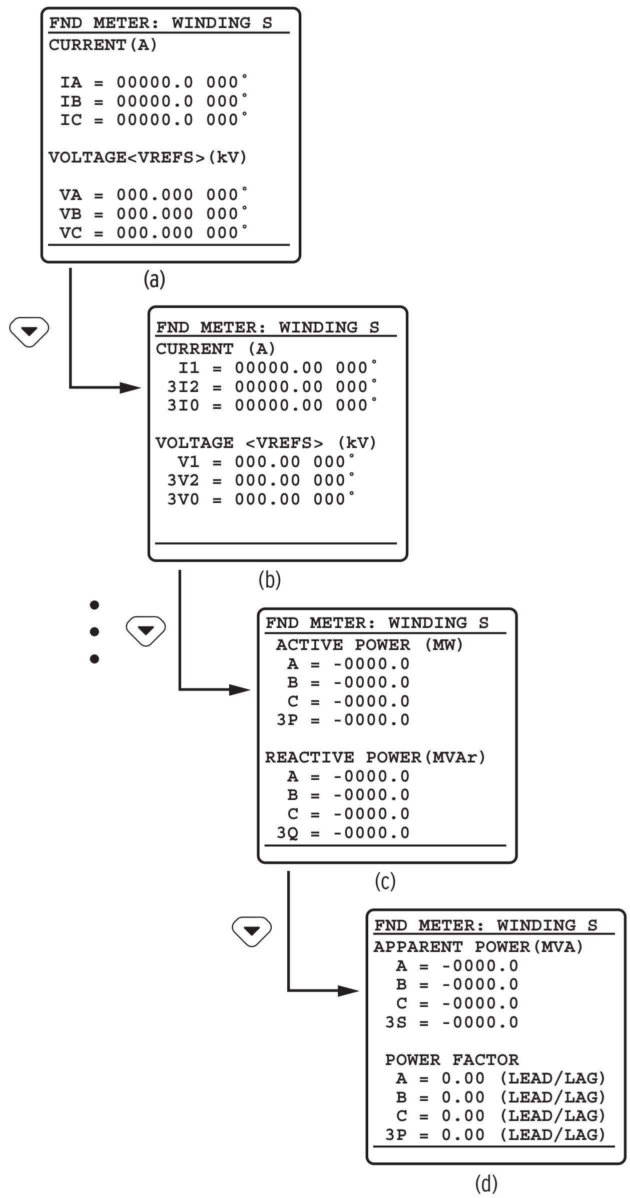


Figure 8.13 Fundamental Single Winding Screens

Screens for the combined winding are: the fundamental meter combined winding screens, including positive, negative, and zero-sequence screens.

Demand Meter

Following the fundamental meter screens are the demand meter screens. In the SEL-487E, the demand meter operate quantities are not fixed. Instead of fixed operating quantities, select a suitable operating quantity (see *Appendix H: Analog Quantities*) for each of the 10 demand elements (see *Demand Meter on page 5.62* for more information).

Because you can select the number of demand elements, there will be either one or two sets of demand meter screens. If you select five or less demand elements, then there is only one screen; for more than five demand elements there are two screens. *Figure 8.14* shows the four demand screens. Screen (a) and Screen (b) show the selected demand element operating quantities (Screen (b) is shown only if more than five operating quantities are selected). Also, each operating quantity can be either a rolling or a thermal calculation. This selection is shown by ROLL PK or THERM PK in front of the MAX quantity in Screen (a) and Screen (b). Screen (c) and Screen (d) show reset options for demand and maximum demand quantities. Use the **{Left Arrow}** and **{Right Arrow}** pushbuttons to select a NO or YES response to the reset prompt, and then press **{ENT}** to reset the all of the metering quantities.

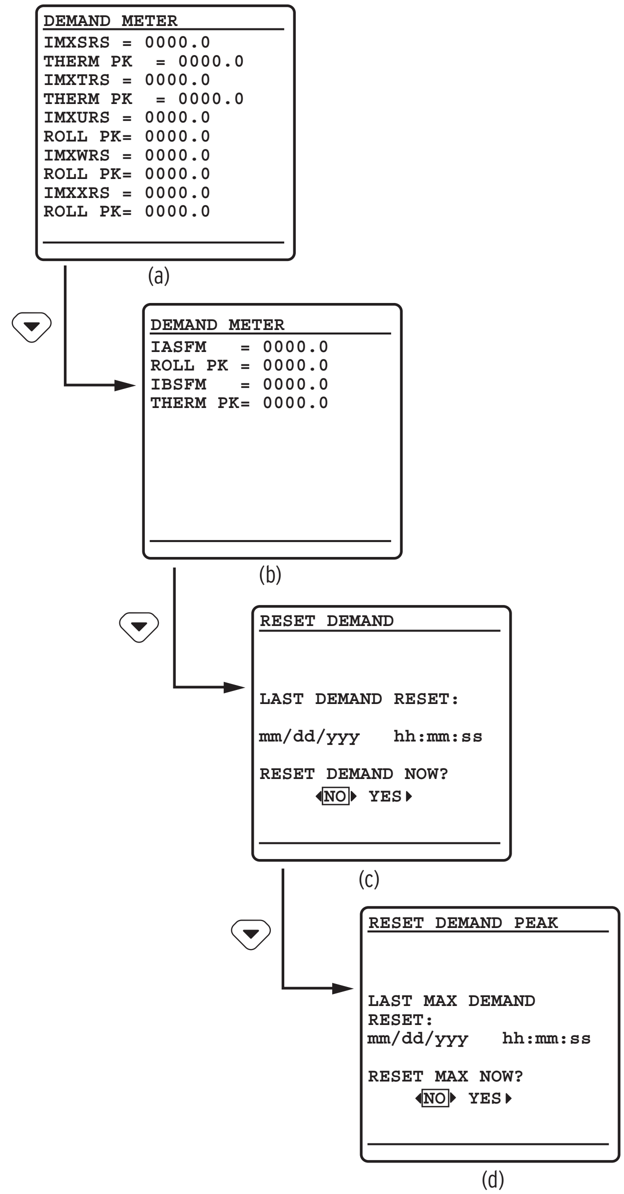


Figure 8.14 Demand Meter Screens

Energy Meter

Energy metering is the final front panel display screen. *Figure 8.15*(a) shows the screen for a single winding, *Figure 8.15*(b) the screen for a combined winding and *Figure 8.15*(c) the energy reset screen. Use the **{Left Arrow}** and **{Right Arrow}** pushbuttons to select a NO or YES response to the reset prompt, and then press **{ENT}** to reset all of the metering quantities.

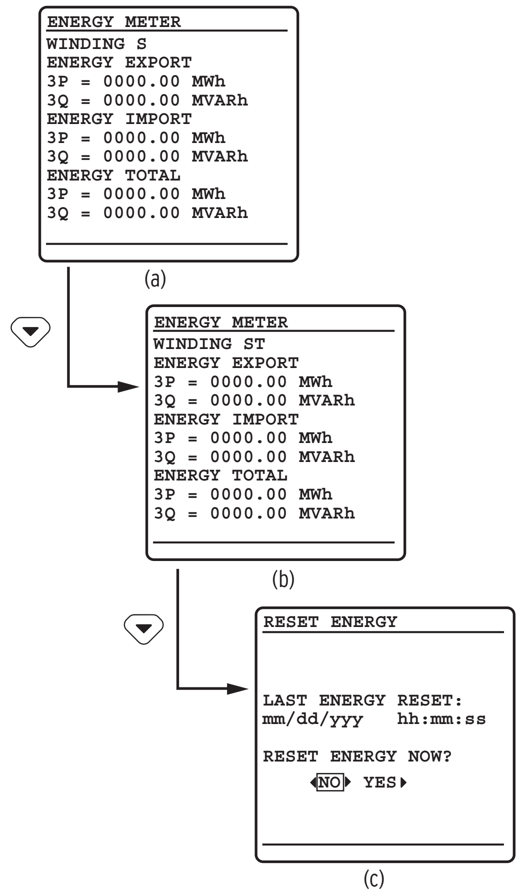


Figure 8.15 Energy Meter Screens

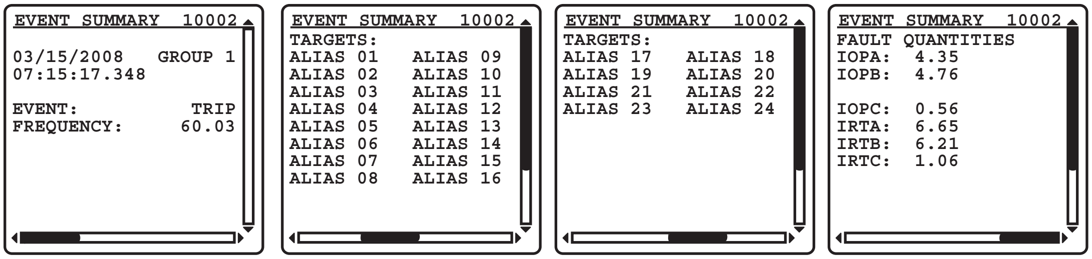
EVENTS

The SEL-487E front panel features summary event reporting, which simplifies post-fault analysis. These summary event reports include the items shown in *Table 8.8*. The front-panel event buffer size is 100 summaries. The relay numbers summary events in order from 10000 through 42767 and displays the most recent summaries on the LCD.

Table 8.8 Event Elements

Event	Description
87RA, 87RB, 87RC, REF	Differential elements involvement for event reports generated by 87A, 87B, or 87C. REF is the OR combination of REFF1, REFF2, and REFF3
TRIP	Rising edge of Relay Word bit TRIP
ER (event report trigger)	Rising edge of ER (SELOGIC control equation)
TRIG	Execution of the **TRIGGER** (**TRI**) command (manually triggered)

You can view summary event reports from the relay front-panel display by selecting EVENTS from the MAIN MENU. *Figure 8.16* shows sample EVENT SUMMARY screens for a phase-to-phase-to-ground fault. Use the and pushbuttons to show each of the summary screens for the event. The horizontal scroll bar indicates that you can view other event 10002 screens. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to move among the other events in the summary buffer. Press **{ESC}** to return to the MAIN MENU.



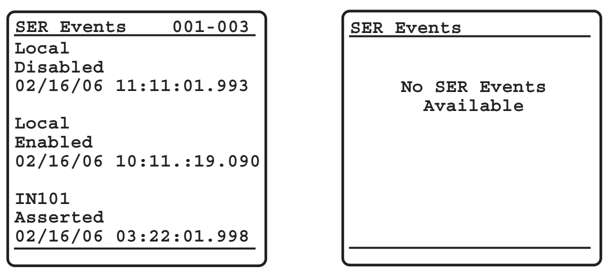
(a) (b) (c) (d)

Figure 8.16 EVENT SUMMARY Screen

To assist with fault analysis, the SEL-487E display those targets that asserted during the event on the front panel. Use the **{Right Arrow}** key to move from Screen (a) to Screen (b) in *Figure 8.16*. There are 24 alias items (ALIAS 01 through ALIAS 24), one for each of the front panel LEDs. Use the **SET T** command to enter alias settings for Relay Word bits TLED_1 through TLED_24. If no alias is defined for a particular TLED_*x* (*x* = 1 though 24), then the TLED_*x* Relay Word bit name is displayed. Also, if the particular TLED_*x* target is not set to be a tripping target, (i.e., T*x*LEDL setting is N), then it is not displayed. *Figure 8.16*(d) shows the differential quantities for the event.

SER

The Sequential Events Recorder (SER) records state changes of user-programmable Relay Word bits. State changes are time-tagged for future analysis of relay operations during an event. See *SER (Sequential Events Recorder) on page 10.30* for more information on SER events. To view SER events from the front panel, select EVENTS from the MAIN MENU and SER Events from the Events Menu as shown in *Figure 8.17*(a).



(a) (b)

Figure 8.17 SER Events on the Front Panel

Figure 8.17(a) illustrates the SER Events display screen. Data reported in this screen for each event are the SER number, SER Point Alias Name, Asserted or De-asserted state, and the Date and Time of the event. When in the SER Events screen, three SER records are displayed. Using the navigation pushbuttons, the most recent 200 SER events are viewable on the front-panel display. The topmost event is the most recent event and the bottommost event is the oldest. The upper right of the screen displays the number of the SER events currently being viewed. If a new event occurs while viewing the SER events, the display does not update with the new event automatically. To include the new SER event in the display, exit the SER screen by pressing **{ESC}** and re-enter the SER Events screen by pressing **{ENT}** with the SER Events selection highlighted. This rebuilds the SER Events display and contains the latest SER events triggered. If no SER events are available, *Figure 8.17*(b) is displayed.

While viewing the SER events, front-panel pushbuttons provide navigation and control functions as indicated in *Table 8.9*.

Table 8.9 Front-Panel Pushbutton Functions While Viewing SER Events

Pushbutton	Description
{Up Arrow}, {Down Arrow}	Navigates one screen at a time up or down. Each screen contains three SER events. Accelerated scrolling is obtained when the push-button remains pressed (see accelerated scrolling behavior below).
{Left Arrow}, {Right Arrow}	Navigates between SER events to allow adjacent SER events to be displayed on one screen. For example, if events 1, 2, and 3 are displayed, press the **{Right Arrow}** once to display events 2, 3, and 4 in the same screen. No accelerated scrolling is provided with the **{Left Arrow}** and **{Right Arrow}** pushbuttons.
{ESC}	Returns to the Events Menu
{ENT}	Does nothing

Hold down either the **{Up Arrow}** or **{Down Arrow}** to achieve accelerated scrolling. Holding down the **{Up Arrow}** or **{Down Arrow}** navigates one screen at a time for the first five screens, and then increases to five screens at a time if the button remains pressed. Accelerated scrolling stops at the newest or oldest SER event record available, depending on the direction of the scrolling.

When the upper limit of the SER events is reached, press the **{Down Arrow}** one more time and the report will wrap around to display the screen containing the first SER event. Similarly, when the lower limit of the SER events is reached, press the **{Up Arrow}** one more time and the report will wrap around to display the screen containing the last SER event.

Breaker Monitor

The SEL-487E features an advanced circuit breaker monitor. Select BREAKER MONITOR screens from the MAIN MENU to view circuit breaker monitor alarm data on the front-panel display. *Figure 8.18* shows the case where Monitor setting EBMON = S T U, i.e., three breakers are enabled. (If only one breaker is enabled (EBMON = S), then *Figure 8.18*(b) is not shown, and *Figure 8.7*(c) appears directly). Use the navigation pushbuttons to choose between BREAKER S, BREAKER T, or BREAKER U. Press **{ENT}** to view the selected circuit breaker monitor information, as shown in *Figure 8.18*(c). The BKR n ALARM COUNTER screen displays the number of times the circuit breaker exceeded certain alarm thresholds (see *Circuit Breaker Monitor on page 5.2*).

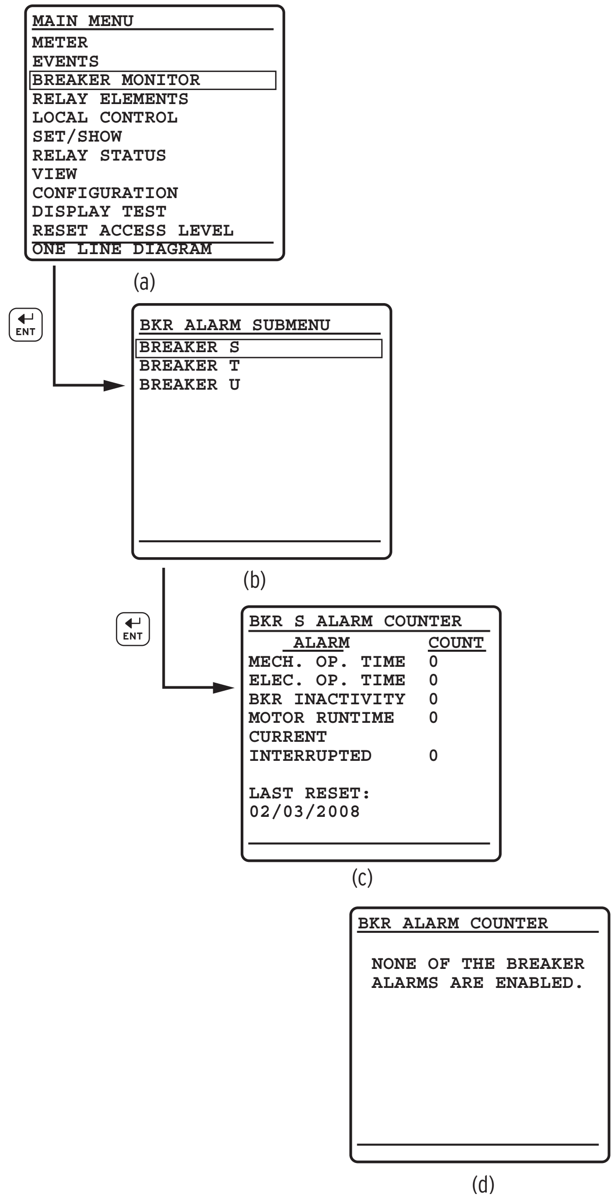


Figure 8.18 BREAKER MONITOR Report Screens

Figure 8.18(d) shows the screen when no breaker monitors are enabled (EBMON = OFF).

RELAY ELEMENTS (Relay Word Bits)

You can view the RELAY ELEMENTS screen to check the state of the Relay Word bits in the SEL-487E. The relay has two unique manual-scrolling features for viewing these elements:

- Accelerated navigation
- Search

These Relay Word bit scrolling features make selecting elements from among the many relay targets easy and efficient. *Figure 8.19* shows an example of the RELAY ELEMENTS screen. If an alias exists for an element, the alias name is displayed instead of the element name. The asterisk (*) in *Figure 8.19* indicates that this Relay Word bit position is reserved for future use.

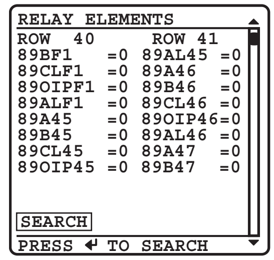


Figure 8.19 RELAY ELEMENTS Screen

When you move screen by screen through the Relay Word bit table, pressing the **{Up Arrow}** or **{Down Arrow}** pushbuttons shows each previous or next screen in turn. Accelerated navigation occurs when you press and hold the **{Up Arrow}** or **{Down Arrow}** pushbuttons.

Holding the **{Up Arrow}** or **{Down Arrow}** pushbuttons repeats the regular pushbutton action at 2 rows every second for the first 10 rows. Continue pressing the **{Up Arrow}** or **{Down Arrow}** pushbutton to cause the relay screen scrolling to accelerate to 20 rows per second. When you are scrolling up in accelerated scrolling, scrolling will stop at the first relay elements screen. When you are scrolling down, scrolling will stop at the last screen.

Search mode allows you to find a specific relay target element quickly. *Figure 8.20* shows the menu screen that the relay displays when you select the SEARCH option of the RELAY ELEMENTS initial menu.

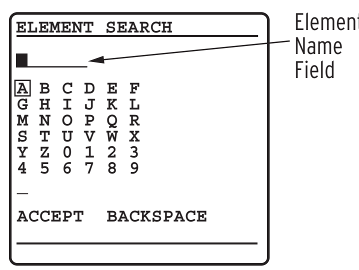


Figure 8.20 ELEMENT SEARCH Screen

When you first enter this search menu, the block cursor is at the beginning of the element name field and the highlight box in the alphanumeric field is around the letter A. Use the navigation pushbuttons to move through the alphanumeric characters. If the highlight is on one of the characters, pressing **{ENT}** enters the character at the block cursor location in the element name field. Next, the block cursor moves automatically to the character placeholder to the right. To backspace the cursor in the element name field, move the highlight to BACKSPACE and press **{ENT}**. When you have finished entering an element name, move the highlight to ACCEPT and press **{ENT}**. At any time, pressing **{ESC}** returns the display to the RELAY ELEMENTS screen.

If the highlight is on ACCEPT, the relay finds the matching relay element when you press **{ENT}**. The relay first searches for alias names, seeking an exact match. If the relay does not find an exact alias name match, it searches for an exact primitive name match. If there is no exact primitive name match, the relay initiates a partial alias name string search, followed by a partial primitive name string search. If the relay finds no match, the screen displays an error message and stays in the ELEMENT SEARCH screen. If the relay finds a match, the screen displays the element row containing the matching element.

LOCAL CONTROL

The SEL-487E provides great flexibility in power system control through the LOCAL CONTROL menus. In addition to the bay control functions (see *Section 9: Bay Control*), you can use the front-panel LOCAL CONTROL menus to perform the following relay functions:

- BREAKER CONTROL to trip and close circuit breakers (password required)
- Local bits control to assert, de-assert, and pulse relay control outputs to command station control actions
- OUTPUT TESTING to test relay outputs (password required)

Breaker control and output testing are always available, as shown in *Figure 8.21*. You must install the circuit breaker control enable jumper to enable circuit breaker control and output testing capability (see *Jumpers on page 2.14*). The submenu will not display the --BREAKER CONTROL-- option and the --OUTPUT TESTING-- option if the breaker jumper is not installed. (The relay checks the status of the breaker jumper whenever you activate the front-panel settings and at power-up.)

Local bits provide 32 additional variables you can program to perform control functions. Because there are no Local bits configured in the factory settings, be sure to program all Local bits where required. After programming Local bits, those bit appear between the breaker control and the output testing controls, shown in *Figure 8.21*(b) as Interlock 1 and Interlock 2.

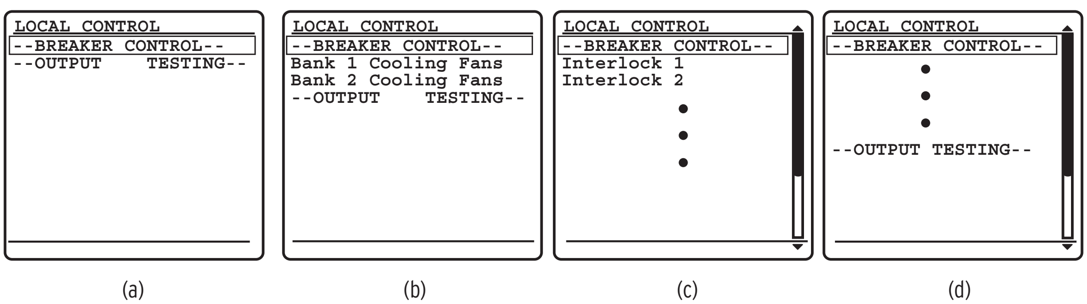


Figure 8.21 LOCAL CONTROL Initial Menu

If you program more than eight Local bits, then the controls are displayed over two screens, as shown in *Figure 8.21*(c) and (d). Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the local control action you want to perform. Pressing **{ENT}** takes you to the specific LOCAL CONTROL screen.

If the breaker jumper is not installed, and there are no local bits enabled, then the relay displays an information message when you attempt to enter LOCAL CONTROL and the screen returns to the MAIN MENU after a short delay.

BREAKER CONTROL

NOTE: Default settings for the trip and output SELOGIC control equations do not include Relay Word bits OCnn. Include Relay Word bits OCnn in the TRnn SELOGIC control equations for those terminals you want to control from the front panel.

The BREAKER CONTROL option presents a circuit breaker selection submenu if more than one breaker is entered in the BK_SEL setting. Use the navigation pushbuttons and **{ENT}** to select the circuit breaker you want to control. *Figure 8.22* shows the BREAKER CONTROL submenu and sample circuit breaker control screens for BREAKER S. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the TRIP BREAKER S or CLOSE BREAKER S control actions.

When you highlight the trip option and press **{ENT}**, the relay displays the confirmation message OPEN COMMAND ISSUED and trips Circuit Breaker S. The BREAKER S STATUS changes to OPEN. When you highlight the close option and press **{ENT}**, the relay displays the confirmation message `CLOSE COMMAND ISSUED` and closes Circuit Breaker S. The `BREAKER S STATUS` changes to `CLOSED`.

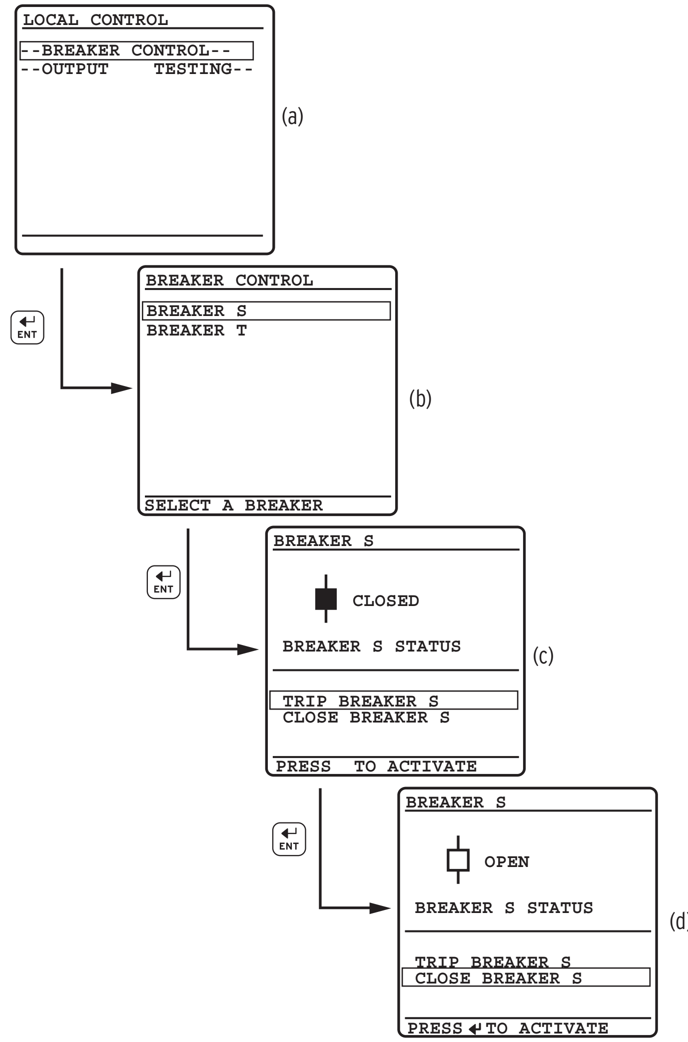


Figure 8.22 BREAKER CONTROL Screens

Local Control Bits

The SEL-487E provides 32 local control bits with SELOGIC control equation supervision. These local bits replace substation control switches to perform switching functions such as bus transfer switching. The SEL-487E saves the states of the local bits in nonvolatile memory and restores the local bit states at relay power-up.

Setting Descriptions

There are a number of settings for the local bits, grouped into the Local Control category and the Local Bit SELOGIC category. The Local Bit SELOGIC category is hidden until a Local Bit is entered. The Local Control category is a comma-delimited, composite setting, shown below and defined in *Table 8.10*:

Local Bit, Local Name, Local Set State, Local Clear State, Pulse Enable

Table 8.10 Local Bit Control Settings

Setting	Description	Range	Default	Category
Local Bit *nn*[a]	Identifies the Local bit	LB01–LB32	Blank	Front Panel
Local Name	Select a meaningful name to describe the function of the Local bit (e.g., Bank 1 Cooling Fans)	20-character	Blank	Front Panel
Local Set State	Select a meaningful name to describe the action/state when the local bit is asserted (Start)	20-character	Blank	Front Panel
Local Clear State	Select a meaningful name to describe the action/state when the local bit is de-asserted (Stop)	20-character	Blank	Front Panel
Pulse Enable	Select "Y" if the output should assert momentarily, or N if the output must assert permanently	Y, N	N	Front Panel

[a] nn = 1 though 32.

Local Bit SELogic Category

There are two setting in the Local Bit SELogic category, namely the Local control bit supervision settings (LB_SP*nn*) and the Local bit status display settings (LB_DP*nn*).

NOTE: The default settings for LB_SPnn are "1". The default settings satisfy the local bit supervision logic so that local bit operations can take place.

Supervision bits (LB_SP*nn*) provide a way to supervise Local bit operations. For local bit operations to take place, the corresponding LB_SP*nn* SELogic control equation must assert. *Figure 8.23* shows the logic that supervises all local bit operations (Set, Clear, Pulse).

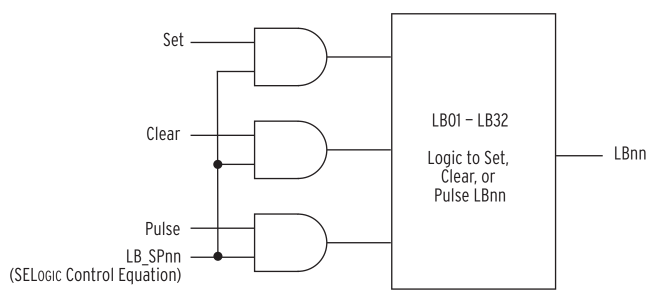


Figure 8.23 Local Bit Supervision Logic

NOTE: The default settings for LB_DPnn are LBnn. The default settings cause the local bit switch to move the corresponding state of the local bit (asserted = 1, deasserted = 0).

Local bit status display (LB_DP*nn*) is a SELogic control equation that returns the status of a device that is being controlled by the local bit. When setting LB_DP*nn* = LB*nn* (default setting), then the LB_DP*nn* Relay Word bits drive the state of the graphical switch on the display. For example, when LB01 asserts (changes to logical 1), then LB_DP01 also asserts and moves the control switch to the "1" position. Conversely, when LB01 de-asserts (changes to logical 0), then LB_DP01 also de-asserts, and moves the switch to the "0" position, as shown in *Figure 8.24*.

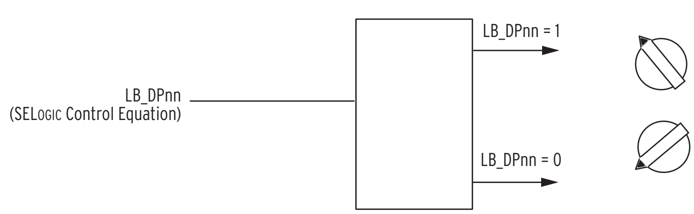


Figure 8.24 Local Bit Status Display

Table 8.11 shows the information for the Local Bit SELogic category.

Table 8.11 Local Bit Settings

Setting	Description	Range	Default	Category
LB_SP01	Local Bit Supervision *nn*[a]	SV	1	Front Panel
LB_DP01	Local Bit Status Display *nn*	SV	LB*nn*	Front Panel

[a] n = 1 though 32, only available if the corresponding local bit is defined.

Any unused local control bits default to the clear (logical 0) state. Also, any reconfigured local bit retains the existing bit state after you change the bit setting. Deleting a local bit sets that bit to the clear (logical 0) state.

EXAMPLE 8.1

As an example, assume you want to control the cooling fans of the transformer from the control house. To enable a local bit, enter the local bit settings in Table 8.11 (nn = 1–32). Names or aliases can contain any printable ASCII character except double quotation marks. Use double quotation marks to enclose the name or alias. Figure 8.25(a) shows this as Bank 1 Cooling Fans. Use the composite setting to program the following Local Control settings:

(Local Bit) = LB01, (Local Name) = "Bank 1 Cooling Fans",(Local Set State) = "Start",(Local Clear State) = "Stop",(Pulse Enable) = N

where:

Bank 1 Cooling Fans = alias name for Local Name

Start = alias name for Local Set State

Stop = alias name for Local Clear State

The pulse state enable setting at the end of the setting string is optional. If your application requires a pulsed or momentary output, you can activate an output pulse by setting the option at the end of the local bit command string to Y (for Yes). The default for the pulse state is N (for No); if you do not specify Y, the local bit defaults at N and gives a continuous set or clear switch level.

If you enter an invalid setting, the relay displays an error message prompting you to correct your input. If you do not enter a valid local bit number, the relay displays A local bit element must be entered. If you enter a local bit number and that local bit is already in use, the relay displays The local bit element is already in use. Likewise, if you do not enter valid local bit name, set alias, and clear alias, the relay returns an error message. If an alias is too long, the relay displays Too many characters.

For this example, leave the supervision settings (LB_SP01) and the Local bit status display (LB_DP01) at their respective default settings, i.e., LB_SP01 = 1 (always asserted), and LB_DP01 = LB01 (reflects the status of LB01).

Figure 8.25(a) shows Local Control screen that includes Local bit programming. With Bank 1 Cooling Fans highlighted, use the **{ENT}** key to move to *Figure 8.25*(b).

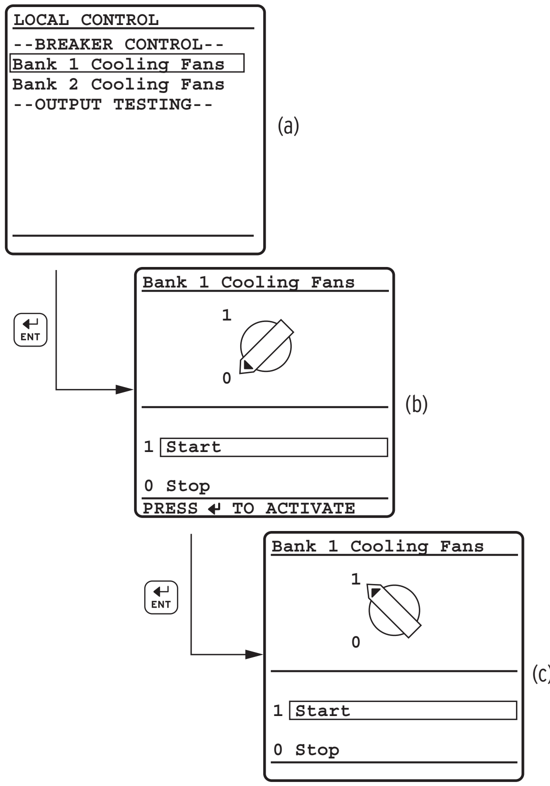


Figure 8.25 Local Control Screens

In *Figure 8.25*(b), use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to highlight the set or "Start" (1), or clear or "Stop"(0) control actions. Highlighting the set ("Start") option and pressing **{ENT}** changes the local control bit and performs the required control action. If the LB_DP*nn* Relay Word bit asserts, the graphical switch moves to 1 to indicate the asserted local bit status, as shown in *Figure 8.25*(c).

OUTPUT TESTING

NOTE: The circuit breaker control enable jumper J18C must be installed to perform output testing. See Main Board Jumpers on page 2.14.

You can check for proper operation of the SEL-487E control outputs by using the OUTPUT TESTING submenu of the LOCAL CONTROL menu. A menu screen similar to *Figure 8.26* displays a list of the control outputs available in your relay configuration. For more information on output testing, see *Control Outputs on page 2.6*.

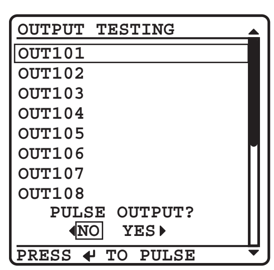


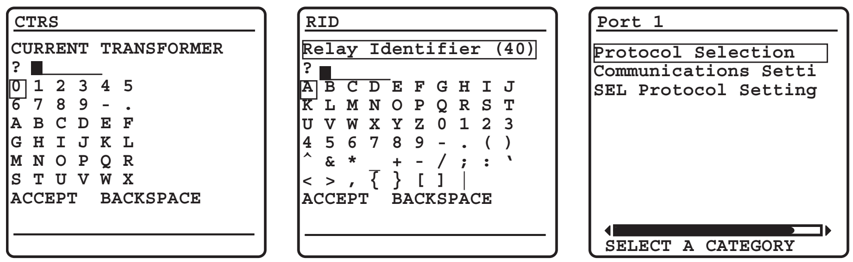
Figure 8.26 OUTPUT TESTING Screen

SET/SHOW

The SEL-487E displays different settings entry screens for the following input data types:

- ➤ Basic alphanumeric
- ➤ Character or string or SELOGIC control equations
- ➤ Setting options

For alphanumeric settings, the relay presents the character or string input screen. Some settings have specific options; use the setting options screens to select these options. *Figure 8.27* shows examples of the settings input screens.



Basic Alphanumeric — Character or String or SELOGIC Control Equations — Setting Options

Figure 8.27 Sample Settings Input Screens

You can use the SET/SHOW menus to examine or modify SEL-487E port settings and date/time. From the front panel you can change only the settings classes and settings listed in *Table 8.12*.

NOTE: You cannot use the front-panel SET/SHOW menus to change front-panel settings. To change front-panel settings, use a communications port interface and the SET F command or use the ACSELERATOR QuickSet front-panel settings.

Table 8.12 Settings Available From the Front Panel

Class/Setting	Description
PORT	Relay communications port settings
ACTIVE GROUP	Active settings group number 1–6
DATE/TIME	Date and time settings

Figure 8.27 shows how to select DNP protocol for Port 1. From the main menu, select SET/SHOW **{ENT}** to move to *Figure 8.28*(a). Press **{ENT}** to select Port 1, and **{ENT}** to select Protocol Selection. Again, press **{ENT}** to move to (e). Press the **{Down Arrow}** key to select DNP, and press **{ENT}** to move to (f). Press the **{ESC}** key twice to move to (g). The relay prompts you with a Save Settings screen. Using the navigation pushbuttons, answer YES to make the settings change(s), or NO to abort the settings change(s). Press **{ENT}** to save.

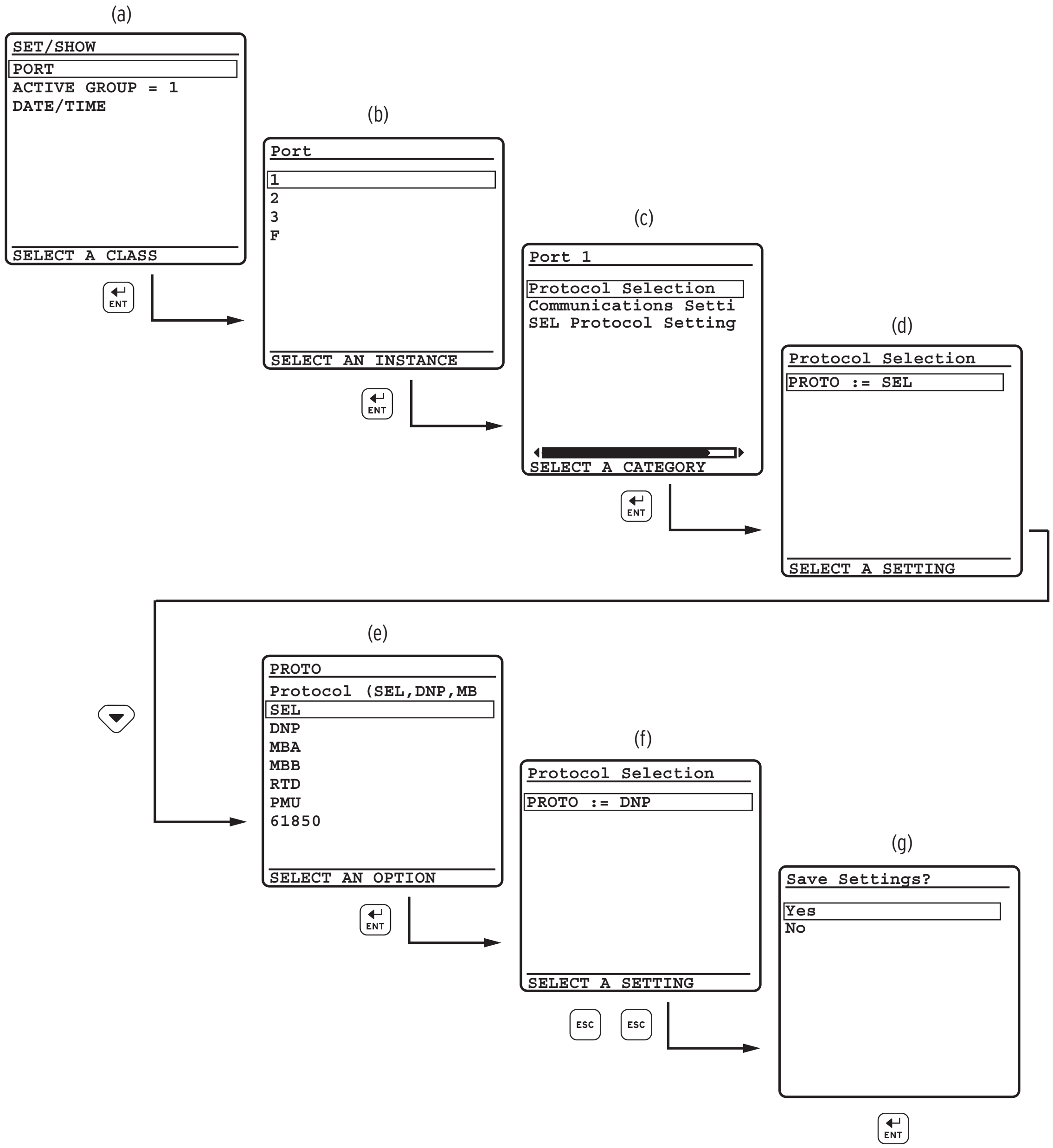


Figure 8.28 Select DNP Protocol

ACTIVE GROUP

Perform the following steps to change the active setting group:

Step 1. Select the ACTIVE GROUP option of the SET/SHOW submenu screen (see *Figure 8.29*) to change the settings group. The relay performs a password validation test at this point to confirm that you have Breaker Access Level authorization or above.

Step 2. If access is allowed, and all the results of SELOGIC control equations SS1–SS6 are not logical 1 (asserted), then the relay displays the EDIT ACTIVE GROUP screen in *Figure 8.29*. The relay shows the active group and underlines the group number after NEW GROUP =.

Step 3. Use the **{Up Arrow}** and **{Down Arrow}** pushbuttons to increase or decrease the NEW GROUP number.

Step 4. Once you have selected the new active group, press **{ENT}** to change the relay settings to this new settings group.

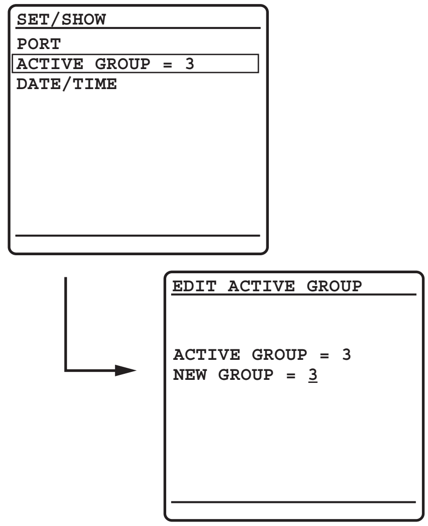


Figure 8.29 Changing the ACTIVE GROUP

DATE/TIME

Another submenu item of the SET/SHOW first screen (*Figure 8.28*) is the DATE/TIME screen shown in *Figure 8.30*. The SEL-487E generates date and time information internally, or you can use external high-accuracy time modes with time sources such as a GPS receiver. *Figure 8.30* is the relay date/time screen when a high-accuracy source is in use. If you use a high-accuracy time source, edits are disabled, the DATE/TIME display does not show the highlight, and the screen does not show the help message on the bottom line.

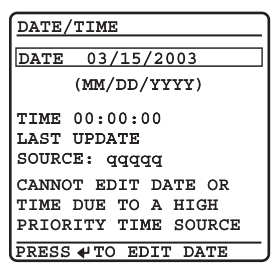


Figure 8.30 DATE/TIME Screen

When operating from a non-high-accuracy time source, you can use the front panel DATE and TIME entry screens to set the date and time. *Figure 8.30* shows an example of these edit screens. Use the **{Left Arrow}** and **{Right Arrow}** navigation pushbuttons to move the underscore cursor; use the **{Up Arrow}** and **{Down Arrow}** navigation pushbuttons to increment or decrement each date and time digit as appropriate to set the date and time. For a description of the LAST UPDATE SOURCE field, see *Appendix D: High-Accuracy Timekeeping*.

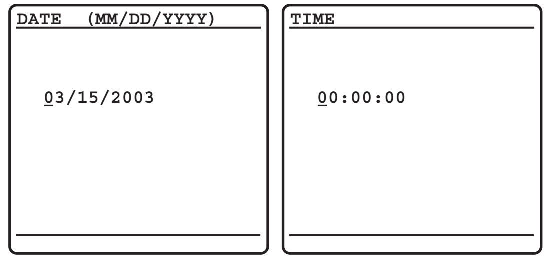


Figure 8.31 Edit DATE and Edit TIME Screens

To enable a high-accuracy external time source, connect an IRIG-B clock to the relay. For a discussion of the IRIG timing modes in the SEL-487E see *Appendix D: High-Accuracy Timekeeping*.

RELAY STATUS

The SEL-487E performs continuous hardware and software self-checking. If any vital system in the relay approaches a failure condition, the relay issues a status warning. If the relay detects a failure, the relay displays the status failure RELAY STATUS screen immediately on the LCD.

For both warning and failure conditions, the relay shows the error message for the system or function that caused the warning or failure condition. You can access the RELAY STATUS screen via the MAIN MENU. The RELAY STATUS screen shows the firmware identification number (FID), serial number, whether the relay is enabled, and any status warnings.

Figure 8.32 shows examples of a normal RELAY STATUS screen, a status warning RELAY STATUS screen, and a status failure RELAY STATUS screen. For more information on status warning and status failure messages, see *Relay Self-Tests on page 14.59*.

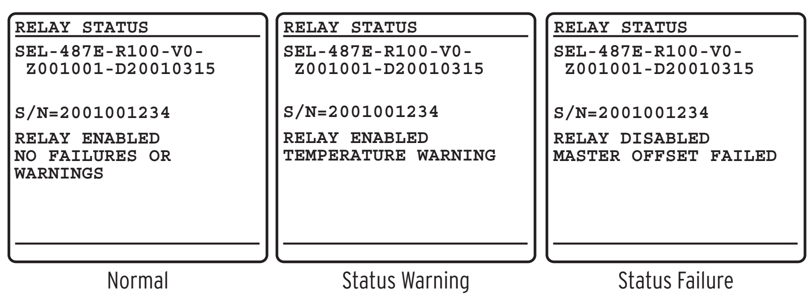


Figure 8.32 Relay STATUS Screens

VIEW CONFIGURATION

You can use the front panel to view detailed information about the configuration of the firmware and hardware components in the SEL-487E. In the MAIN MENU, highlight the VIEW CONFIGURATION option by using the navigation pushbuttons. The relay presents five screens in the order shown in *Figure 8.33*. Use the navigation pushbuttons to scroll through these screens. When finished viewing these screens, press **{ESC}** to return to the MAIN MENU.

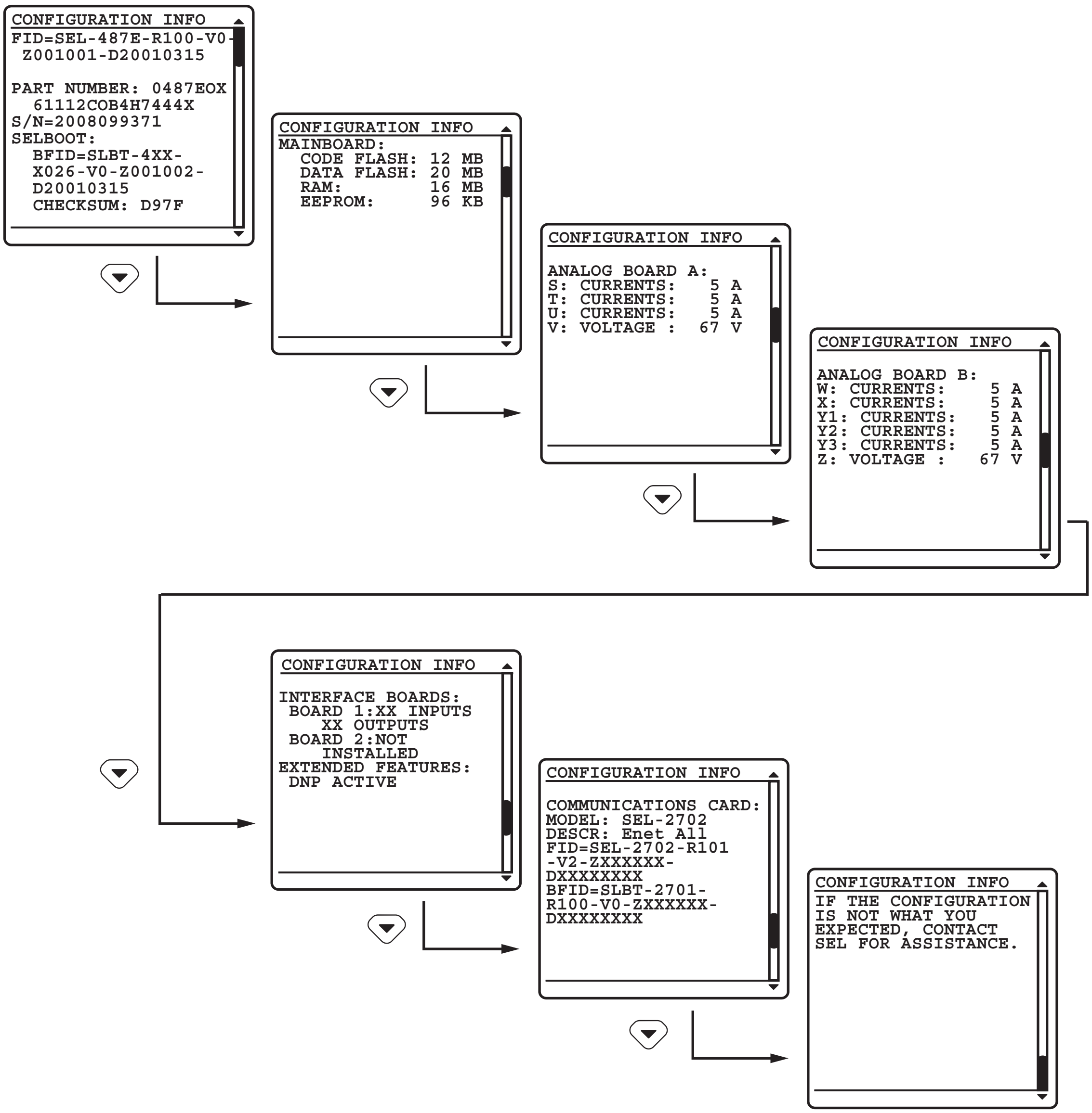


Figure 8.33 VIEW CONFIGURATION Sample Screens

DISPLAY TEST

You can use the DISPLAY TEST option of the MAIN MENU to confirm operation of all of the LCD pixels. The LCD screen alternates the on/off state of the display pixels once every time you press **{ENT}**. *Figure 8.34* shows the resulting two screens. The DISPLAY TEST option also illuminates all of the front-panel LEDs. To exit the test mode, press **{ESC}**.

NOTE: The LCD DISPLAY TEST does NOT reset the front-panel LED targets.

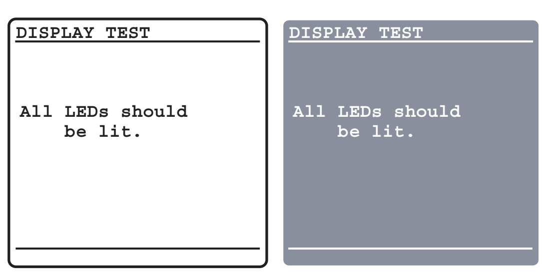


Figure 8.34 DISPLAY TEST Screens

ONE LINE DIAGRAM

Access the bay controller functions with the ONE LINE DIAGRAM option. *Figure 8.35* shows an example of one of the pre-configured bays in the SEL-487E relay. See *Section 9: Bay Control* for more information.

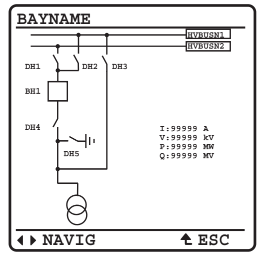


Figure 8.35 Example Bay Control Screen

RESET ACCESS LEVEL

The SEL-487E uses various passwords to control access to front-panel functions. As you progress through these menus, the relay detects the existing password level and prompts you for valid passwords before allowing you access to levels greater than Access Level 1 (see *Password* in this section). When you want to return the front panel to the lowest access level (Access Level 1), highlight RESET ACCESS LEVEL item on the MAIN MENU. Pressing **{ENT}** momentarily displays the screen of *Figure 8.36* and places the front panel at Access Level 1.

The relay automatically resets the access level to Access Level 1 upon front-panel time-out (setting FP_TO is not set to OFF). Use this feature to reduce the front-panel access level before the time-out occurs.

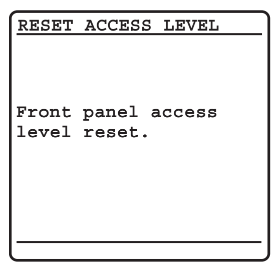


Figure 8.36 RESET ACCESS LEVEL Screen

Event, Display Point, and Alarm Point Displays

The SEL-487E automatically displays alert and information messages on the HMI. Any alert message takes precedence over the normal ROTATING DISPLAY and the MAIN MENU. Alert and information conditions include the following:

- Event reports and trips (user defined)
- Alarm Point assertions
- Status warnings
- Status failures
- Display Point assertion

Event Display

In order to display event reports automatically, set front-panel setting DISP_ER to Y. Set front-panel setting TYPE_ER to define which types of event reports will be automatically displayed from the normal ROTATING

DISPLAY. Selecting ALL displays all event types described in *Table 8.4*, and TRIP displays only the event types that include the assertion of the TRIP Relay Word bit. For alarm point assertions, qualified event reports (including trip events), and status warnings, the relay displays the corresponding full-screen automatic message, only if the front-panel display is in the time-out or standby condition (the relay is scrolling through the default display points/ enabled metering screens of the ROTATING DISPLAY or is displaying the MAIN MENU). When a status warning, alarm, or event is triggered, the relay full-screen presentation is similar to the screens of *Figure 8.37* (also see *Figure 8.16* and *EVENTS* description).

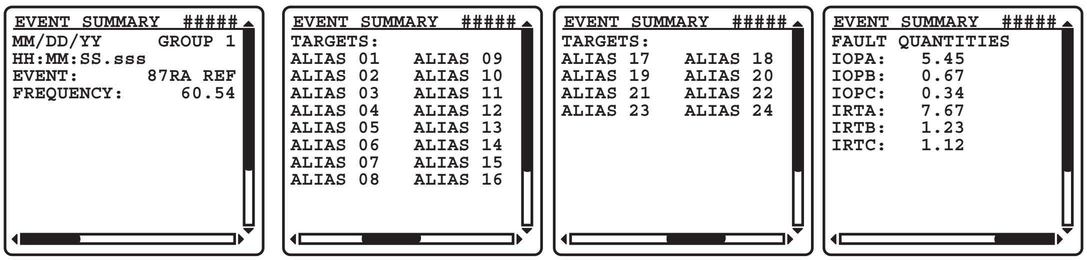


Figure 8.37 Front-Panel Event Summary

The targets are checked in order from T1_LED to T24_LED. The first valid target that is asserted will have its alias placed at position “ALIAS 01”, subsequent ones will have their aliases listed in the order shown. Only the first 16 picked-up targets for the event are listed.

The strings “ALIAS XX” will be replaced with the customer supplied alias using the **SET T** command for Relay Word bits TLED_1 through TLED_24. Only targets asserted during the event are listed. If no alias is defined for a particular TLED_*x*, then display the TLED_*x* Relay Word bit name. If the target is not setup to be a tripping target, (i.e., its T*x*LEDL setting is N), it will not be displayed.

Display Points

Use up to 96 display points to display messages on the SEL-487E front-panel LCD that indicate conditions of interest. To illustrate the use of display points and alarm points, assume you want information about the status of a two-stage cooling system (Cooling Bank 1 and Cooling Bank 2) on your transformer bank. Furthermore, assume you want an alarm when the winding hot-spot temperature exceeds the HST1 setting (see *Thermal Element on page 5.19* for more information). When the temperature exceeds the setting, Relay Word bit HS1 asserts. *Figure 8.38* shows an example of a display point screen that displays the cooling system information. For the cooling system information, wire an auxiliary contact from Bank 1 to Input IN101 and an auxiliary contact from Bank 2 to Input IN102. For the alarm, use Relay Word bit HS1 (see *Alarm Points*).

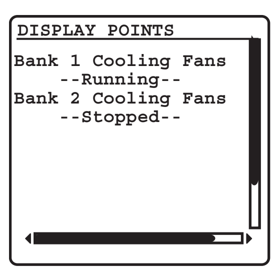


Figure 8.38 Sample Display Points Screen

Display points can show the status of Relay Word bits or display the value of analog quantities. *Table 8.13* and *Table 8.14* list the display point settings.

Table 8.13 Display Point Settings—Boolean

Description	Range
Relay Word Bit Name	*Appendix G: Relay Word Bits*
Alias	ASCII string
Set String	ASCII string
Clear String	ASCII string
Text Size	S, D

Table 8.14 Display Point Settings—Analog

Description	Range
Analog Quantity Name	*Appendix H: Analog Quantities*
User Text and Formatting	ASCII string
Text Size	S, D

The relay updates the display points data once per second if you are viewing the display points in manual-scrolling mode; in auto scrolling mode the relay updates the display points information each time the screen appears in the ROTATING DISPLAY sequence.

To enable a display point, enter the display point settings listed in *Table 8.13* and *Table 8.14*. All display points occupy one, and only one, line on the display at all times. The height of the line is determined by the "Text Size" setting parameter. Display points of single-line height span one screen in total width.

Display points of double-line height span two screens in total width. You can use multiple display points to simulate multiple lines. Use the following syntax to display the given Relay Word bit exactly as seen in the navigational menu (name and value).

DPxx := **Name**

Use the following syntax to display the given Relay Word bit as seen in the navigational menu, replacing the name of the value with the given alias string. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Text Size"**

Use the following syntax to display the given Relay Word bit with the given alias. If the Relay Word bit is asserted (logical 1), the LCD displays the set string in the place of the value. If the Relay Word bit is de-asserted (logical 0), the LCD displays the clear string in the place of the value. One or all of Alias, Set String, or Clear String can be empty. If Alias is empty, then the LCD displays only the Set or Clear Strings. If either Set String or Clear String is empty, then an empty line is displayed when the bit matches that state. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, "Alias", "Set String", "Clear String", "Text Size"**

Use the following syntax to display the given analog quantity with the given text and formatting. Formatting must be in the form {Width.Decimal,Scale} with the value of Name, scaled by "Scale," formatted with total width "Width" and "Decimal" decimal places. The width value includes the decimal point and sign character, if applicable. The “Scale” value is optional; if omitted, the scale factor is processed as 1. If the numeric value is smaller than the field size requested, the field is padded with spaces to the left of the number. If the numeric value will not fit within the field width given, “$” characters are displayed. The text size determines if the display will be in single font or double font. If the text size is empty, the display will be in single font.

DPxx := **Name, “Text1 {Width.Decimal,Scale} Text2”, “Text Size”**

Table 8.15 shows examples of Boolean and analog programming (left column) and the way the display appears on the screen.

Table 8.15 Display Point Settings—Boolean and Analog Examples

Example Display Point Setting Value	Example Display 12345678901234567890
IN101	`IN101=1` `IN101=0`
MWHAIN,“{7.2}”	`1234.56`
50P1,Overcurrent,,	`Overcurrent=1` `Overcurrent=0`
PSV01,Control,On,Off	`Control=On` `Control=Off`
PSV02,Breaker,Tripped,	`Breaker=Tripped` *Empty Line*
50P1,,,Overcurrent	*Empty Line* `Overcurrent`
MWHAIN,“A Ph Import={7.2}”	`A Ph Import=1234.56`
MWHAIN,“A Ph Import={7.3}”	`A Ph Import=$$$.$$$`
MWHAIN,“A Ph Imp {4}MWh”	`A Ph Imp 1234MWh`
PAD,“{7.2}”	`1234.56`
PAD,“A Ph Dem Pwr={4.1}”	`A Ph Dem Pwr=1234.5`
ICD,“C Demand={5}”	`C Demand= 1230`
ICD,“C Demand={4.2,0.001} kA”	`C Demand=1.23 kA`
MWHAOUT,“A Phase Out={3, 1000}”	`A Phase Out=1234`
MWHAOUT,“A Phase Out={3, 1000} kWh”	`A Phase Out=$$$ kWh`
1,“Fixed Text”	`Fixed Text`
0,“Fixed Text”	`Fixed Text`
1,	*Empty Line*
0,	*Empty Line*
	Display Point is hidden

If you enter a Relay Word bit or analog quantity that does not match a valid relay element, the relay displays Invalid element. If you enter a display point that exceeds the allowable length, the relay displays: Too many characters. If you enter an invalid scale factor, invalid width, too many parameters, or omit necessary quotation marks or brackets, the relay displays an error message. If a display point was used previously and you want to remove the display point, you can delete the display point. In the Front Panel settings (**SET F**), at the Display Points and Aliases prompt, use the text-edit mode line editing commands to set the display points (see *Making Text-Edit Mode Settings Changes on page 14.11* for information on text-edit mode line editing). To delete Display Point 1, type **DELETE <Enter>** at the Front Panel settings Line 1 prompt.

EXAMPLE 8.2 Creating a Display Point

This example demonstrates a method to set the display point messages that are shown in Figure 8.35.

Input IN101 asserts when the fans from Cooling Bank 1 run, and Input IN102 asserts when the fans from Cooling Bank 2 run. In the Front Panel settings (SET F), enter the following after the Display Points and Aliases line 1 prompt:

1: **1,"Bank 1 Cooling Fans"**

2: **IN101,," --Running--","--Stopped--"**

3: **0**

4: **0," Bank 2 Cooling Fans"**

5: **IN102,," -- Running --"," -- Stopped --"**

6: **0**

Fixed text is set by assigning an alias to a "1" or "0." Blank lines are set by assigning a blank alias to a "1" or "0." The set state, " --Running--" indicates when the fans are running, where leading spaces are added to center the set state message. Add a clear state named "--Stopped--" to show that the fans are not running.

Alarm Points

Although Alarm points are part of the SER settings, you can configure up to 66 Alarm points to display messages on the SEL-487E front-panel LCD that indicate alarm conditions. To enable an alarm point, enable the HMI alarm parameter (last parameter in the SER setting) of the SER Point Settings. The format for entering the SER point data is the following comma-delimited string (also see *Table 8.16*):

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

See the *SER (Sequential Events Recorder) on page 10.30* for more SER information.

Table 8.16 SER Point Settings

Description	Range
Relay Word Bit	Any valid relay element
Reporting Name	20-character maximum ASCII string
Set State Name (logical 1)	20-character maximum ASCII string
Clear State Name (logical 0)	20-character maximum ASCII string
HMI Alarm	Y,N

Using the hop-spot temperature as an example, enter the following SER settings:

(Relay Word Bit) = HS1, (Reporting Name) = "Hot-Spot Temp", (Set State Name) = "Hot-Spot Alarm", (Clear State Name) = "Normal", (HMI Alarm) = Y

Setting HMI Alarm = Y causes the message "Hot-Spot Alarm" to appear on the HMI when Relay Word bit HS1 asserts. *Figure 8.39* shows sample alarm points screens. The relay automatically displays new alarm points while in manual-scrolling mode and in auto scrolling mode. While you navigate the HMI menu structure, the relay does not automatically display the alarm points. Instead, ALARM EVENT displays in the footer. When you escape the HMI menu structure, the relay displays the alarm points screen.

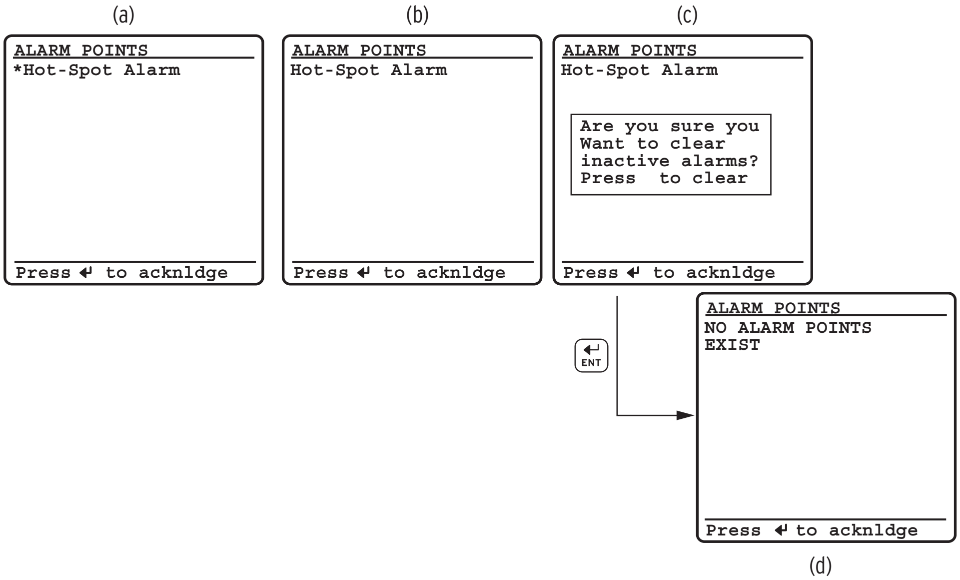


Figure 8.39 Sample Alarm Points Screen

While in the scrolling mode, the assertion of IN101 causes *Figure 8.39*(a) to automatically display. Upon the de-assertion of IN101, the asterisk will disappear, as in *Figure 8.39*(b).

Pressing the {ENT} pushbutton will allow the user to acknowledge and clear de-asserted alarms (asserted alarms remain active). Before clearing, you will be prompted to confirm that this is the intended action, as shown in *Figure 8.39*(c).

In the case that all alarms are de-asserted, pressing the {ENT} pushbutton will allow the user to acknowledge and clear all alarms. After clearing, you will see a screen showing the results of the action, as depicted in *Figure 8.39*(d).

Alarm points are not updated for a particular element if it has been deleted from the SER due to chatter criteria (See *Automatic Deletion and Reinsertion on page 10.35*). Upon reinsertion, the element state will be updated on the alarm point display. If the relay enters a period of SER buffer overflow, the status of alarm points cannot be determined. The screen shown in *Figure 8.40* will appear until you exit the buffer overflow condition, at which point the alarm point elements will be polled and displayed if asserted. Subsequent alarm point assertions will be displayed above the data loss message.

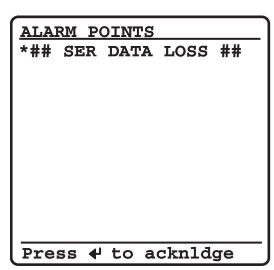


Figure 8.40 Alarm Points Data Loss Screen

Operation and Target LEDs

The SEL-487E gives you at-a-glance confirmation of relay conditions via 24 color-programmable operation and target LEDs, located in the middle of the relay front panel, as shown in *Figure 8.41*. To provide clear visual indication, choose between red and green for the **Enable** and **Trip** LED colors. For the remaining LEDs, choose among red, green, or amber.

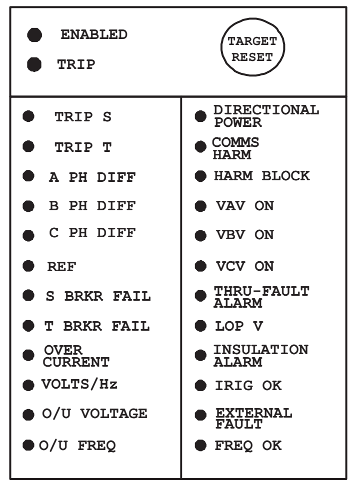


Figure 8.41 Factory Default Front-Panel Target

Table 8.17 shows the LED labels (top to bottom in *Figure 8.41*) and the actual settings. These settings are based on a two-winding transformer with directional overcurrent elements and REF protection enabled. All voltage elements are with reference to PT V.

Table 8.17 LED Settings (Sheet 1 of 2)

LED Label	Settings	Comment
TRIP S	TRIPS	Trip logic asserted, Terminal S
TRIP T	TRIPT	Trip logic asserted, Terminal T
A PH DIFF	87RA OR 87UA	Restraint or unrestraint differential element A
B PH DIFF	87RB OR 87UB	Restraint or unrestraint differential element B
C PH DIFF	87RC OR 87UC	Restraint or unrestraint differential element C
REF	REF51T1	REF Element 1 TOC element timed out
S BRKR FAIL	FBFS	Breaker failure, Terminal S
T BRKR FAIL	FBFT	Breaker failure, Terminal T
OVER CURRENT	50TP1 OR 67TPT1 OR 51T01	Overcurrent
VOLTS/HZ	24D1T OR 24D2T OR 24U1T OR 24U2T	Volts/hertz
U/O VOLTAGE	271P1T OR 591P1T	Voltage Element 1 under or overvoltage function asserted
U/O FREQUENCY	81D1T	Frequency Element 1 under or overpower function asserted
DIRECTIONAL POWER	32OPT01 OR 32UPT01	Power Element 1 under or overvoltage function asserted
COMMS ALARM	CCALARM	Communications Alarm

Table 8.17 LED Settings (Sheet 2 of 2)

LED Label	Settings	Comment
HARM BLOCK	87AHB OR 87BHB OR 87CHB OR 87AHR OR 87BHR OR 87CHR	Harmonic block or harmonic restraint differential element A, B, or C
VAV ON	VAVFM > 55	A-phase from V PT present
VBV ON	VBVFM > 55	B-phase from V PT present
VCV ON	VCVFM > 55	C-phase from V PT present
THRU-FAULT ALARM	TFLTALA OR TFLTALB OR TFLTALC	Through-fault element asserted, phase A, B, or C
LOP V	LOPV or LOPZ	Loss-of-potential, PT V or PT Z
INSULATION ALARM	FAA1	Thermal Element 1 ageing acceleration factor asserted
IRIG OK	TIRIG	
EXTERNAL FAULT	CON	External fault detected; relay in high-security mode
FREQ OK	FREQOK	Frequency OK

You can reprogram all of these indicators except the **ENABLED** and **TRIP** LEDs to reflect other operating conditions than the factory default programming described in this subsection. Settings T*n*_LED are SELOGIC control equations that, when asserted during a relay trip event, light the corresponding LED. Parameter *n* is a number from 1 through 24 that indicates each LED.

Program settings T*n*LEDL := Y to latch the LEDs during trip events; when you set T*n*LEDL := N, the trip latch supervision has no effect and the LED follows the state of the T*n*_LED SELOGIC control equation. The asserted and de-asserted colors for the LED are determined with settings T*n*LEDC. Options include red, green, amber, or off.

After setting the target LEDs, issue the **TAR R** command to reset the target LEDs.

Use the slide-in labels to mark the LEDs with custom names. Included on the SEL-487E Product Literature CD are Customer Label Templates to print labels for the slide-in label carrier.

Operational

The **ENABLED** LED indicates that the relay is active. Trip events illuminate the **TRIP** LED. The prominent location of the TRIP LED in the top target area helps you recognize a trip event quickly. Program settings EN_LED*c* and TR_LED*c* to determine the color of the respective LED. Options include red or green.

TARGET RESET and Lamp Test

For a trip event, the relay latches the trip-involved target. Press the **{TARGET RESET}** pushbutton to reset the latched target LEDs. When a new trip event occurs and you have not reset the previously latched trip targets, the relay clears the latched targets and displays the new trip targets.

Pressing the **{TARGET RESET}** pushbutton illuminates all the LEDs. Upon releasing the **{TARGET RESET}** pushbutton, two possible trip situations can exist:

- the conditions that caused the relay to trip have cleared
- the trip conditions remain present at the relay inputs

If the trip conditions have cleared, the latched target LEDs turn off. If the trip event conditions remain, the relay re-illuminates the corresponding target LEDs. The {TARGET RESET} pushbutton also removes the trip automatic message displayed on the LCD menu screens if the trip conditions have cleared.

Lamp Test Function With TARGET RESET

The {TARGET RESET} pushbutton also provides a front-panel lamp test. Pressing {TARGET RESET} illuminates all the front-panel LEDs, and these LEDs remain illuminated for as long as you press {TARGET RESET}. The target LEDs return to a normal operational state after you release the {TARGET RESET} pushbutton.

Lamp Test Function With LCD DISPLAY TEST Menu

The LCD menus provide a front-panel DISPLAY TEST mode. This menu activated lamp test, from the DISPLAY TEST menu, does not reset the target LEDs.

Other Target Reset Options

You can reset the target LEDs with the ASCII command **TAR R**. The **TAR R** command and the {TARGET RESET} pushbutton also control the TRGTR Relay Word bit, which can be used for other functions. TRGTR is the factory default setting for the unlatch trip SELOGIC control equation, ULTR*k* (*k* = S, T, U, W, X.), in the group settings. You can reset the targets from the ACSELERATOR QuickSet Control branch of the HMI tree view. Programming specific conditions in the SELOGIC control equation RSTTRGT is another method to reset the relay targets. Access RSTTRGT in the relay Global settings (Data Reset Control).

Front-Panel Operator Control Pushbuttons

The SEL-487E front panel features large operator control pushbuttons coupled with color-programmable annunciator LEDs for local control. *Figure 8.42* shows this region of the relay front panel with factory default configurable front-panel label text.

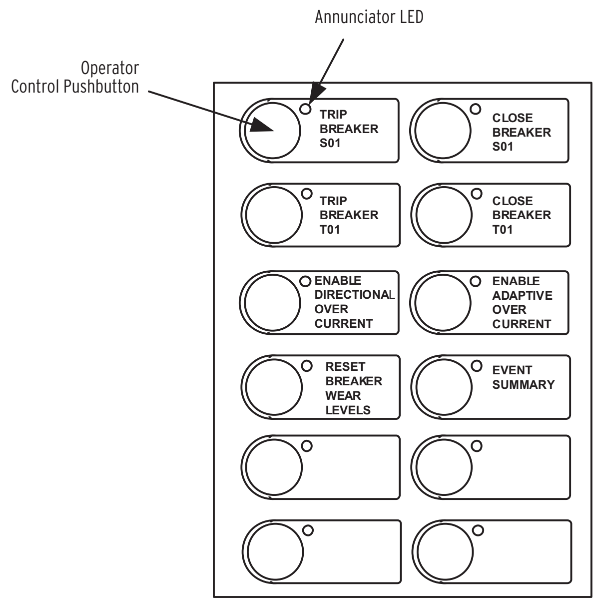


Figure 8.42 Operator Control Pushbuttons and LEDs

Table 8.18 shows the LED labels and the actual settings. These settings are based on a two-winding transformer with directional overcurrent elements and REF protection enabled.

Table 8.18 Pushbutton LED Settings

LED Number	LED Label	Settings
1	Trip Breaker S01	NOT 52CLS
2	Trip Breaker S01	NOT 51CLT
3	Enable Directional Overcurrent	PLT03
4	Reset Breaker Wear Levels	RST_BKS OR RST_BKT
5	Blank	NA
6	Blank	NA
7	Close Breaker S01	52CLS
8	Close Breaker T01	52CLT
9	Enable Adaptive Overcurrent	PLT09
10	Event Summary	
11	Blank	NA
12	Blank	NA

Press the operator control pushbuttons momentarily to toggle on and off the functions listed adjacent to each LED/pushbutton combination.

There are two ways to program the operator control pushbuttons. The first is through front-panel settings PB*nn*_HMI (*nn* = 1–12). These settings allow any of the operator control pushbuttons to be programmed to display a particular HMI screen category. The HMI screen categories available are Alarm Points, Display Points, and Event Summaries, and SER. Front-panel setting NUM_ER allows the user to define the number of event summaries that are displayed via the operator control pushbutton; it has no effect on the event summaries automatically displayed or the event summaries available through the main menu. Each HMI screen category can be assigned to a single pushbutton.

Attempting to program more than one pushbutton to a single HMI screen category will result in an error. After assigning a pushbutton to an HMI screen category, pressing the pushbutton will jump to the first available HMI screen in that particular category. If more than one screen is available, a navigation scroll bar will be displayed. Pressing the navigation arrows will scroll through the available screens. Subsequent pressing of the operator control pushbutton will advance through the available screens, behaving the same as the **{Right Arrow}** or the **{Down Arrow}** pushbutton. Pressing the **{ESC}** pushbutton will return the user to the ROTATING DISPLAY. The second way to program the operator control pushbutton is through SELOGIC control equations, using the pushbutton output as a programming element.

Using SELOGIC control equations, you can readily change the default LED functions. Use the slide-in labels to mark the pushbuttons and pushbutton LEDs with custom names to reflect any programming changes that you make. The labels are keyed; you can insert each Operator Control Label in only one position on the front of the relay. Included on the SEL-487E Product Literature CD are word processor templates for printing slide-in labels. See the instructions included in the Configurable Label kit for more information on changing the slide-in labels.

The SEL-487E has two types of outputs for each of the front-panel pushbuttons. Relay Word bits represent the pushbutton presses. One set of Relay Word bits follows the pushbutton and another set pulses for one processing interval when the button is pressed. Relay Word bits PB1-PB12 are the “follow” outputs of operator control pushbuttons. Relay Word bits PB1_PUL-PB12PUL are the pulsed outputs.

Annunciator LEDs for each operator control pushbutton are **PB1_LED** through **PB12_LED**. The asserted and deasserted colors for the LED are determined with settings PB*nn*COL. Options include red, green, amber, or off. You can change the LED indications to fit your specific control and operational requirements. This programmability allows great flexibility and provides operator confidence and safety, especially in indicating the status of functions that are controlled both locally and remotely.

FP_TO Front-Panel Time-Out

Use the front-panel time-out setting to set the time (in minutes) that the LCD remains active after the last control button was pressed. Once the front panel times out, LCD dims, and the relay enters the rotating display mode.

Setting	Description	Range	Default	Category
FP_TO	Front Panel Display Time-Out	OFF, 1–60 mins	15	Front Panel

EN_LEDC (Enable LED Color)

Select either red or green for the **Enable** LED color. You cannot set the conditions for which the LED illuminates, but you can select the color.

Setting	Description	Range	Default	Category
EN_LEDC	Enable LED Asserted Color	R, G	G	Front Panel

TR_LEDC (Front-Panel Time-Out)

Select either red or green for the **TRIP** LED color. You cannot set the conditions for which the LED illuminates, but you can select the color.

Setting	Description	Range	Default	Category
TR_LEDC	Trip LED Asserted Color	R, G	R	Front Panel

PBnn_LED (Pushbutton LED Control)

Enter the condition(s) that controls the pushbutton LED.

Setting	Description	Range	Default	Category
PB*nn*_LED[a]	Pushbutton LED *nn*	SV	See *Table 8.18*.	Front Panel

[a] nn = 1 - 12.

PBnn_COL (Pushbutton LED Color)

Settings PB*nn*COL (*nn* = 1–12) determine the asserted and deasserted colors for the annunciation LEDs. Options include red, green, amber, or off. Select a color for both the asserted and deasserted state, with the asserted state the first entry. If you do not want the LED to illuminate for a particular state, then set that state to O (OFF).

Setting	Description	Range	Default	Category
PB1_COL	PB1_LED Assert & De-assert Color	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO[a]	AO	Front Panel

[a] A = Amber, G = Green, R = Red, and O = OFF.

Taa_LED (Target LED Control)

Enter the condition(s) that controls the pushbutton LED.

Setting	Description	Range	Default	Category
T*aa*_LED[a]	Target LED *aa*	SV	See *Table 8.17*.	Front Panel

[a] aa = 1-24.

Taa_LEDL (Target LED Latch)

Enter whether the LED latches (Y) or resets (N) after assertion. When you set T*aa*LEDL := N, the LED does not latch, but follows the state of the T*aa*_LED SELOGIC control equation.

Setting	Description	Range	Default	Category
T*aa*LEDL[a]	Target LED 1 Latch	Y, N	Y	Front Panel

[a] aa = 1-24.

TaaLEDC LED Color

Settings T*aa*LEDC (*aa* = 1–24) determine the asserted and deasserted colors for the target LEDs. Options include red, green, amber, or off. Select a color for both the asserted and deasserted state, with the asserted state the first entry. If you do not want the LED to illuminate for a particular state, then set that state to O (OFF).

Setting	Description	Range	Default	Category
T1LEDC	T1_LED Assert & De-assert Color	AG, AO, AR, GA, GO, GR, OA, OG, OR, RA, RG, RO[a]	AO	Front Panel

[a] A = Amber, G = Green, R = Red, and O = OFF.

SCROLD (Display Update Rate)

Front-panel setting SCROLD defines the period of time each screen is shown in the auto scrolling mode. With SCROLD := OFF the screen remains on the first screen in the rotating display order, i.e., automatic rotation of additional screens is disabled.

Setting	Description	Range	Default	Category
SCROLD	Front Panel Display Update Rate	OFF, 1–15 seconds	5	Front Panel

RDDxx (Display Update Rate)

Front-panel setting SCROLD defines the period of time each screen is shown in the auto scrolling mode. With SCROLD := OFF the screen remains on the first screen in the rotating display order, i.e., automatic rotation of additional screens is disabled.

Setting	Description	Range	Default	Category
RDD*xx*[a]	Front Panel Screens Selection	See *Table 8.2* through *Table 8.6*	RMS_VLL	Front Panel

[a] xx = 1–99.

PBnn (Selectable Operator Pushbuttons)

These settings allow any of the operator control pushbuttons to be programmed to display any of the HMI screen categories, i.e., Alarm Points, Display Points, Event Summaries, SER, and Bay Control. After assigning a pushbutton to an HMI screen category, pressing the pushbutton will jump to the first available HMI screen in that particular category.

Setting	Description	Range	Default	Category
PB*nn*_HMI[a]	Pushbutton 1 HMI Screen	(OFF, AP, DP, EVE, SER, BC)	OFF[b]	Front Panel

[a] nn = 1–12.
[b] Except PB10HMI = EVE.

DISPE_ER (Enable HMI Auto Event Summaries Display)

In order to display event reports automatically from the ROTATING DISPLAY, set front-panel setting **DISP_ER** to Y. Front-panel setting **TYPE_ER** allows the user to define which types of event reports will be automatically displayed from the normal ROTATING DISPLAY.

Setting	Description	Range	Default	Category
DISP_ER	Enable HMI Auto Display of Event Summaries (Y, N)	Y, N	N	Front Panel

TYPE_ER (Type of Events)

With DISP_ER set to Y, use setting TYPE_ER to define which types of event reports will be automatically displayed from the normal ROTATING DISPLAY; ALL will display all event types described in *Table 8.5* and TRIP will display only the event types that include the assertion of the TRIP Relay Word bit.

Setting	Description	Range	Default	Category
TYPE_ER	Types of Events for HMI Auto Display (ALL, TRIP)	ALL, TRIP	TRIP	Front Panel

NUM_ER (Type of Events)

This setting is only available if at least one of the PB*n*_HMI settings is set to EVE. Use the NUM_ER setting to state the number of event summaries the relay displays. For example, if there are six faults recorded in the relay and NUM_ER = 3, the relay displays only the last three fault summaries.

Setting	Description	Range	Default	Category
NUM_ER	Operator Pushbutton Events to Display	1–100	3	Front Panel

DISPLAY POINTS

Use up to 96 display points to display messages on the SEL-487E front-panel LCD that indicate conditions of interest. The settings format is shown below, and summarized in *Table 8.13* (Boolean) and *Table 8.14* (analog).

(Boolean): Relay Word Bit Name, “Label”, “Set String”, “Clear String”, “Text Size”

(Analog): Analog Quantity Name, “User Text and Formatting”, “Text Size”

Table 8.19 Display Point Settings-Boolean

Description	Range
Relay Word Bit Name	*Appendix G: Relay Word Bits*
Alias	ASCII string
Set String	ASCII string
Clear String	ASCII string
Text Size	S, D

Table 8.20 Display Point Settings-Analog

Description	Range
Analog Quantity Name	*Appendix H: Analog Quantities*
User Text and Formatting	ASCII string
Text Size	S, D

Local Control

See the *LOCAL CONTROL* settings description.

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Section 9

Bay Control

Overview

The SEL 487E Relay provides bay configuration on the front-panel screen with disconnect and breaker control capabilities for 20 predefined user selectable busbar layouts and seven transformer bay types. Additional user-selectable bay types are available via an SEL-5030 Quickset interface that can be downloaded at www.selinc.com. With the bay control, you can control as many as eight disconnects (*m* = 1 through 8) and five breakers (*n* = 1 through 5). Although there are eight disconnects and five breakers available, these are the total numbers for the HV busbar, the transformer, and the LV busbar. Because you individually select the HV busbar layout, LV busbar layout and transformer type, be sure that the total number of breakers does not exceed five, and that the total number of disconnects does not exceed eight. You can operate disconnects and breakers with ASCII commands, SELOGIC® control equations, Fast Operate Messages, and from the one-line diagram on the front-panel screen. One-line diagrams include user-configurable apparatus labels and as many as six user-definable analog quantities. This section covers all aspects of the SEL 487E bay control.

Circuit Breaker Status Logic

The SEL-487E circuit breaker state and circuit breaker alarm conditions are determined by the circuit breaker status logic presented in this section; see *Circuit Breaker Status Logic on page 9.2*

Disconnect Logic

The disconnect logic in the SEL-487E safely operates the disconnect switches and reports status of the disconnect switches. The SEL-487E disconnect logic is independent for each of the disconnect switches. This section presents the SEL-487E disconnect logic and definitions of close, open, and undetermined state indications:

- *Disconnect Switch Close and Open Control Logic on page 9.3*
- *Disconnect Switch Status and Alarm Logic on page 9.6*
- *Close and Open Immobility Timer Logic on page 9.9*
- *Close, Open, and Undetermined State Indications on page 9.11*

Bay Control Front-Panel Operations

The one-line diagram in the SEL-487E presents the bay configuration on the front-panel display. Breaker and disconnect switch control within the one-line diagram is one of the supported means of operating breakers and disconnect switches. This section presents the unique one-line diagram front-panel operations in the SEL-487E and definitions of symbols in the one-line diagrams:

- *Bay Control Front-Panel Operations on page 9.12*
- *One-Line Diagram and One-Line Diagram Labels on page 9.13*
- *Front-Panel Pushbutton Navigation Operations in the One-Line Diagram on page 9.14*
- *Circuit Breaker and Disconnect Definitions and State Representations on page 9.15*
- *Circuit Breaker and Disconnect Switch Operations From the Front Panel on page 9.17*

ACSELERATOR QuickSet SEL-5030 Software Bay Control Screens Example

For the bay control, ACSELERATOR QuickSet® SEL-5030 Software includes interactive one-line diagram settings screens. This section presents ACSELERATOR QuickSet one-line diagram setting screen functionality: see *Figure 9.14 on page 9.24.*

Predefined Bay Control One-line Diagrams

The SEL-487E supports as many as 20 user-selectable bay configurations and 7 transformer types (ANSI and IEC). This section defines the one-line diagram and illustrates the 20 bay configurations and transformer types supported in the SEL-487E:

- *One-Line Diagram and One-Line Diagram Labels on page 9.13*
- *Main Bus and Auxiliary Bus on page 9.34*
- *Bus 1, Bus 2, and Transfer Bus on page 9.35*
- *Main Bus and Transfer Bus on page 9.36*
- *Main Bus on page 9.37*
- *Breaker-and-a-Half on page 9.38*
- *Ring Bus on page 9.40*
- *Double Bus Double Breaker on page 9.41*

Circuit Breaker Status Logic

The SEL-487E includes circuit breaker status logic for five circuit breakers. The circuit breaker status logic uses the 52_*n* (*n* = 1 through 5) Relay Word bit and open phase detection logic to determine the state of Circuit Breaker *n*, and declare Circuit Breaker *n* alarm conditions. A Circuit Breaker *n* alarm condition is declared by the circuit breaker status logic, when Relay Word bit 52_*n* deasserts and current is detected by the open phase detection logic. See *Circuit Breaker Status on page 4.107* for a description of circuit breaker status logic Relay Word bits and circuit breaker status logic diagrams.

Disconnect Logic

Disconnect Switch Close and Open Control Logic

Introduction

Figure 9.1 and *Figure 9.2* shows the Disconnect Logic that generates open and close output signals necessary to perform the open and close disconnect operations. Use the seal-in timers (89CSIT*m* and 89OSIT*m*) to monitor and control disconnect operations. All disconnect control methods (HMI, ASCII, SELOGIC control equations, and Fast Operate) drive the Close and Open Control Logic in the SEL-487E.

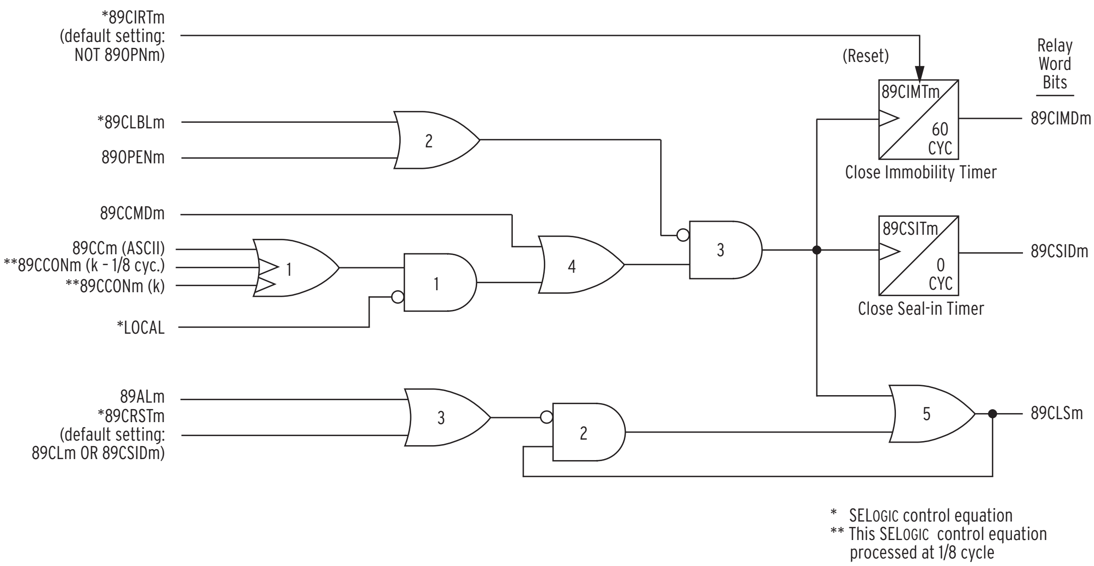


Figure 9.1 Disconnect Switch Close Logic

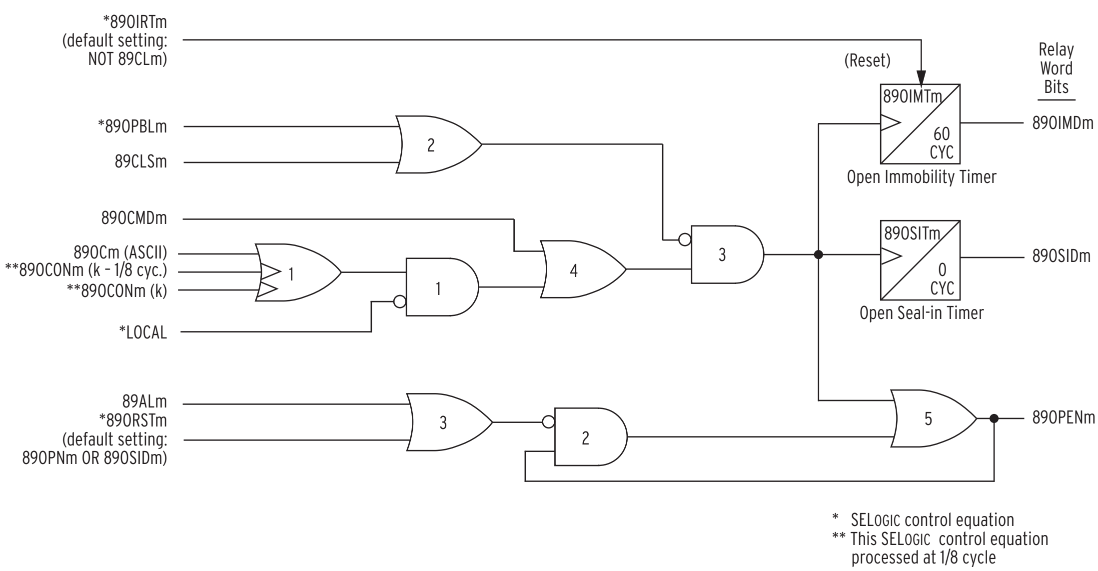


Figure 9.2 Disconnect Switch Open Logic

Disconnect Switch Close and Open Control Logic Status Inputs

89CLSm, 89OPENm

Disconnect Switch Close Logic (*Figure 9.1*) and Open Logic (*Figure 9.2*) generate Relay Word bits 89CLS*m* and 89OPEN*m* which drive the open and close operations. To ensure that an open and close disconnect signal cannot occur at the same time, 89CLS*m* and 89OPEN*m* also block operation of the opposing logic. Therefore, Relay Word bit 89CLS*m* is an input to the Disconnect Open Logic, and Relay Word bit 89OPEN*m* is an input to the Disconnect Close Logic.

89CLBLm, 89OPBLm

The 89CLBL*m* and 89OPBL*m* SELOGIC control equations provide an alternative customizable method for blocking the initiation of a disconnect switch open or close command, respectively.

89CRSTm, 89ORSTm

The 89CRST*m* and 89ORST*m* SELOGIC control equations provide the flexibility to select the signals that reset the close (89CLS*m*) or open (89OPEN*m*) outputs. 89CRST*m* defaults to (89CL*m* OR 89CSID*m*), and 89ORST*m* defaults to (89OPN*m* OR 89OSID*m*).

89CSIDm, 89OSIDm

Set 89CSIT*m* and 89OSIT*m* to seal in the open and close signals for each individual installation. Relay Word bits 89CSID*m* and 89OSID*m* are the outputs of the close and open seal-in timers, and assert after the appropriate timers expire. By default, 89CSID*m* and 89OSID*m* are used in the 89CRST*m* and 89ORST*m* SELOGIC control equations to reset the close and open signals, 89CLS*m* and 89OPEN*m*, that drive the disconnect switch motor.

89CLm, 89OPNm

The 89CL*m* and 89OPN*m* Relay Word bits report the state of the disconnect switches. If the disconnect switch is closed, Relay Word bit 89CL*m* is asserted; if the disconnect switch is open, Relay Word bit 89OPN*m* is asserted. See *Figure 9.3* for a description of these inputs. With the default settings, when Relay Word bit 89CL*m* asserts, the close seal-in circuit is blocked, causing 89CLS*m* to deassert. Likewise, with the default settings, when Relay Word bit 89OPN*m* asserts, the open seal-in circuit is blocked, causing 89OPEN*m* to deassert.

89ALm

The disconnect switch status and alarm logic in *Figure 9.3* generates the 89AL*m* Relay Word bit. When Relay Word bit 89ALm asserts, it resets the seal-in circuits, deasserting the 89CLS*m*/89OPEN*m* signals.

LOCAL

The LOCAL Relay Word bit asserts when LOCAL SELOGIC control equation asserts to a logical 1. When the LOCAL Relay Word bit asserts, only the HMI commands (**89CCMD*m*** and **89OCMD*m***), can initiate close and open operations. When the LOCAL Relay Word bit is deasserted, the **89CLOSE**, **89OPEN**, SELOGIC disconnect close/open, and Fast Operate disconnect close/open commands can perform disconnect close and open operations.

Disconnect Switch Close and Open Control Logic Action Inputs

89CCONm, 89OCONm

89CCON*m* and 89OCON*m* SELOGIC control equations are for programmable close and open disconnect switch operations. The LOCAL Relay Word bit must be deasserted for the close or open SELOGIC equations to initiate a disconnect switch operation. Use care when using SELOGIC control equations for disconnect switch operations; this disconnect operate method is not supervised by the breaker jumper or appropriate relay access levels as is the case with other disconnect operation methods.

89CCMm, 89OCMm

89CCMD*m* and 89OCMD*m* Relay Word bits pulse for one-quarter cycle when close or open disconnect operations are initiated from the one-line diagram on the front-panel screen. If the LOCAL Relay Word bit is not asserted, then Relay Word bits 89CCMD*m* or 89OCMD*m* cannot assert.

89CCm, 89OCm

The **89CLOSE** command or Fast Operate disconnect close message, pulses Relay Word bit 89CC*m* for one-quarter cycle. The **89OPEN** command or Fast Operate disconnect open message, pulses Relay Word bit 89OC*m* for one-quarter cycle. The LOCAL Relay Word bit must be deasserted for a disconnect switch operation to be initiated by a Fast Operate message or **89CLOSE** and **89OPEN** commands.

Disconnect Seal-In Timer Settings

89CSITm, 89OSITm

89CSIT*m* and 89OSIT*m* settings are for defining the time required for the disconnect switch to complete a close or open operation.

Disconnect Switch Close and Open Control Logic Output

89CLSm, 89OPENm

The 89CLS*m* and 89OPEN*m* Relay Word bits are used in SELOGIC output equations to perform close and open disconnect switch operations.

Disconnect Switch Close and Open Control Logic Processing

Figure 9.1 shows the Disconnect Switch Close Logic and *Figure 9.2* shows the Disconnect Switch Open Logic.

Some motor-operated disconnect switches have their own seal-in circuits to seal the closing and opening signals in. Other motor-operated disconnect switches, however, require external sealed-in circuits to maintain the closing and opening signals for the duration of the disconnect operation.

With SELOGIC equations 89CRST*m* and 89ORST*m* set to the default settings (include Relay Word bits 89CSID*m* and 89OSID*m*), the open and close signals remain asserted for the time settings of the Close and Open Seal-In Timers, 89CSIT*m* and 89OSIT*m*.

⚠CAUTION
The outputs in the SEL-487E are not designed to break the coil current in the disconnect motor. An auxiliary contact with adequate current interrupting capacity must clear the coil current in the disconnect motor before the output on the SEL-487E opens. Failure to observe this safeguard could result in damage to the SEL-487E output contacts.

If the 89OPBL*m* SELOGIC control equation and the 89OPEN*m* and the LOCAL Relay Word bits are deasserted, then any of the SEL 487E close disconnect operate methods can assert Relay Word bit 89CLS*m*, and initiate the Close Seal-In Timer, 89CSIT*m*. Enter Relay Word bit 89CLS*m* into a SELOGIC output equation to drive the motor of the disconnect.

Set the Close Seal-In Timer, 89CSIT*m*, long enough to keep Relay Word bit 89CLS*m* asserted long enough to complete the disconnect operation.

To account for slow operate times due to cold weather or low battery voltage, set the 89CSIT*m* time 10 to 15 percent longer than the expected operate time. This guarantees that the disconnect switch has fully operated before the 89CLS*m* signal is removed. When the 89CSIT*m* seal-in timer expires, 89CSID*m* asserts, or the disconnect switch normally open contact closes (89CL*m* asserted), the 89CLSm output deasserts. This completes an open-to-close cycle of the Disconnect Close Logic; the Disconnect Open Logic in *Figure 9.2* behaves in the same manner.

Disconnect switch status and alarm logic in *Figure 9.3* generates Relay Word bit 89AL*m*. When Relay Word bit 89AL*m* asserts, a disconnect alarm condition exists. The 89AL*m* Relay Word bit ensures that the close or open signal does not remain asserted when a disconnect switch alarm condition exists. When Relay Word bit 89AL*m* asserts or the seal-in timer expires, the 89CLS*m* or 89OPEN*m* signals deassert.

When a close operation is inadvertently initiated with the disconnect switch already closed, and the 89CRST*m* SELOGIC control equation is set as defaulted (89CL*m* OR 89CSID*m*), the asserted 89CL*m* Relay Word bit (close status) will block the seal-in circuit before the timer expires. This will deassert the 89CLS*m* Relay Word bit, which drives the disconnect switch motor. In this way, 89CLS*m* asserts for only one processing interval.

If an open command was sent within the 89CSIT*m* time, an open and close signal could be sent to the disconnect switch at the same time. The 89CLS*m* Relay Word bit input to the Disconnect Switch Open Logic guarantees that open and close commands are not transmitted to the disconnect switch simultaneously. When the 89CLS*m* Relay Word bit deasserts, an open command can be performed. The 89OPBL*m* SELOGIC control equation provides an additional customizable method for blocking the initiation of a close command. The Relay Word bit 89OPEN*m*, and 89CLBL*m* inputs to the Disconnect Switch Close Logic serves the same purpose.

Disconnect Switch Status and Alarm Logic

Introduction

The disconnect switch auxiliary contacts are inputs to the Disconnect Switch Status and Alarm Logic as shown in *Figure 9.3*. SELOGIC control equation 89AM*m* is the input for the normally open a auxiliary contact, and SELOGIC control equation 89BM*m* is the input for the normally closed b auxiliary contact. For the Status and Alarm Logic to function correctly, wire the a and b contacts each to separate inputs on the SEL-487E. Depending on the one-line diagram selected, as many as five disconnect switches are supported. This means that for five disconnect switches, you should wire ten relay inputs to the disconnect switch auxiliary contacts. When ordering the SEL-487E, consider the number of inputs required for the bay configuration being controlled. The number of auxiliary contacts for some bay configurations may require that the SEL-487E be configured with additional I/O boards; see the SEL-487E Model Option Table for ordering options.

Disconnect operations are possible with only one auxiliary contact input, but with this implementation the Status and Alarm Logic will not provide accurate Alarm, Operation in Progress, or Bus-zone protection reporting. When only one auxiliary contact is available for input, set one SELOGIC control equation to the available auxiliary contact input and invert the other SELOGIC control equation:

89AMm := **IN102**

89BMm := **NOT IN102**

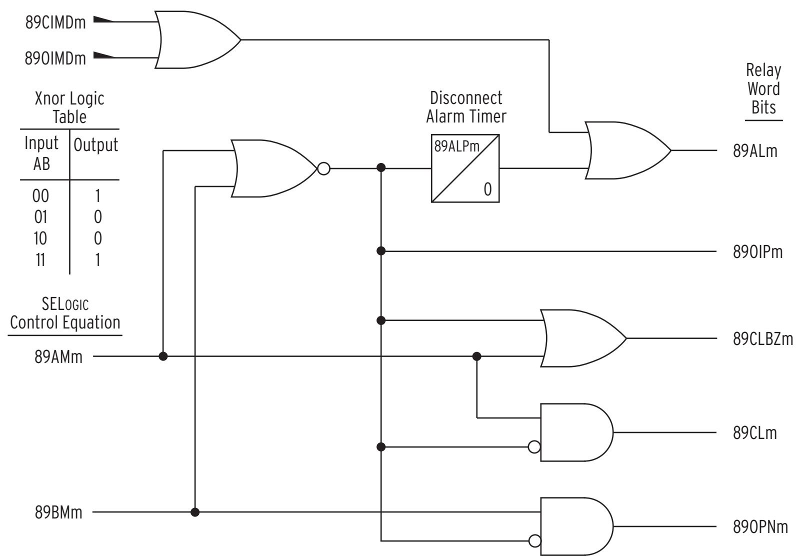


Figure 9.3 Disconnect Switch Status and Alarm Logic

Disconnect Switch Status and Alarm Logic Inputs

89AMm, 89BMm

The 89AM*m* and 89BM*m* SELOGIC control equations represent the normally open and normally closed disconnect switch auxiliary contacts. Typically, these are set to SEL-487E inputs that are wired to the auxiliary contacts.

89CIMDm, 89OIMDm

If the close or open immobility timer expires, 89CIMD*m* or 89OIMD*m* asserts. Expiration of the immobility timer indicates that the disconnect failed to move for a disconnect switch close or open command initiated from the front panel.

Disconnect Switch Status and Alarm Logic Settings

89ALPm

This setting in the Bay settings class defines the disconnect switch alarm time.

Disconnect Switch Status and Alarm Logic Outputs

89ALm

If a disconnect switch operation initiated from the front panel does not start, the 89ALP*m* timer expires and the 89AL*m* Relay Word bit asserts. Expiration of the 89ALP*m* timer indicates that an initiated disconnect operation failed to complete and the disconnect switch is in an undetermined state. In addition, the 89CSIT*m* or 89OSIT*m* timer also expires to deassert the output signal (89CLS*m* or 89OPEN*m*), thus ensuring that there is not a constant signal applied to the disconnect.

89OIPm

When Relay Word bit 89OIP*m* asserts, a disconnect switch operation is in progress. Relay Word bit 89OIP asserts when the states of the 89BM*m* and 89AM*m* Relay Word bits are the same, i.e., both asserted or both deasserted.

89CLBZm

This Relay Word bit is used for Bus Zone protection and asserts when the disconnect is no longer open (89BM*m* deasserted).

89CLm

When Relay Word bit 89CL*m* asserts, the disconnect switch is closed.

89OPNm

When Relay Word bit 89OPN*m* asserts, the disconnect switch is open.

Disconnect Switch Status and Alarm Logic Processing

Figure 9.3 shows the Disconnect Switch Status and Alarm Logic. Inputs to this logic are the Normally Open (89AM*m*) and Normally Closed (89BM*m*) disconnect switch auxiliary contacts. As discussed before, the SEL-487E supports as many as five disconnect switches, depending on the one-line diagram selected.

To understand the logic in *Figure 9.3*, consider an open-to-close operation. The first disconnect operation scenario looks at a successful open-to-close disconnect switch operation; a successful close-to-open operation is similar. In the open state, 89AM*m* is deasserted and 89BM*m* is asserted. Once a close command is initiated in the SEL-487E, the disconnect switch starts to move and 89BM*m* deasserts. When 89BM*m* deasserts, the 89ALP*m* pickup timer starts to time. With 89BM*m* deasserted, the state of the disconnect switch cannot be determined, because both disconnect switch auxiliary contacts are deasserted. Set the 89ALP*m* timer longer than the expected undetermined disconnect state time, but less than the 89CSIT*m* or 89OSIT*m* seal-in timers. If the 89ALP*m* timer expires, the 89AL*m* Relay Word bit asserts. Relay Word bit 89AL*m* asserts when the disconnect operation does not complete successfully. When the 89ALP*m* timer begins timing, the operation in progress, Relay Word bit 89OIP*m*, and Relay Word bit 89CLBZ*m* assert. The 89CLBZ*m* Relay Word bit is for bus-zone protection, this bit asserts when the 89BM*m* input deasserts.

During the disconnect switch operation-in-progress condition, Relay Word bits 89CL*m* and 89OPN*m* are both deasserted since the state of the disconnect switch is undetermined. Once the disconnect switch auxiliary contact Relay Word bit 89AM*m* asserts, the condition has been met to declare the disconnect switch closed. When 89AMm asserts, the 89CL*m* Relay Word bit asserts, 89ALP*m* stops timing, Relay Word bit 89OIP*m* deasserts, and Relay Word bit 89CLBZ*m* remains asserted. This sequence completes a successful open-to-close disconnect switch operation.

The scenario in which both 89AM*m* and 89BM*m* are asserted simultaneously would occur on a rare disconnect switch failure or a short-circuited auxiliary contact wire connection. When this condition occurs for 89ALP seconds, the 89AL*m* alarm status output will assert.

Close and Open Immobility Timer Logic

Introduction

The Close and Open Immobility Timer Logic detects when a disconnect operation failed to initiate.

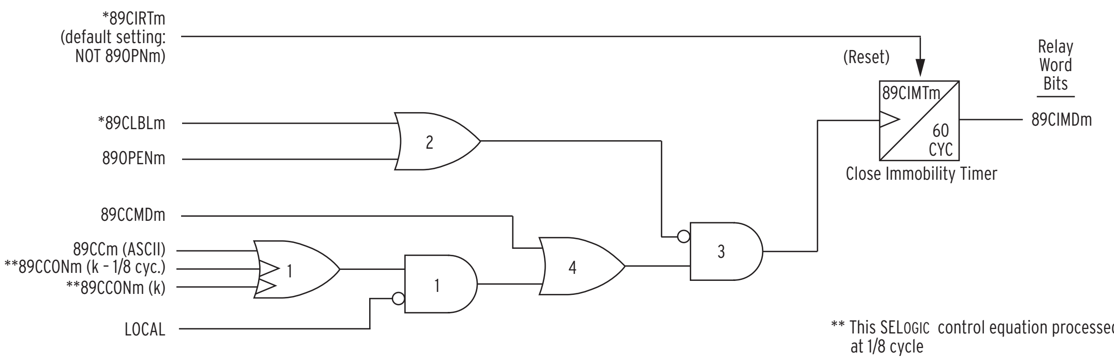


Figure 9.4 Close Immobility Timer Logic

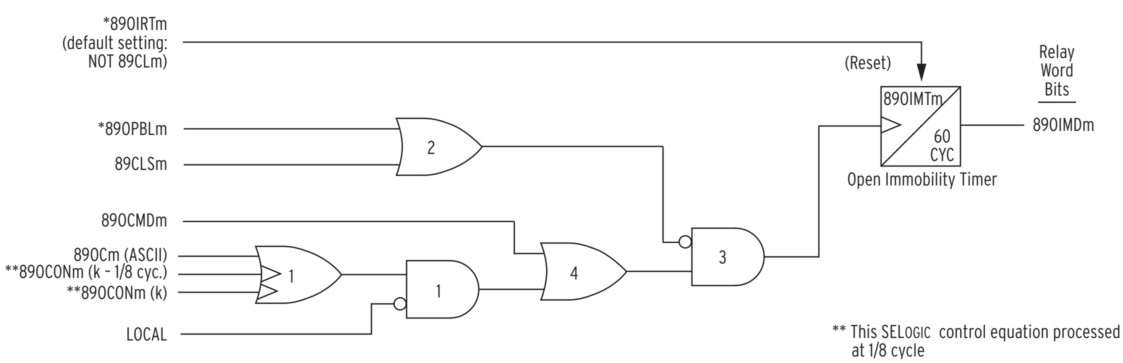


Figure 9.5 Open Immobility Timer Logic

Close and Open Immobility Timer Logic Inputs

LOCAL

The LOCAL Relay Word bit supervises local disconnect control and is based on the LOCAL SELOGIC control equation in the Bay settings class. Disconnect switch operations from the front panel are possible when the LOCAL Relay Word bit is asserted, in other words, the LOCAL Relay Word bit prevents control from the HMI without proper supervision.

89CLBLm, 89OPBLm

The 89CLBL*m* and 89OPBL*m* SELOGIC control equations provide an alternative customizable method for blocking the initiation of a disconnect switch open or close command, respectively.

89CIRTm, 89OIRTm

The 89CIRT*m* and 89OIRT SELOGIC control equations provide the flexibility to customize resetting the Close and Open Immobility Timers. By default, 89CIRT*m* is set to NOT 89OPN*m*, and 89OIRT is set to NOT 89CL*m*.

89CLm, 89OPNm

The 89CL*m* and 89OPN*m* Relay Word bits report the state of the disconnect switches. If the disconnect switch is closed, Relay Word bit 89CL*m* is asserted; If the disconnect switch is open, Relay Word bit 89OPN*m* is asserted. See *Figure 9.3* for a description of these inputs.

Disconnect Switch Close and Open Control Logic Action Inputs

89CCONm, 89OCONm

89CCON*m* and 89OCON*m* SELOGIC control equations are for programmable close and open disconnect switch operations. The LOCAL Relay Word bit must be deasserted for the SELOGIC close or open to initiate a disconnect switch operation. Use care when using SELOGIC control equations for disconnect switch operations; this disconnect operate method is not supervised by the breaker jumper or appropriate relay access levels as is the case with other disconnect operation methods.

89CCMDm, 89OCMDm

89CCMD*m* and 89OCMD*m* Relay Word bits pulse for one-quarter cycle when close or open disconnect operations are executed from the one-line diagram on the front-panel screen. The LOCAL Relay Word bit must be asserted, for Relay Word bits 89CCMD*m* or 89OCMD*m* to assert.

89CCm, 89OCm

The **89CLOSE** command or Fast Operate disconnect close message, pulses Relay Word bit 89CC*m* for one-quarter cycle. The **89OPEN** command or Fast Operate disconnect open message, pulses Relay Word bit 89OC*m* for one-quarter cycle. The LOCAL Relay Word bit must be deasserted for a disconnect switch operation to be initiated by a Fast Operate message or **89CLOSE** and **89OPEN** commands.

Close and Open Immobility Timer Logic Settings

89CSITm, 89OSITm

89CIMT*m* and 89OIMT*m* timer settings in the Bay settings class define the close and open immobility timers.

Close and Open Immobility Timer Logic Outputs

89CIMDm, 89OIMDm

When 89CIMD*m* or 89OIMD*m* asserts, the close or open immobility timer has expired.

Close and Open Immobility Timer Logic Processing

The Close and the Open Immobility Timer Logic detect when one of the close or open disconnect switch methods does not initiate successfully. In other words, it reports when the disconnect switch failed to start moving. The open and close immobility timer logic circuits are similar. When a close operation is initiated, the rising-edge-triggered Close Immobility Timer starts timing. Once the disconnect switch starts to move away from its closed position, Relay Word bit 89OPN*m* deasserts (see the Disconnect Switch Status and Alarm Logic shown in *Figure 9.3*). If the 89OPN*m* Relay Word bit deasserts, the close immobility timer resets and 89CIMD*m* remains deasserted. On the other hand, if the 89OPN*m* Relay Word bit stays asserted, the close immobility timer does not reset. After the close immobility timer expires, 89CIMD*m* asserts for one second. When 89CIMD*m* asserts, the close operation is considered to have failed to initiate. 89CIMD*m* is an input to the disconnect switch status and alarm logic for alarm condition indications.

This logic also uses the LOCAL Relay Word bit to supervise front-panel operations. With the LOCAL Relay Word bit deasserted, no disconnect operations can be initiated from the one-line diagram. With the LOCAL Relay Word bit asserted, Relay Word bit 89CCM*m* asserts for one-quarter cycle when the **{ENT}** pushbutton is pressed and a disconnect switch is highlighted in the one-line diagram.

Close, Open, and Undetermined State Indications

This subsection discusses the way the close and open immobility timers work in conjunction with the disconnect alarm timer to provide disconnect control and alarm indications. When the disconnect switch main contact is stationary (closed or open) the state of the disconnect switch is easily determined.

If the disconnect switch main contact is open:

- normally closed b auxiliary contact (89BM*m* asserted) is closed
- normally open a auxiliary contact (89AM*m* deasserted) is open

If the disconnect switch main contact is closed:

- normally closed b auxiliary contact (89BM*m* deasserted) is open
- normally open a auxiliary contact (89AM*m* asserted) is closed

If an operation of the disconnect switch is in progress, the state of the disconnect switch main contact is undetermined:

- normally closed b auxiliary contact (89BM*m* deasserted) is open
- normally open a auxiliary contact (89AM*m* deasserted) is open

Any undetermined state of the disconnect switch main contact should be monitored. The SEL-487E can be configured to wait for the disconnect switch operation to complete, and issue an alarm if the disconnect switch remains in the undetermined state longer than the 89ALP*m* time. *Figure 9.6* illustrates how the state of the auxiliary contacts change for an open-to-close operation in progress and how the 89CIMT*m* and 89ALP*m* timers are configured to manage the undetermined time. The close-to-open scenario would be similar.

With the disconnect switch in the open state, the normally closed b auxiliary contact is closed (89BM*m* asserted) and the normally open a auxiliary contact is open (89AM*m* deasserted). The 89CSIT*m* seal-in timer starts timing when a disconnect switch close command is issued. The output of the 89CSIT*m* seal-in timer keeps the close signal asserted for the duration of the expected disconnect switch operate time. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time, to allow for slow disconnect operation times caused by cold temperatures or low battery voltages.

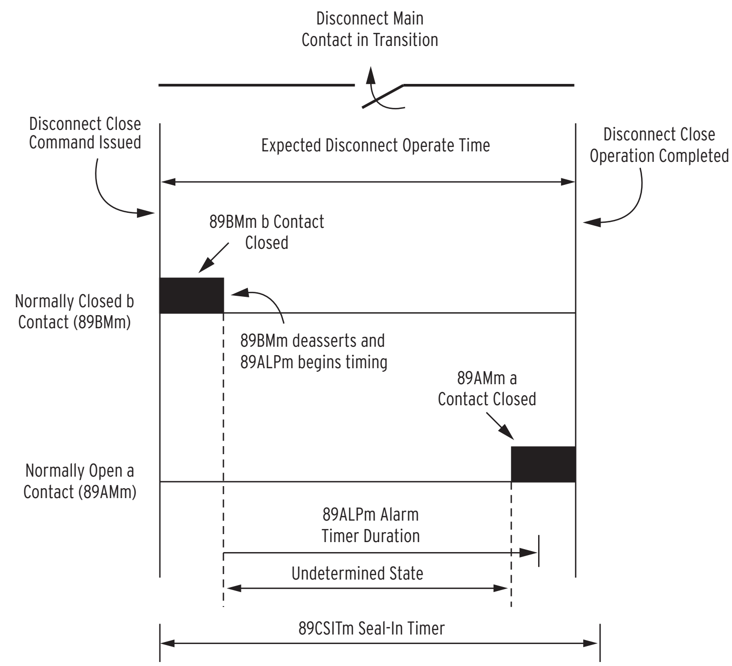


Figure 9.6 Disconnect in Transition

When the normally closed auxiliary contact (SELOGIC input 89BM*m*) deasserts, the disconnect switch is in an undetermined state. No proper position indication from either of the disconnect switch auxiliary contacts (89BM*m* or 89AM*m*) is available. Once the auxiliary normally closed contact (SELOGIC input 89BM*m*) deasserts, the 89ALP*m* timer starts timing. The 89ALP*m* timer monitors the undetermined state of the disconnect switch. For the 89ALP*m* timer to initialize, the disconnect switch has to move a minimum distance to open the normally closed auxiliary contact (open-to-close operation). Set the 89ALP*m* timer longer than the expected undetermined state time, but less than the 89CSIT*m* seal-in timer. If the normally open auxiliary contact fails to close within the undetermined state time, the 89ALP*m* timer expires and an alarm condition is declared.

The Close Immobility Logic starts the Close Immobility Timer for an operation where the disconnect switch does not move the minimum distance to open the normally closed auxiliary contact (open-to-close operation). When the close immobility timer expires, an alarm condition is declared and Relay Word bit 89AL*m* asserts. If the disconnect moves enough to open the normally closed auxiliary contact, the Close Immobility timer resets and no alarm condition is declared. See *Figure 9.4*.

Bay Control Front-Panel Operations

For improved visibility on the front-panel HMI, the transformer terminal is displayed over two screens, i.e., an HV and an LV bay control screen. *Figure 9.7* shows these two screens, displaying the HV and the LV sides of the transformer. The transformer itself is common to both screens.

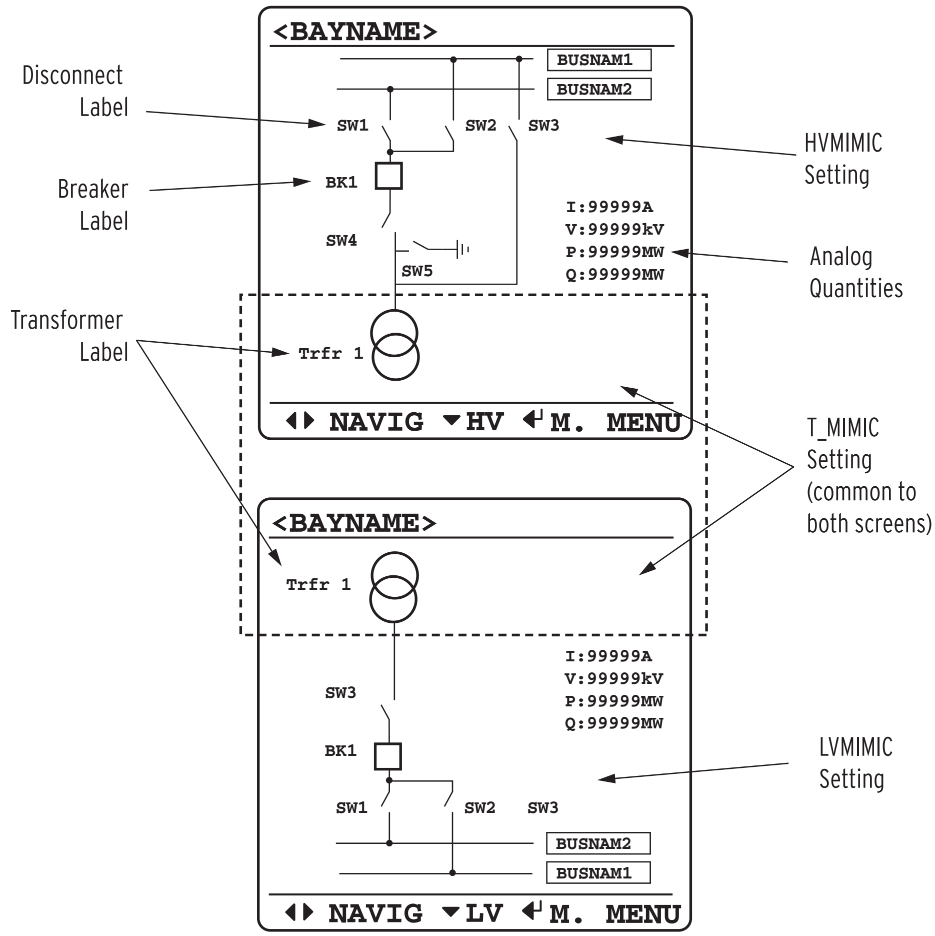


Figure 9.7 Dual Screen Display

One-Line Diagram and One-Line Diagram Labels

Figure 9.8 is an example of one of 20 selectable one-line diagrams in the SEL-487E. Compose the one-line diagram from a combination of HVMIMIC, T_MIMIC, and LVMIMIC MIMIC settings in the Bay settings class. If an additional user-selectable bay type has been configured, it is selected by setting the specific MIMIC setting to any number in the range of 21–100. The Bay settings class also has additional Bay class settings for defining labels and analog quantities. One-line diagrams are comprised of the following:

- ➤ Bay Names and Bay Labels (Bay Labels available in *Figure 9.56* through *Figure 9.59*. All other one-line diagrams use the Bay Name.)
- ➤ Busbars and Busbar Labels
- ➤ Breakers and Breaker Labels
- ➤ Disconnect Switches and Disconnect Switch Labels
- ➤ Transformer and transformer labels
- ➤ Analog display points

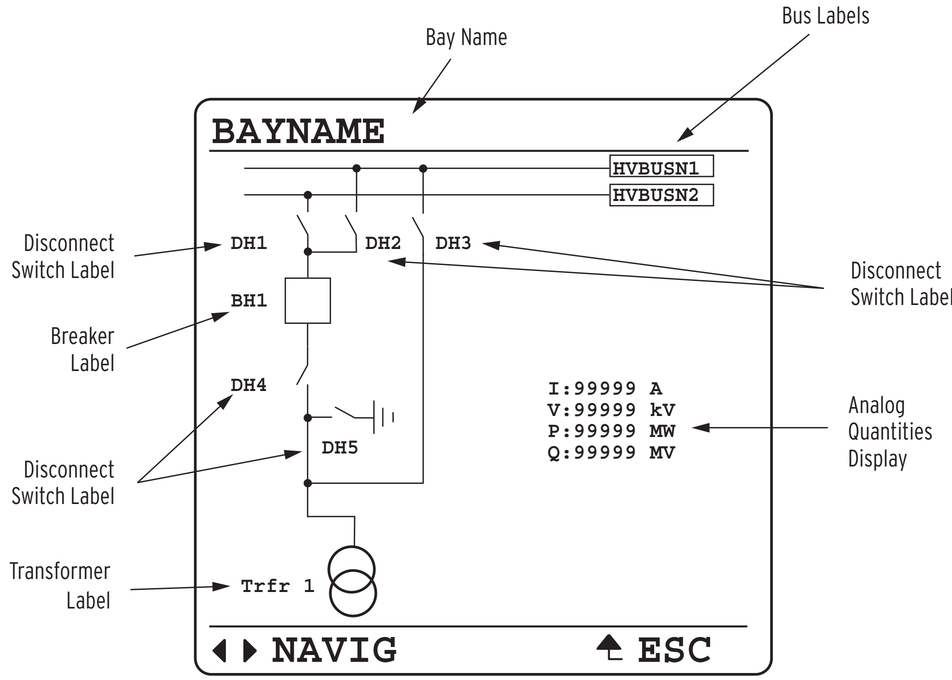


Figure 9.8 Bay Control One-Line Diagram

Front-Panel Pushbutton Navigation Operations in the One-Line Diagram

Navigation within the one-line diagram requires that the front-panel access level be at Breaker Access Level or higher and the Breaker Jumper be installed. If navigation is attempted when:

- the front panel is not at the Breaker Access Level or higher and passwords are enabled, the relay prompts you to enter the appropriate passwords.
- the Breaker Jumper is not installed, the `Breaker Control Disabled Please Install the Breaker Jumper` message briefly appears on the screen.

Use the arrow pushbuttons on the front panel to navigate within the one-line diagram. When you first select the one-line diagram, none of the apparatus on the one-line diagram are highlighted. Press a {Left Arrow} or {Right Arrow} pushbutton to enter the one-line diagram and highlight the apparatus in the one-line diagram. Once you enter the one-line diagram, navigation between the disconnect switch and circuit breaker symbols in the one-line diagram is as follows:

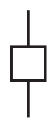
- Pressing the {Right Arrow} key highlights the elements from left-to-right and top-to-bottom.
- When reaching the right-most bottom element, the following {Right Arrow} keystroke “rolls over” and again highlights the left-most top element.
- The {Left Arrow} key operates in reverse, i.e., from right-to-left, and bottom-to-top.
- Pressing the {Down Arrow} key while displaying the HV bay control screen, displays the LV bay control screen.
- Pressing the {Down Arrow} pushbutton while displaying the LV bay control screen, or the {Up Arrow} pushbutton while displaying the HV bay control screen, nothing will occur.

- ➤ Pressing the **{Up Arrow}** pushbutton while displaying the LV bay control screen, displays the HV bay control screen.
- ➤ Select the highlighted symbol: **{ENT}**
- ➤ Go back to the previous screen: **{ESC}**

Circuit Breaker and Disconnect Definitions and State Representations

Table 9.1 shows the apparatus definitions and symbols displayed on the one-line diagram.

Table 9.1 Circuit Breaker and Disconnect Switch Definitions

Circuit Breaker Open	Circuit Breaker Closed	Disconnect Open	Disconnect Closed
			

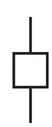
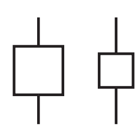
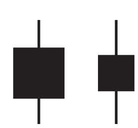
NOTE: The intermediate states only apply to disconnect switches because circuit breaker operations have a short duration.

Each apparatus (circuit breaker or disconnect switch) can be in one of the following six states:

- ➤ Open, not highlighted
- ➤ Open, highlighted
- ➤ Closed, not highlighted
- ➤ Closed, highlighted
- ➤ Intermediate, not highlighted (intermediate = transition between open and closed states)
- ➤ Intermediate, highlighted

Table 9.2 describes how the one-line diagram represents the different states of the breakers, and how highlighting the breaker affects the display of the symbol.

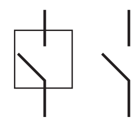
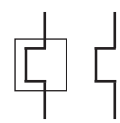
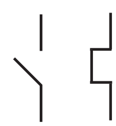
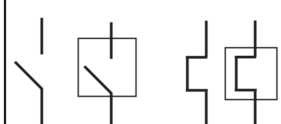
Table 9.2 Circuit Breaker State Representations

Apparatus Position	Symbol	Asserted Relay Word Bit
Circuit breaker open, not highlighted		NOT 52CLSM*m*
Circuit breaker open, highlighted[a]		NOT 52CLSM*m*
Circuit breaker closed, not highlighted		52CLSM*m*
Circuit breaker closed, highlighted[a]		52CLSM*m*

[a] When the circuit breaker is highlighted, the two symbols shown alternate in the display.

Table 9.3 describes how the one-line diagram represents the different states of the disconnect switches, and how highlighting the disconnect switch affects the display of the symbol. Unlike the fast operation time of the circuit breaker, the disconnect switch operation-in-progress time is longer than the breaker operation time. *Table 9.3* describes how apparatus appear in the one-line diagram when a disconnect operation is in progress.

Table 9.3 Disconnect Switch State Representations

Apparatus Position	Symbol	Asserted Relay Word Bit
Disconnect open, not highlighted		89OPN*m*
Disconnect closed, not highlighted		89CL*m*
Disconnect open, highlighted[a]		89OPN*k*
Disconnect closed, highlighted[a]		89CL*m*
Disconnect Operation In Progress, not highlighted[b]		89OIP*m*
Disconnect Operation In Progress, highlighted[c]		89OIP*m*

[a] When the disconnect switch is highlighted and no operation is in progress, a square box alternately frames the switch symbol.
[b] For a disconnect switch operation in progress where the disconnect switch is not highlighted, the symbol displayed is the present state symbol and then the opposite state symbol. This sequence repeats until the disconnect switch operation completes.
[c] For a disconnect switch operation in progress where the disconnect is highlighted, the symbol displayed is the present state symbol, then the present state symbol highlighted, then the opposite state symbol, and finally the opposite state symbol highlighted. This sequence repeats until the disconnect switch operation completes.

The one-line diagram indicates highlighted text with a box around the current selection.

Circuit Breaker and Disconnect Switch Operations From the Front Panel

Circuit Breaker Open/Close

Figure 9.9 shows the Breaker Control Screens available after pressing the {ENT} pushbutton (either the HV or LV bay control screen), with the circuit breaker highlighted (Only highlighted breakers on the one-line diagram can initiate breaker open or close operations). Pressing the {ENT} pushbutton with the breaker highlighted and the LOCAL Relay Word bit asserted displays the Breaker Control Screen in *Figure 9.9*. If the LOCAL Relay Word bit is not asserted when the {ENT} pushbutton is pressed, the relay displays the screen in *Figure 9.9*(c) for three seconds and then returns to the screen in *Figure 9.9*(a).

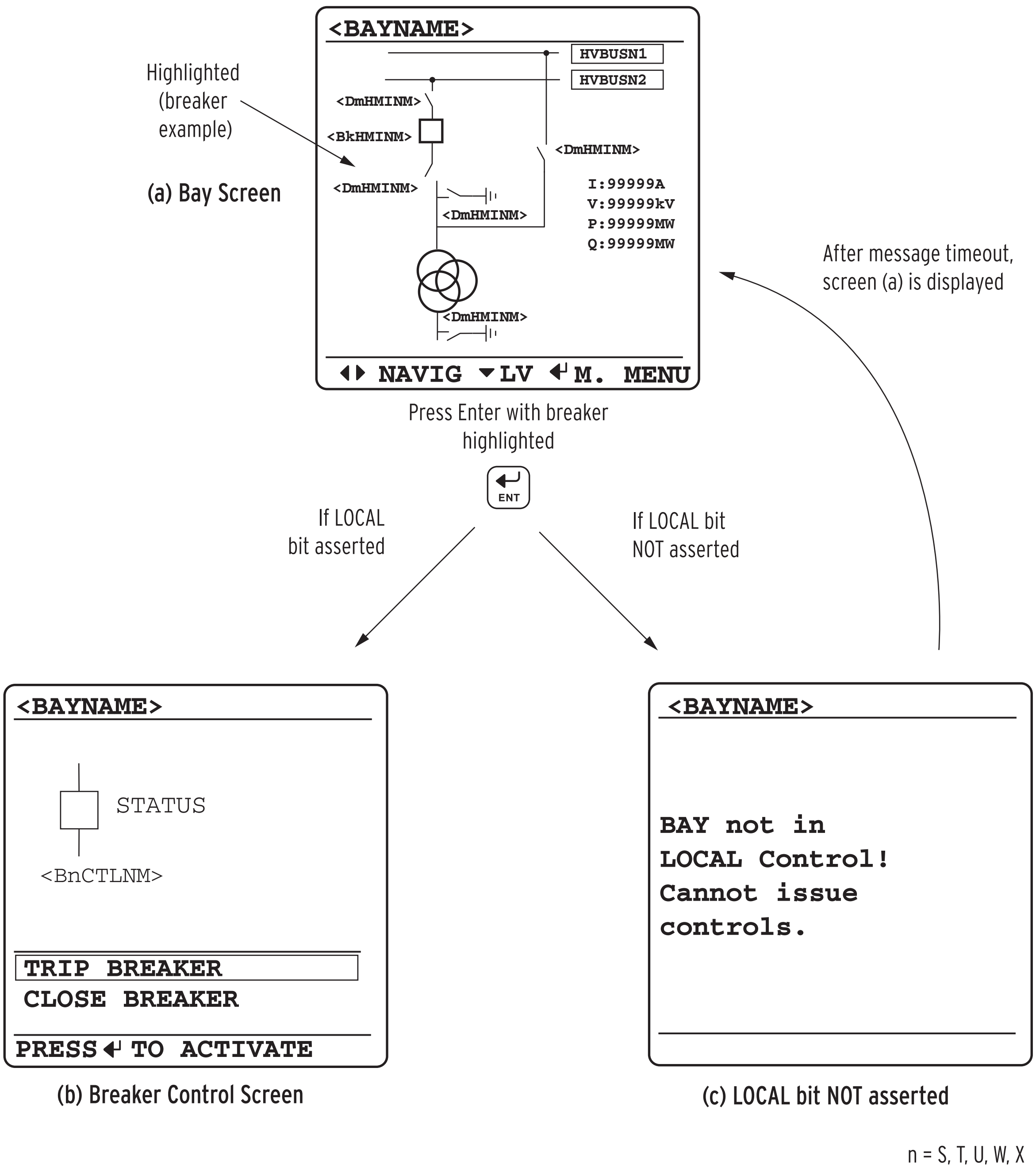


Figure 9.9 Screens for Circuit Breaker Selection

Disconnect Switch Open/Close

Figure 9.10(a) shows the Disconnect Control Screens available when you press the {ENT} pushbutton, in either the HV or LV bay control screen, with the disconnect switch highlighted. If the LOCAL Relay Word bit is asserted and the disconnect switch is highlighted when you press the {ENT} pushbutton, the Disconnect Control Screen in *Figure 9.10*(b) appears. Use the {Up Arrow} and {Down Arrow} pushbuttons to navigate between the disconnect control functions in *Figure 9.10*(b). If the LOCAL Relay Word bit is not asserted when the {ENT} pushbutton is pressed, the relay displays screen in *Figure 9.10*(c) for three seconds and then returns to the screen in *Figure 9.10*(a).

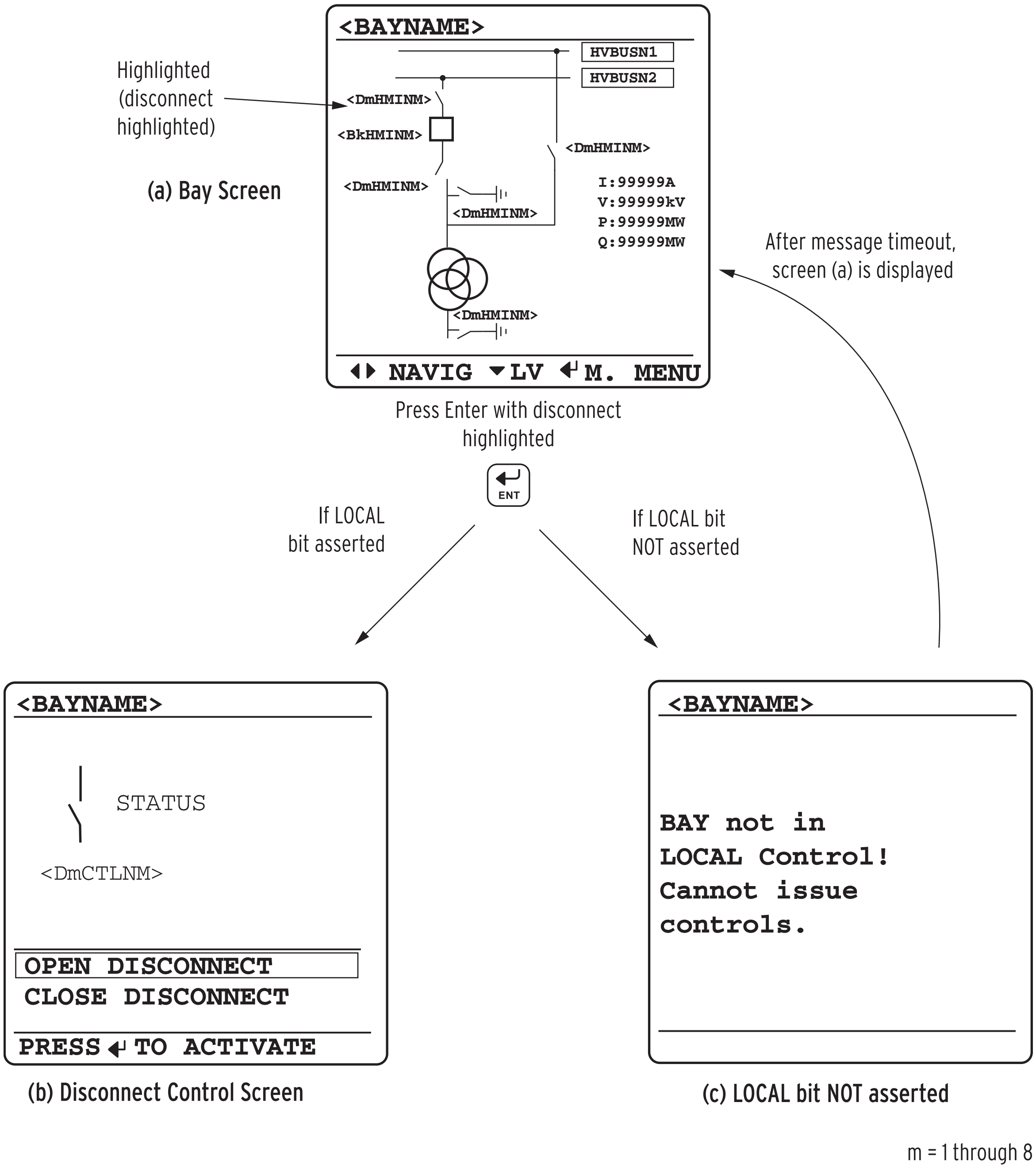


Figure 9.10 Screens for Disconnect Switch Selection

Figure 9.11, *Figure 9.12*, and *Figure 9.13* show all the possible screens during an open-to-close operation of Disconnect 1. Operation of Disconnect 2 through Disconnect 8 is identical. Close-to-open operations are similar, the only difference being that the open Relay Word bits apply instead of the close Relay Word bits. The screen in *Figure 9.11*(a) is displayed after you press the **{ENT}** pushbutton with Disconnect 1 open and highlighted in the one-line diagram. *Figure 9.11*(a) is Screen (b) in *Figure 9.10*.

When you enter the disconnect screen in *Figure 9.11*(a), the state that the disconnect switch is in is highlighted, in other words, if Relay Word bit 89OPN1 is asserted, the `OPEN DISCONNECT` text has a box drawn around it.

To close the disconnect switch, use the **{Up Arrow}** or **{Down Arrow}** pushbutton to highlight the `CLOSE DISCONNECT` text.

If Relay Word bit 89CCM1 asserts after you press the **{ENT}** key, the relay displays the screen with the caption CLOSE COMMAND ISSUED in *Figure 9.11*(c) for three seconds. While the disconnect operation is in progress, the relay displays the screen with the caption IN PROGRESS in *Figure 9.12*(a) and the disconnect symbol alternately displays the present state symbol and the opposite state symbol. If another disconnect operation attempt is made while a disconnect operation is in progress, the relay displays the screen with the caption *NOT ALLOWED* in *Figure 9.12*(b) for three seconds and then the relay returns to the screen in *Figure 9.12*(a).

If Relay Word bit 89CCM1 does not assert, the relay displays the *NOT ALLOWED* error message shown in *Figure 9.11*(d) for three seconds and then displays again the screen in *Figure 9.11*(b).

When Relay Word bit 89CCMD1 asserts, the Close Immobility Timer starts. If Relay Word bit 89CCMD1 asserts, two scenarios are possible: the disconnect fails to close, or the disconnect closes successfully. In the case of a successful close operation, the relay displays the screen in *Figure 9.13*(b).

Failing to close also has two possible scenarios: the disconnect starts to move, but does not complete the operation, or the disconnect switch operation does not initiate.

When Relay Word bit 89OPN1 deasserts, the Close Immobility timer resets, indicating that the disconnect switch has started to move. If Relay Word bit 89CL1 fails to assert in the expected operation time, the disconnect switch has failed to complete the close operation in the expected time. Failure of the 89CL1 Relay Word bit to assert in the expected disconnect switch operation time causes the 89AL1 Relay Word bit to assert. When Relay Word bit 89AL1 asserts, the relay displays the screen *Figure 9.13*(a); see *Disconnect Switch Status and Alarm Logic on page 9.6.*

If Relay Word bit 89OPN1 fails to deassert before the Close Immobility Timer expires, Relay Word bit 89ICM1 asserts and the relay displays the screen with the caption STATUS UNKNOWN in *Figure 9.13*(a). See *Close and Open Immobility Timer Logic on page 9.9* for more information regarding the close and open immobility timer logic.

When the disconnect operation completes successfully, the relay displays the screen in *Figure 9.13*(b) until the front-panel timer times out or the **{ESC}** pushbutton is pressed.

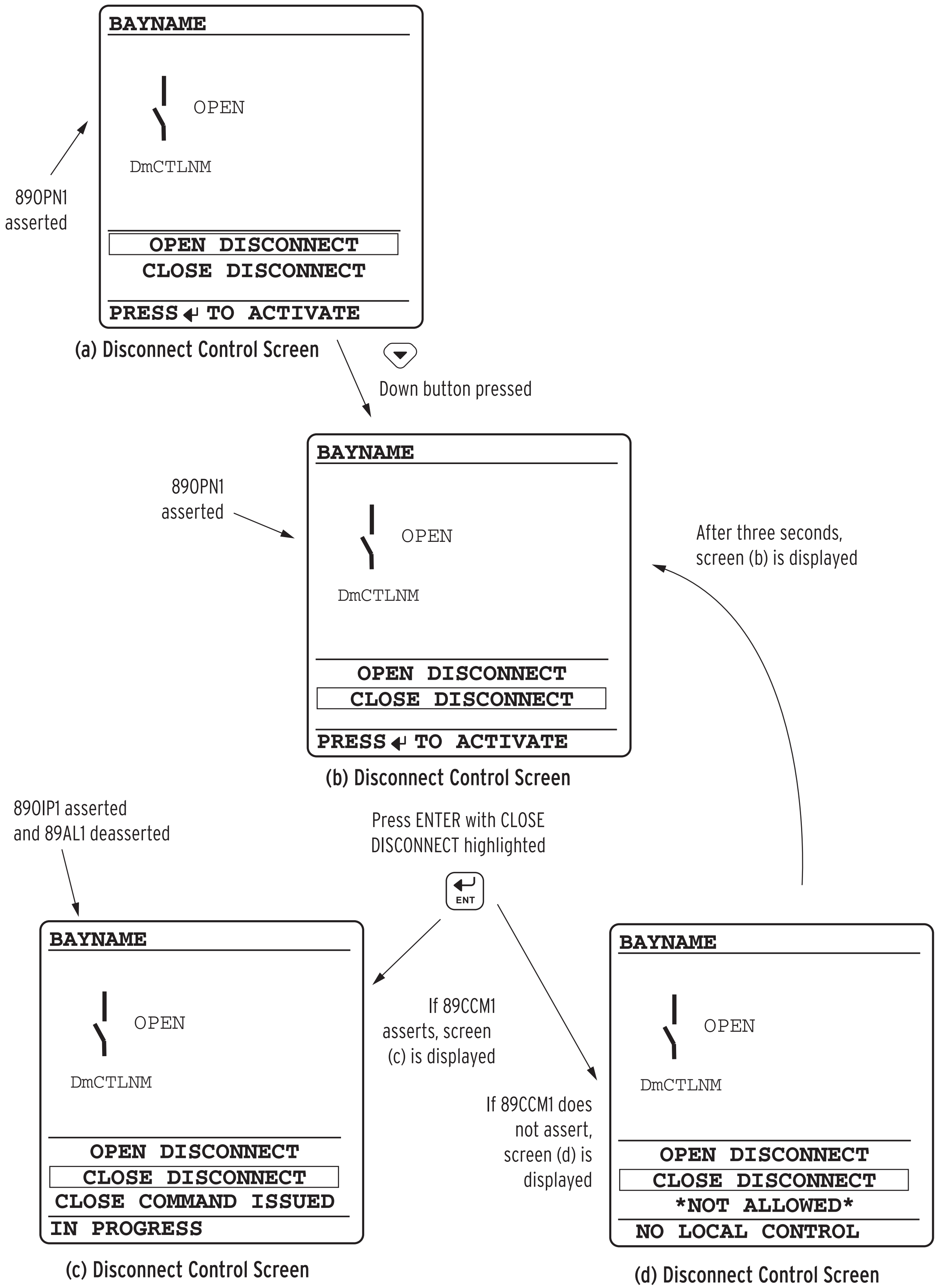


Figure 9.11 HMI Disconnect Operation Initiation

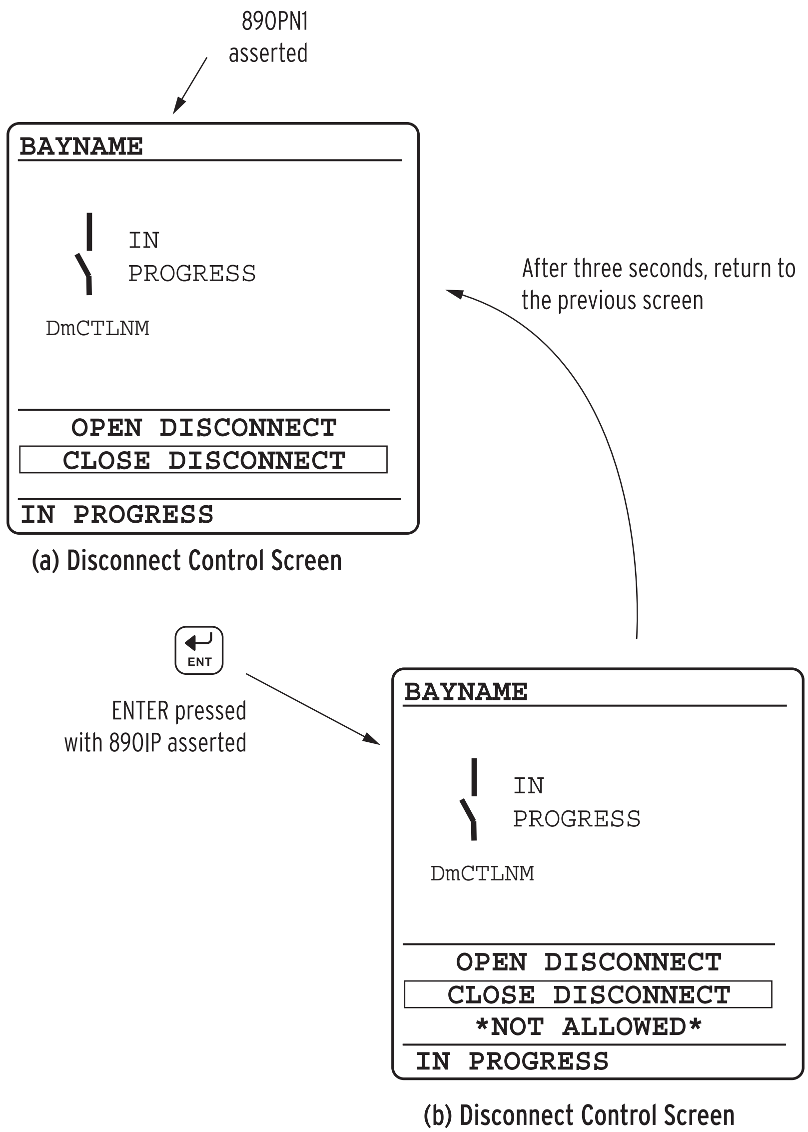


Figure 9.12 HMI Disconnect Operation in Progress

When you initially enter the Disconnect Control Screen, the disconnect switch is in one of four states: disconnect open (89OPN*m*), disconnect closed (89CL*m*), disconnect undetermined without alarm (89OIP*m*), or disconnect undetermined with alarm (89AL*m*). If Relay Word bit 89OIP*m* is asserted, the relay displays the screen in *Figure 9.12*(a); if Relay Word bit 89AL*m* is asserted, the relay displays the screen in *Figure 9.13*(a). If both Relay Word bits 89OIP*m* and 89AL*m* are asserted, Relay Word bit 89AL*m* takes priority. If Relay Word bit 89OPN*m* is asserted, the relay displays the screen in *Figure 9.11*(a). This is the initial screen for an open-to-close operation. If Relay Word bit 89CL*m* is asserted, the relay displays the screen in *Figure 9.13*(b). This is the initial screen for a close-to-open operation.

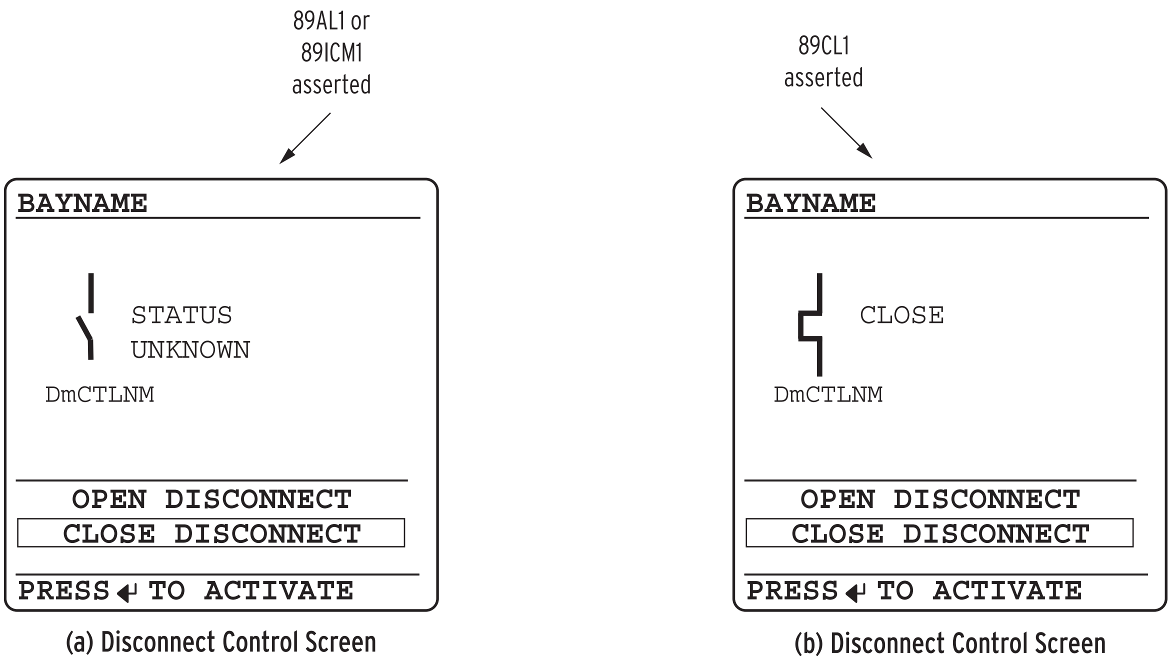


Figure 9.13 HMI Disconnect Operation Completed

ACSELERATOR QuickSet SEL-5030 Software Bay Control Screens

ACSELERATOR QuickSet provides an easy and intuitive way to configure and set the bay control function. This section shows the ACSELERATOR QuickSet screens and settings by means of the example application shown in *Figure 9.14*.

Choice of Screens

There are twenty screens available in the relay that will suit most applications. However, if you need different screen(s), please contact your SEL representative, to order your customized screen(s).

Regardless of the screens you select, there are a maximum of eight disconnects and five breakers available for the complete applications. Therefore, be sure to choose screens combinations that do not exceed these numbers.

Double Bus, Single Breaker Bay Without Ground Switch

In *Figure 9.14*, the 132/69 kV transformer bay has identical HV and LV layouts, consisting of a double busbar with a disconnect to each busbar, and a single breaker.

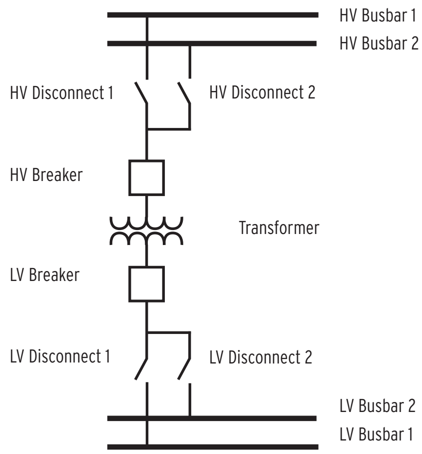


Figure 9.14 Example Application

In order to configure the transformer bay, you need to select three components, namely the HV mimic screen (HVMIMIC), the LV mimic screen (LVMIMIC), and the transformer screen (T_MIMIC).

Settings Description

Select the Bay Control button from the tree to see the first interactive bay forms in ACSELERATOR QuickSet, as shown in *Figure 9.15*. On this form, you set the conditions to control the LOCAL Relay Word bit, enter the bay name, and select the three screens.

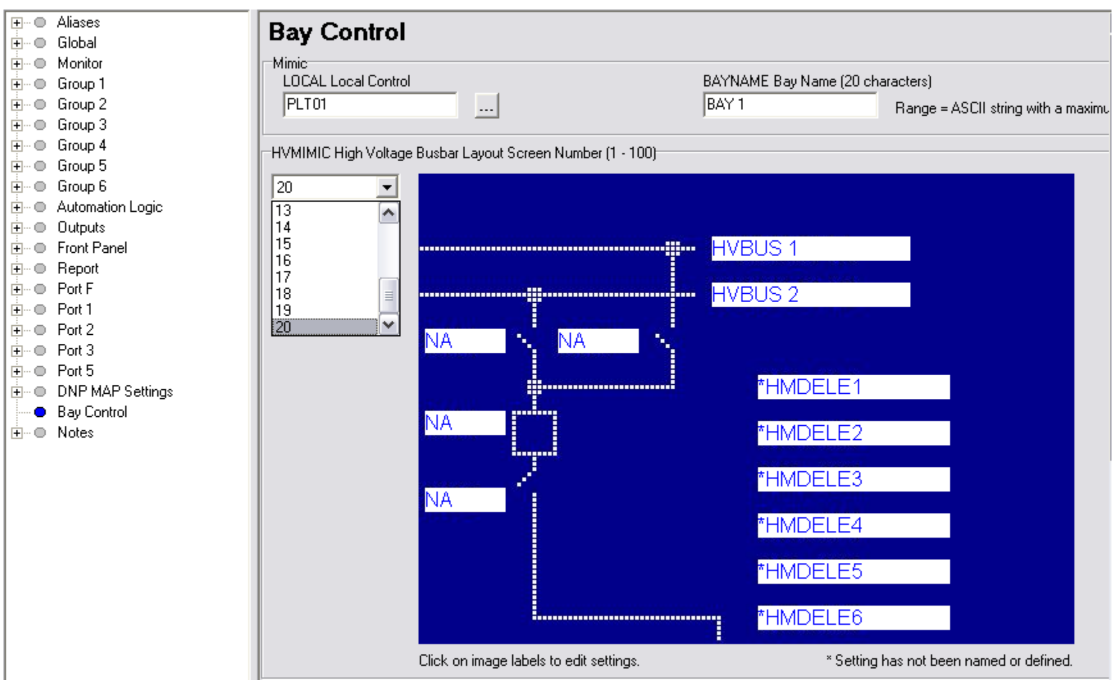


Figure 9.15 HV Interactive Bay Control Setting Form

Bay Name

There are 20 characters available for the bay name, so use descriptive names such as Transformer 1. This name appears on all the control screens to identify the transformer to avoid confusion during operating.

Local

The LOCAL SELOGIC control equation enables local and remote control of the disconnect switch. This example illustrates how the SEL-487E input contact **IN107** can accommodate existing bay controls that use a key to manually change from remote to local control. The key switch is made to actuate a contact when the key is turned, as shown in *Figure 9.16*. With the contact of the switch wired to the SEL-487E input, the key switch provides local and remote control. Make the following setting to enable LOCAL control when **IN107** is asserted.

LOCAL := **IN107**

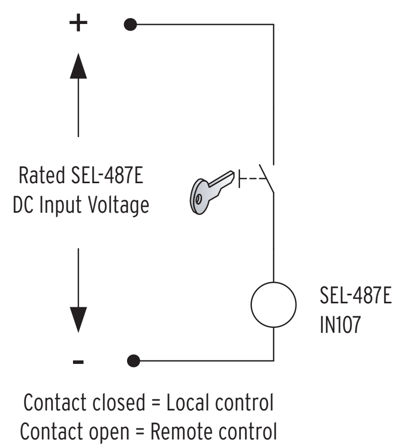


Figure 9.16 Illustration of Local and Remote Control Logic With Key Control

Bus Names

To enter the busbar names, disconnect information, breaker information, or analog information, click on the appropriate box, which causes a dialog box to appear. *Figure 9.17* shows a dialog box for the busbar name. Enter the name of the busbar, e.g., **132 Bus No 1**, and click **OK**. Notice that ACSELERATOR QuickSet converts all text to upper case.

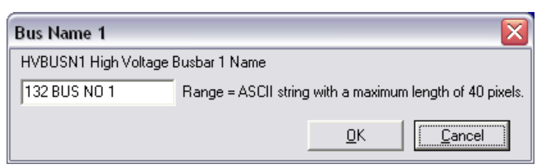


Figure 9.17 Busbar Label

Disconnect Assignments

Next to each disconnect is a box with an NA setting. Click in the box next to the 132 BUS NO 2 disconnect (to set Disconnect 1), and then on the box with the NA label, (to see which of the eight disconnects are available), as shown in *Figure 9.18*.

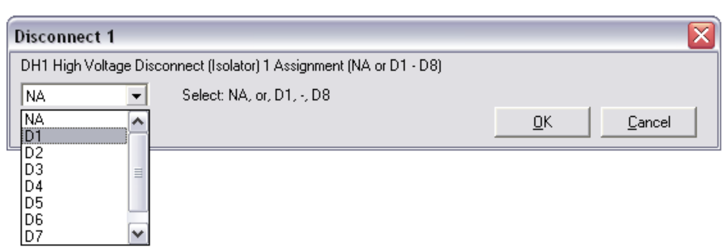


Figure 9.18 Assign Disconnect D1 Settings

Notice the screen labels: Disconnect 1 and DH1 High Voltage Disconnect (Isolator) 1 Assignment. Disconnect 1, together with DH1, identify the particular disconnect position, and is fixed for each screen. However, there is no specific disconnect (D1 through D8) associated with any particular disconnect position on the screen; you must assign a disconnect to each of the three disconnect positions on the HV screen and the three disconnect positions on the LV screen.

Figure 9.18 shows that all eight disconnect are available (D1 through D8 in the drop-down menu) for assignment. This is because you have not assigned a disconnect to any of the disconnect positions. Although you can select any of the eight disconnects, select **D1** and click **OK**. After you click **OK**, the form shown in *Figure 9.19* appears, showing all the D1 disconnect settings.

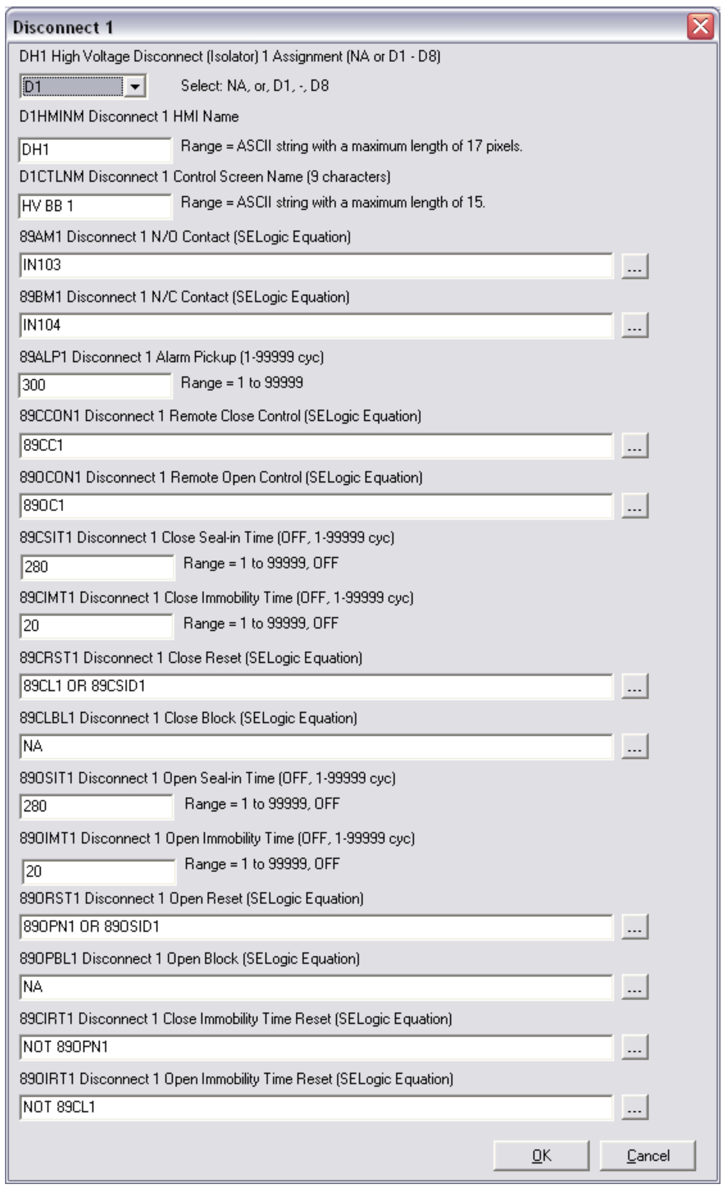


Figure 9.19 Disconnect Settings

At this point, you can still change the disconnect (click in the **DH1**) box and the same option shown in *Figure 9.18* appears. For example, if you select **D3**, then you assign Disconnect D3 to the Disconnect 1 positions, and the D3 disconnect settings appear, as shown in *Figure 9.20* (partial).

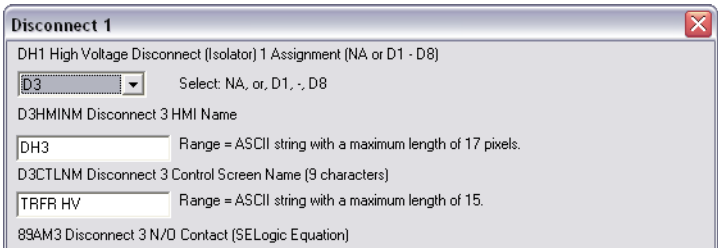


Figure 9.20 Disconnect D3 Settings (Partial)

Disconnect HMI Name Label. With D1 selected for the Disconnect 1 position (*Figure 9.19*(c)), enter a disconnect name for the disconnect on the HMI (*Figure 9.19*). The number of characters is limited to a maximum string width of 17 pixels, so keep the name short.

D1HMINM := **DH1**

Disconnect Control Screen Name Label. This name applies to the control screen. Enter here a descriptive name (there are 15 characters available) to clearly identify the disconnect.

D1CTLNM := **HV BB 1 DISCON**

Disconnect Close Status. Wire the normally open and normally closed auxiliary contacts from each disconnect switch to SEL-487E inputs, and program the relay inputs into 89AM1 and 89BM1 SELOGIC control equations. The 89AM1 and 89BM1 SELOGIC control equations report the state of the disconnect switch auxiliary contacts. Both equations must be programmed for the Disconnect Switch Status and Alarm Logic to function correctly.

89AM1 := **IN103**

89BM1 := **IN104**

Disconnect Alarm Pickup Delay. This setting monitors disconnect open/close operations (the undetermined time) of the disconnect switch. When the disconnect alarm timer expires, an alarm condition exists and the 89AL1 Relay Word bit asserts. Set the 89ALP*m* timer longer than the expected operation (undetermined state) time, but less than the 89CSIT*m* or 89OSIT*m* seal-in timers. The expected disconnect operation time in this example is 300 cycles. 89ALP*m* is entered in cycles and has a range of 1–99999.

89ALP1 := **300**

For this example, assign the expected operation time to every one of the six disconnect switches.

Disconnect Close/Open Control. Program SELOGIC control equations 89CCON*m* and 89OCON*m* to close or open disconnect switch m, respectively. Take care when programming these equations because there is no breaker jumper supervision or access level safeguards in place for this disconnect operate method.

The default settings close the disconnect switch when 89CC*m* is asserted and LOCAL Relay Word bit is deasserted. Similarly, the default settings open the disconnect switch when 89OC*m* is asserted and LOCAL Relay Word bit is deasserted.

89CCON1 := **89CC1**

89OCON1 := **89OC1**

Disconnect Close/Open Seal-in Timers. The seal-in timers assert the close or open signal long enough to allow the disconnect operation to complete. Set the seal-in timer 10 to 15 percent longer than the expected disconnect operate time to give the disconnect switch time to complete the operation. 89CSIT*m* and 89OSIT*m* are entered in cycles and have a range of 1–99999. The example shown anticipates a disconnect switch operate time of approximately 300 cycles.

Cold weather and low battery voltages can impact disconnect switch operation times. Be sure to consider these conditions when setting the seal-in timers.

The SEL-487E contacts must not be used to break the motor coil current. An auxiliary contact with adequate current interrupting capacity must first interrupt current supply to the motor before the relay contact opens. Include the auxiliary contact clearing time when setting the disconnect seal-in timer.

89CSIT1 := **280**

89OSIT1 := **280**

Disconnect Close/Open Immobility Timers. The close/open immobility timers are triggered at the same time as the seal-in timers, and assert only to report a disconnect switch failure to start moving out of its initial open/close position.

Set the immobility timer longer than the expected disconnect time to leave the initial position reported by the 89AM*m* and 89BM*m* Relay Word bits, but less the seal-in timer.

89CIMT*m* and 89OIMT*m* are entered in cycles and have a range of 1–99999. The example shown anticipates a disconnect switch operate time of approximately 20 cycles.

Cold weather and low battery voltages can impact disconnect switch operation times. Be sure to consider these conditions when setting the seal-in timers.

89CIMT1 := **20**

89OIMT1 := **20**

Disconnect Close/Open Reset. Program SELOGIC control equations 89CRST*m* and 89OCRST*m* to close or open disconnect switch *m*, respectively.

The default settings reset the seal-in circuit when either the seal-in timer expires or the intended open/close status signal asserts. This is intended to stop driving the disconnect switch motor close or open, when the desired position has been reached.

89CRSTm := **89CLm OR 89CSIDm**

89ORSTm := **89OPNm OR 89OSIDm**

Disconnect Close/Open Block. Program SELOGIC control equations 89CLBL*m* and 89OPBL*m* to provide an optional custom method for blocking all means of close/open control, respectively.

The default settings are NA.

89CLBLm := **NA**

89OPCLm := **NA**

This concludes the settings for Disconnect 1. *Figure 9.21* shows the HMI name in the box of Disconnect 1. Click on the box to the right of Disconnect 1, and on the disconnect selection box. Because D1 has been assigned to Disconnect 1, D1 is no longer available. Assign D2 to Disconnect 2 and D3 the Disconnect 3.

D2CTLNM := **HV BB 1 DISCON**

D3CTLNM := **TRFR HV DISCON**

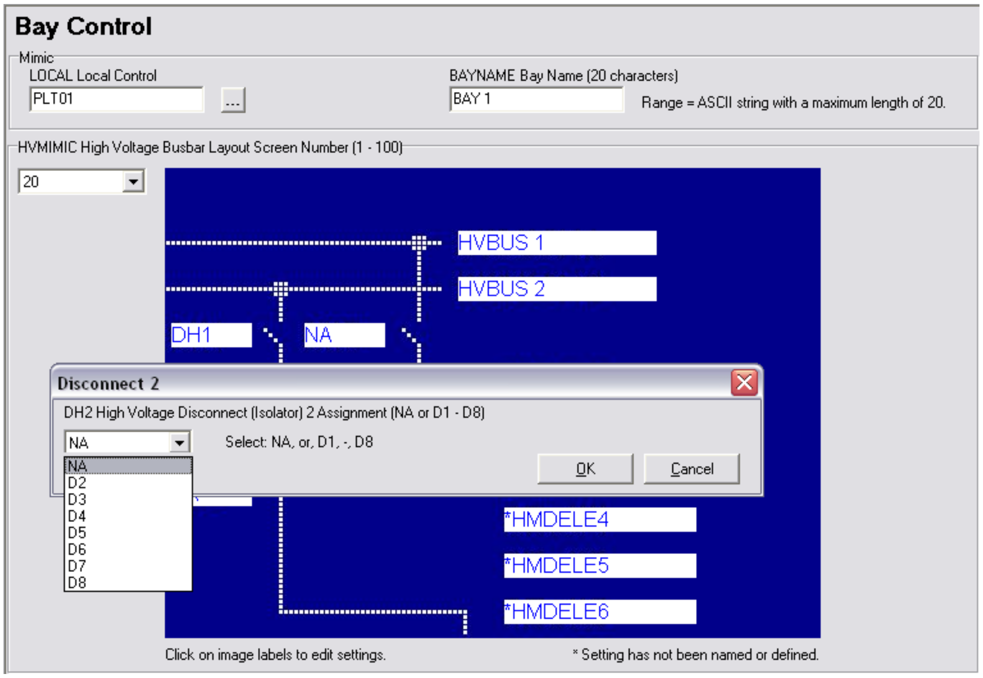


Figure 9.21 Disconnect 2 Assignment

Figure 9.22 shows DL1, the first of the LV disconnects; D1, D2, and D3 are already assigned to the HV disconnects, and only D4 through D8 are available.

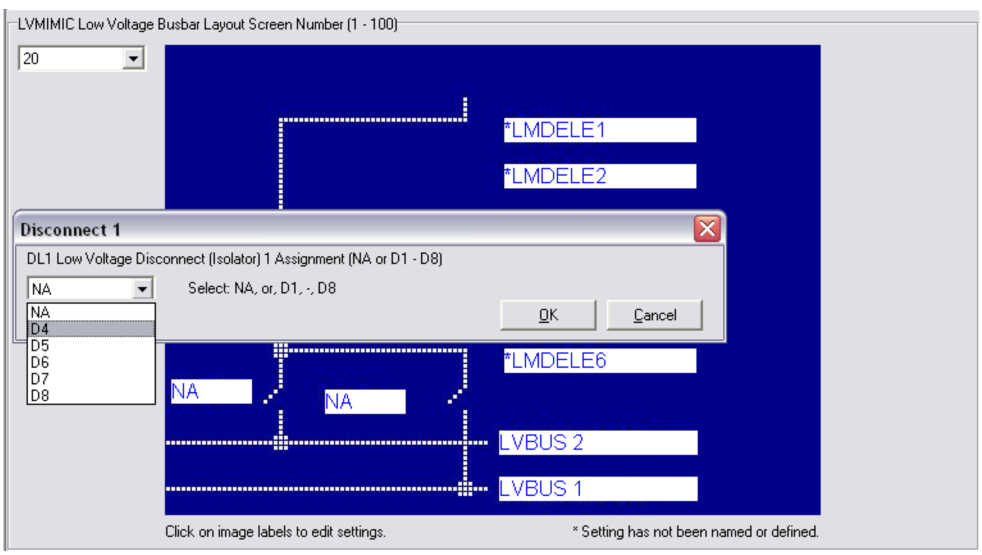


Figure 9.22 Disconnect 4 Assignment

Assign D4 to (LV) Disconnect 1, D5 to Disconnect 2 and D6 to Disconnect 3, with descriptive names, as follows:

D4CTLNM := **HV BB 1 DISCON**

D5CTLNM := **HV BB 2 DISCON**

D6TLNM := **TRFR LV DISCON**

Breaker Assignments

Assign the five breakers similarly to the disconnect assignments. For example, clicking on the box to the left of the HV circuit breaker in the one-line diagram and selecting **S** displays the form illustrated in *Figure 9.23*. When **OK** is clicked, the form is closed and the settings are updated in the Bay Control settings. When **Cancel** is clicked, the form is closed and settings are not saved. Interactive settings operations for all circuit breakers are identical.

Although you can assign any breaker (S, T, U, W, or X) to any breaker position, operating correspondence is clearer if you also assign the selected current input windings (S, T, U, W, or X) to the breakers. In this example, assume the HV winding is Terminal S and the LV winding is Terminal T, then assign:

BH1 := **S**

BL1 := **T**

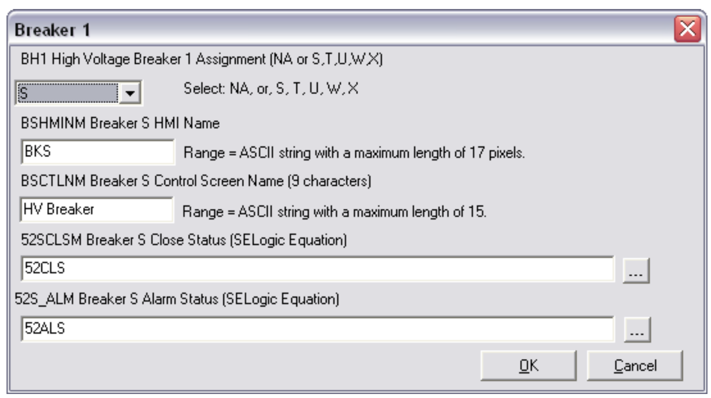


Figure 9.23 Breaker Settings

Breaker HMI Name Label. HMI names are limited to a maximum of 4 characters (depending on pixel width) and serve to identify the equipment, i.e., breakers and disconnects. Enter a more descriptive name at the next setting, Breaker Control Screen Name.

BSHMINM := **BKS**

BTLMINM := **BKT**

Breaker Control Screen Name Label. Enter a descriptive breaker name (up to 15 characters) for every circuit breaker in the high and low voltage control screens.

BSCTLNM := **HV Breaker**

BTCTLNM := **LV Breaker**

Breaker Close Status. This SELOGIC control equation reports breaker close status and breaker alarm status. Any bit in the SEL-487E Relay Word can be programmed into this SELOGIC control equation, as well as logical operators. The equations below return the HV Breaker and LV Breaker status and any HV Breaker and LV Breaker alarm conditions.

52SCLSM := **52CLS**

52S_ALM := **52ALS**

52TCLSM := **52CLT**

52T_ALM := **52ALT**

Analog Display

The one-line diagrams in the SEL-487E contain as many as six Analog Quantity display points. The HVMIMIC and LVMIMIC settings selected in this example displays six Analog Display points each. If no analog display points are not required, leave the setting(s) blank, for the relay display only the defined display points.

Click on analog display label HMDELE1 in the interactive one-line diagram to display the form shown in *Figure 9.24*. Click on the Expression Builder button to display the form in *Figure 9.25*. The Expression Builder helps build the analog quantity setting string. Press the Expression Builder button on the form in *Figure 9.25* to find the Analog or Fixed Element to be displayed.

Figure 9.24 Analog Quantity Setting Form

To display fixed text instead of analog quantities, enter the number **1** in the Analog or Fixed Element field, as shown in *Figure 9.25*. All other field, except the Alias name field.

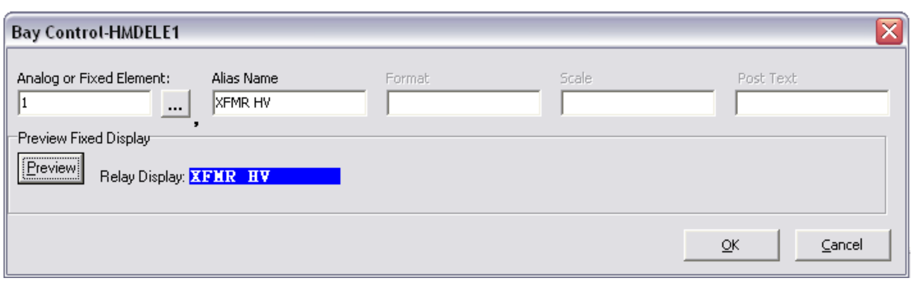


Figure 9.25 Analog Quantity Setting Form

Click on **HMDELE2** to enter the next analog value. For HMDELE2, select the VAVFMC, the A-phase voltage magnitude, as shown in *Figure 9.26*. On the assumption that PT V is connected to Busbar 1, enter **Busbar 1** as the alias name. Because the maximum voltage on the 132 kV system will not exceed 999 kV, enter “3” in the format field. You can scale the numerical value of VAVFMC to display a scaled value of the analog quantity. For example, a scaling value of 0.5 displays only half the value of VAVFMC, whilst a scaling value of 2 displays twice the value of VAVFMC. Enter text, such as the units of the analog quantity in the **Post Text** field. Test the entries by typing a value of 129 in the preview analog display field. Click the **Preview** button, and verify that all entries are correct and will fit on the screen.

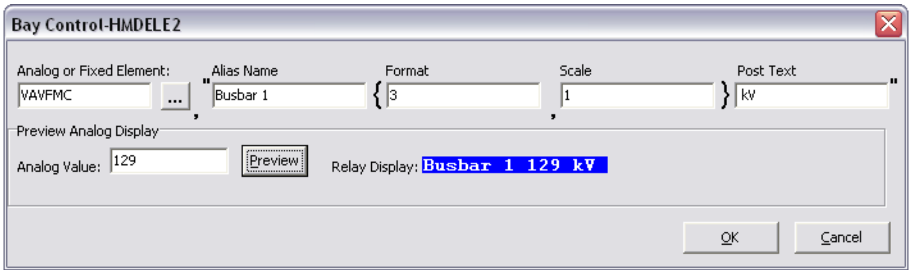


Figure 9.26 Analog Quantity Expression HMDELE2

For the third analog quantity, enter the A-phase current, and the other information as shown in *Figure 9.27*. Again, use the **Preview** button to verify that all entries are correct and will fit on the screen.

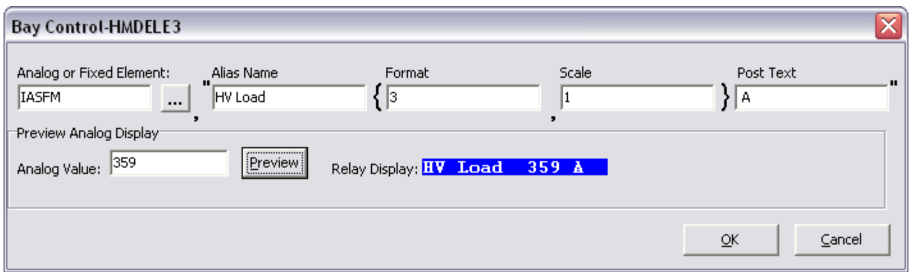


Figure 9.27 Analog Quantity Expression HMDELE3

Enter similar values for the 69 kV side, assuming that the LV CTs are connected to Terminals T:

1. 1, XFMR LV
2. IATFM

Do not enter values for the other analog values.

Figure 9.28 shows the form to select the transformer screen. There are seven transformer screens available in the relay. Select either the ANSI symbols (A1 through A7) or the IEC symbols (I1 through I7).

Click in the box next to the transformer and enter the **TRFR NO 1**.

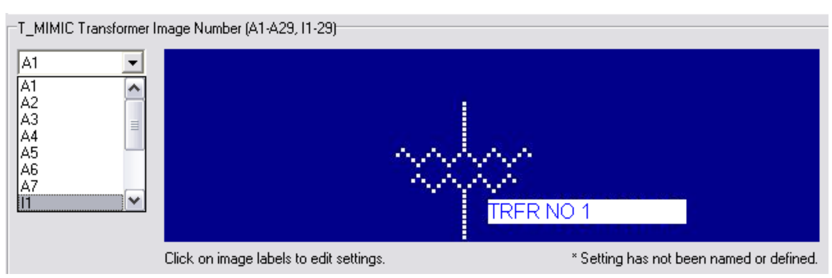


Figure 9.28 Interactive Transformer Image Number

Move the cursor down from the A1 (ANSI) position, and click on **I1** (IEC) to select the transformer screen shown in *Figure 9.29*.

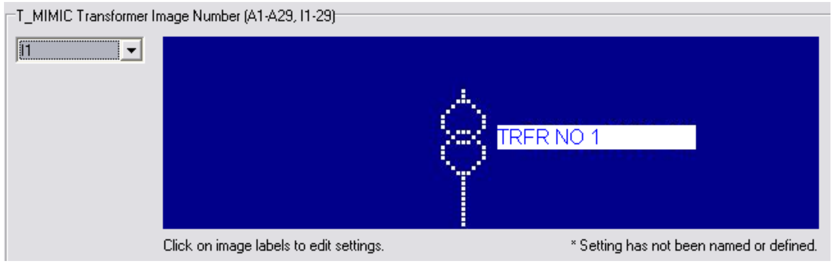


Figure 9.29 Interactive Transformer Image Number

Front-Panel Settings

Selectable Screens for the Front Panel

You can include the bay control screens in the rotating display. Because the relay generates the screen in two parts (LV and HV sides), you must enter both names (Front Panel settings): HV_BAY, LV_BAY, as shown in *Figure 9.30*.

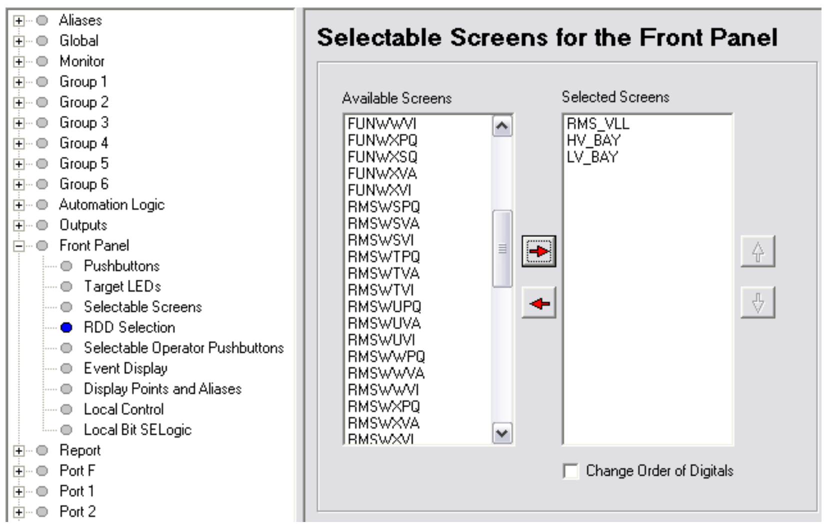


Figure 9.30 Bay Control Screen Selected For Rotating Display

You can also configure a HMI pushbutton to give you direct access to the bay control screen. *Figure 9.31* shows an example how to configure HMI Pushbutton 1 by selecting the BC option from the drop-down menu.

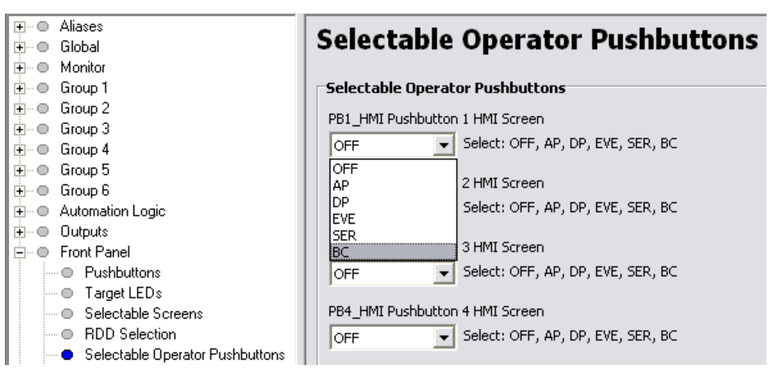


Figure 9.31 Configuring PB1_HMI For Direct Bay Control Access

Predefined Bay Control One-Line Diagrams

Configurations

The following pages illustrate all of the predefined HV, LV, and transfer and bay control configurations in the SEL-487E defined by the (HVMIMIC and LVMIMIC settings). Select the bay combination that exactly matches the bay configuration being controlled from the following figures:

- *Figure 9.32*–*Figure 9.51*: HV one-line diagram
- *Figure 9.52*–*Figure 9.71*: LV one-line diagram
- *Figure 9.72*–*Figure 9.73*: Transformer (IEC) one-line diagram
- *Figure 9.74*–*Figure 9.75*: Transformer (ANSI) one-line diagram

HV Configuration

Main Bus and Auxiliary Bus

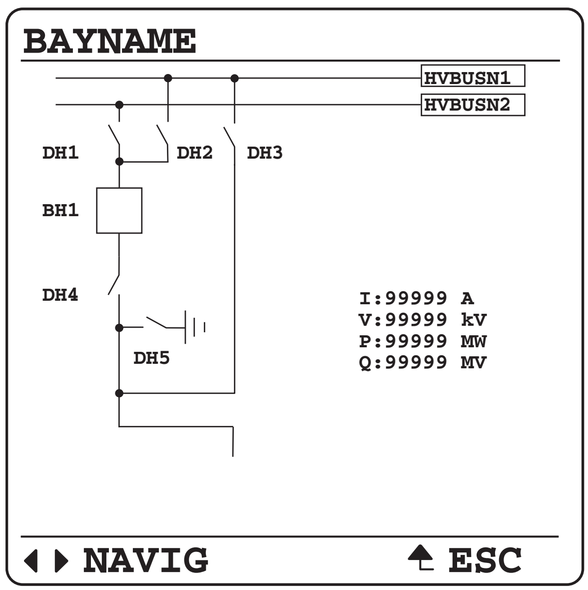


Figure 9.32 HV Bay With Ground SW (Option 1)

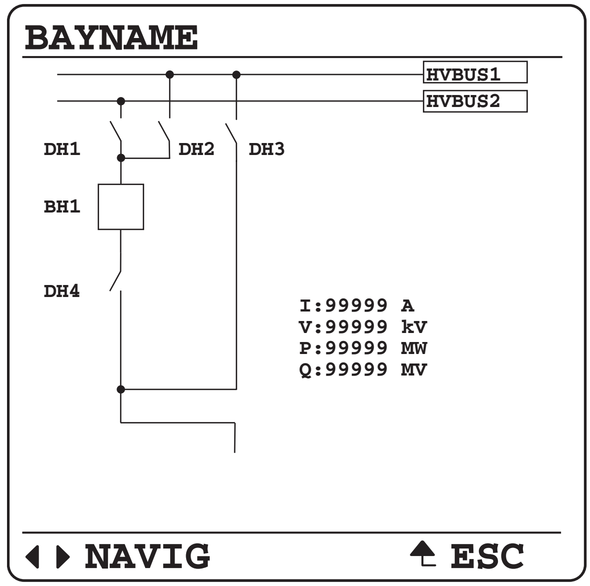


Figure 9.33 HV Bay Without Ground SW (Option 2)

Bus 1, Bus 2, and Transfer Bus

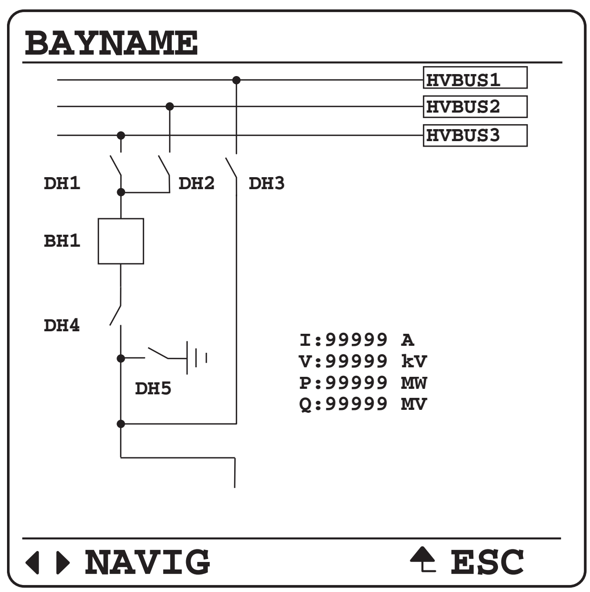


Figure 9.34 HV Bay With Ground SW (Option 3)

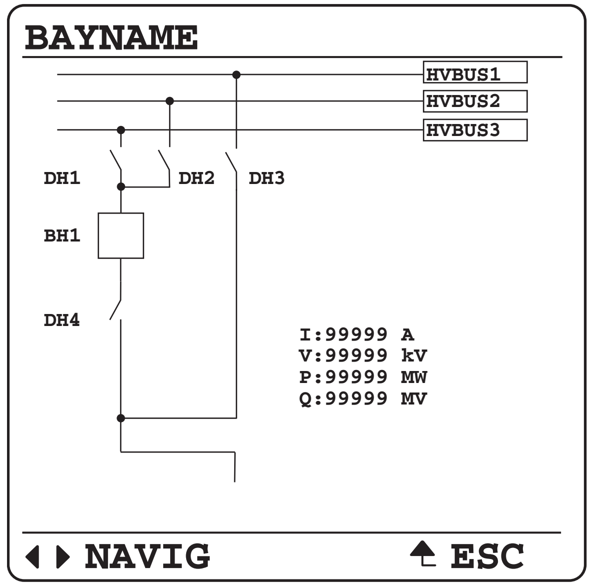


Figure 9.35 HV Bay Without Ground SW (Option 4)

Main Bus and Transfer Bus

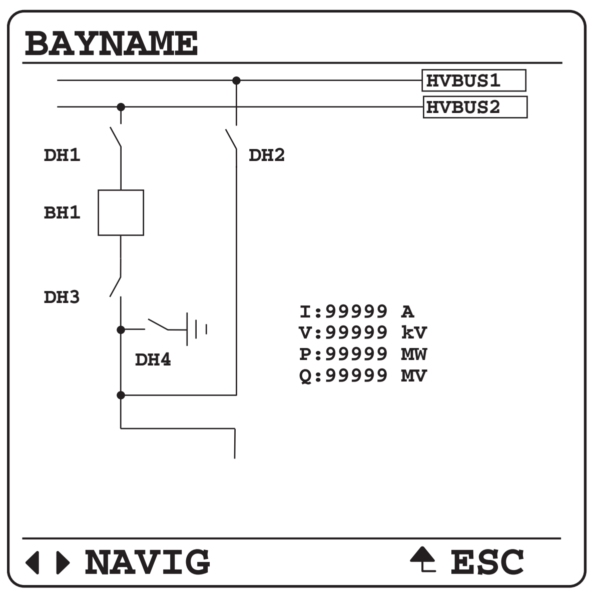


Figure 9.36 HV Bay With Ground SW (Option 5)

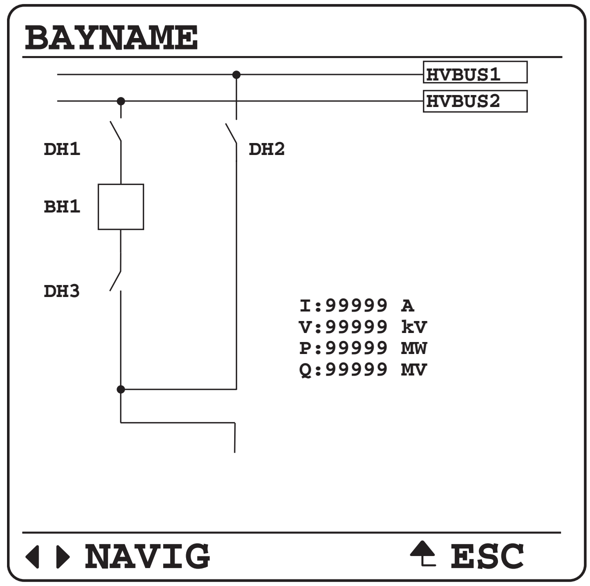


Figure 9.37 HV Bay Without Ground SW (Option 6)

Main Bus

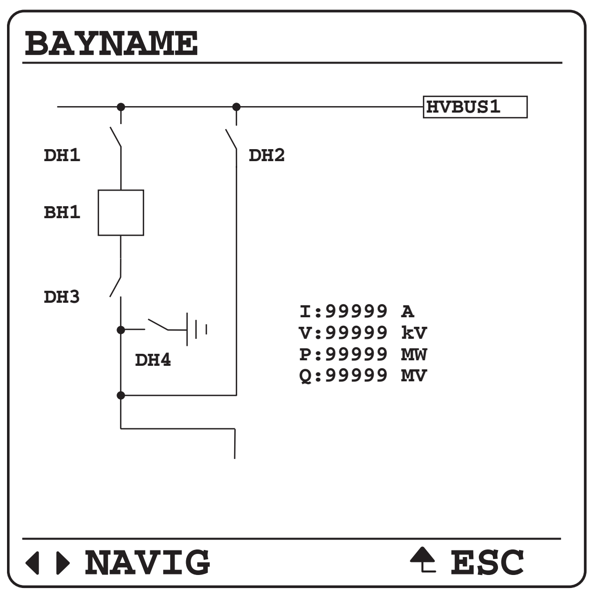


Figure 9.38 HV Bay With Ground SW (Option 7)

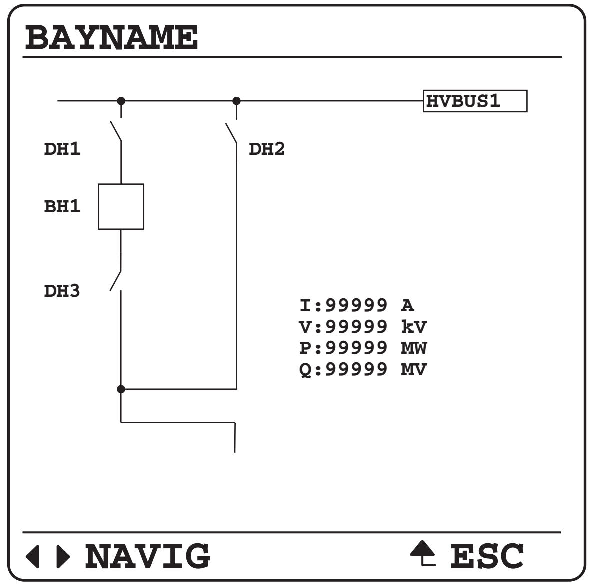


Figure 9.39 HV Bay Without Ground SW (Option 8)

Breaker-and-a-Half

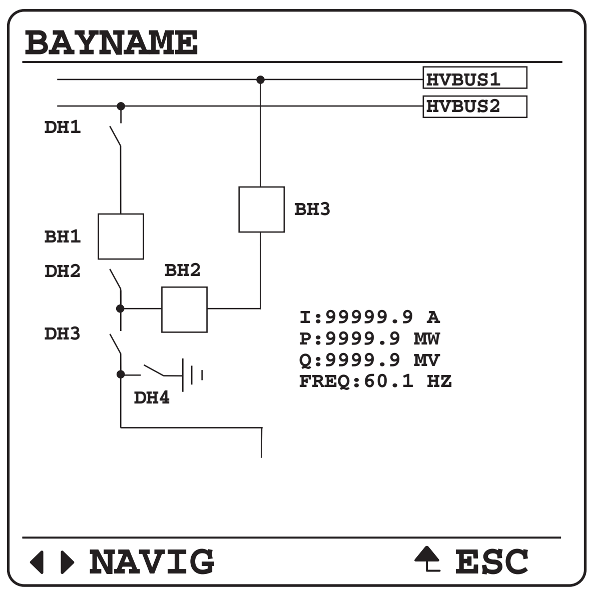


Figure 9.40 HV Left Breaker Bay With Ground SW (Option 9)

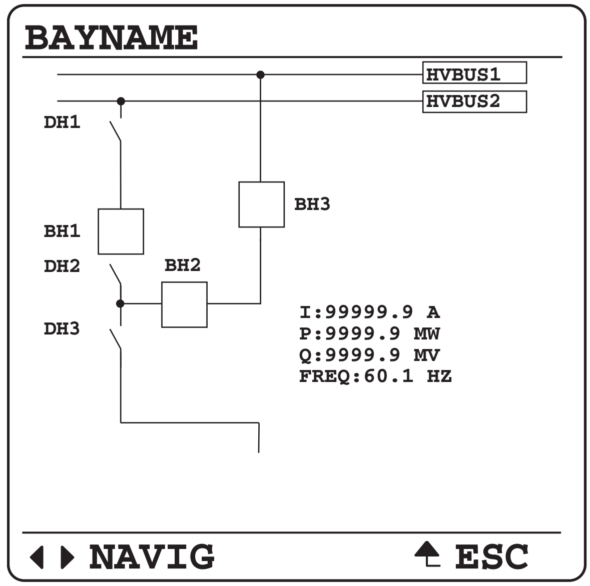


Figure 9.41 HV Left Breaker Bay Without Ground SW (Option 10)

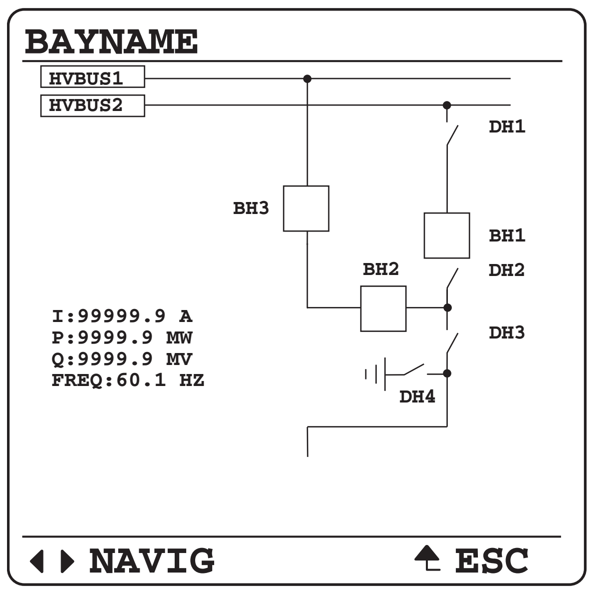


Figure 9.42 HV Right Breaker Bay With Ground SW (Option 11)

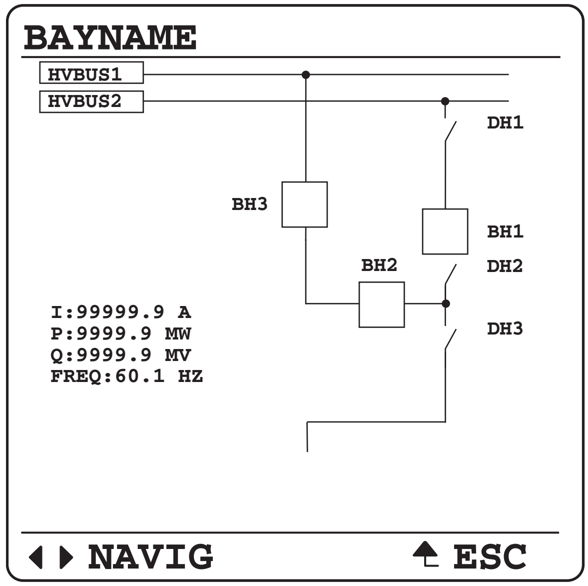


Figure 9.43 HV Right Breaker Bay Without Ground SW (Option 12)

Ring Bus

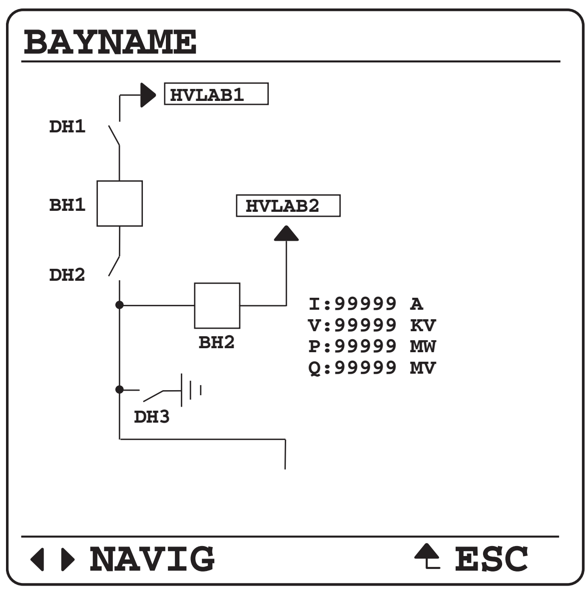


Figure 9.44 HV Bay With Ground SW (Option 13)

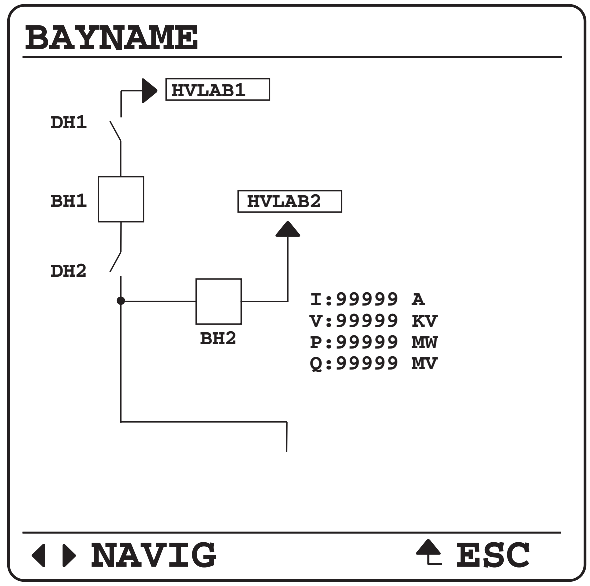


Figure 9.45 HV Bay Without Ground SW (Option 14)

Double Bus Double Breaker

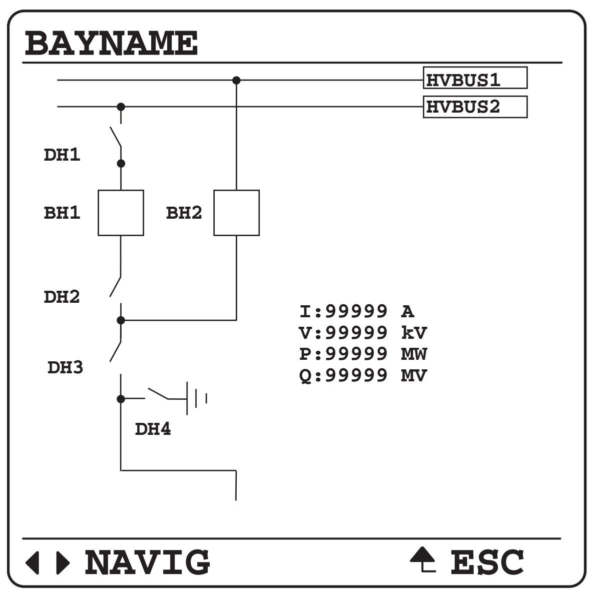


Figure 9.46 HV Left Breaker Bay With Ground SW (Option 15)

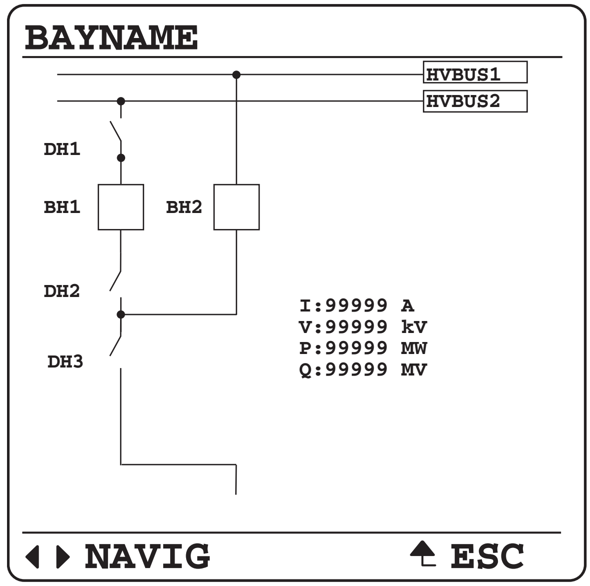


Figure 9.47 HV Left Breaker Bay Without Ground SW (Option 16)

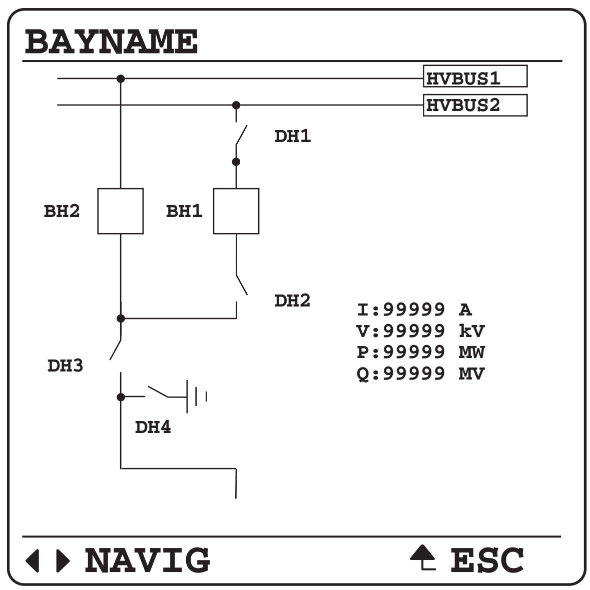


Figure 9.48 HV Right Breaker Bay With Ground SW (Option 17)

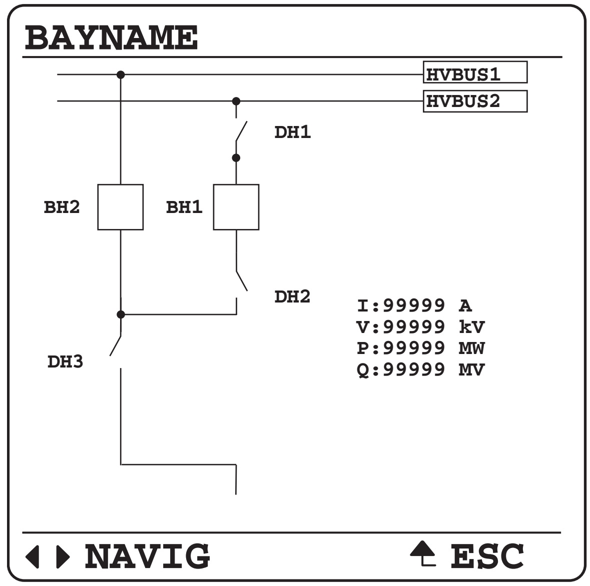


Figure 9.49 HV Right Breaker Bay Without Ground SW (Option 18)

Double Bus Single Breaker

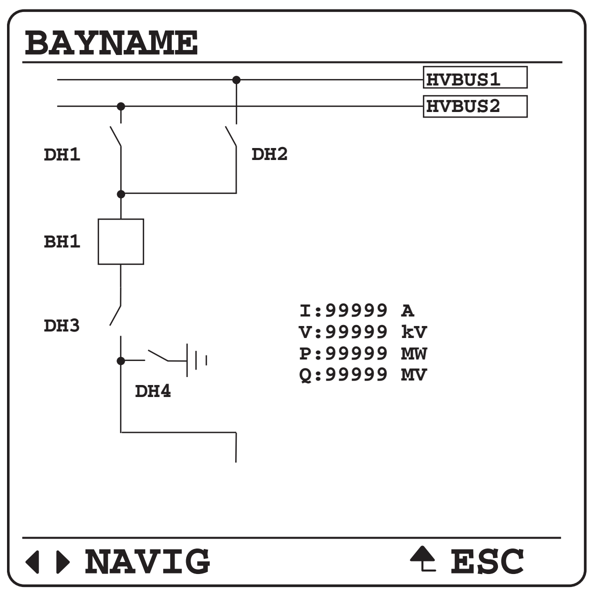


Figure 9.50 HV Right Breaker Bay With Ground SW (Option 19)

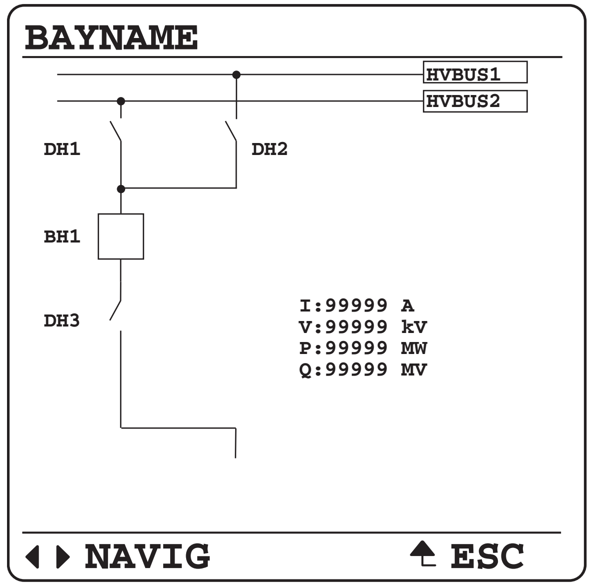


Figure 9.51 HV Right Breaker Bay Without Ground SW (Option 20)

LV Configuration

Main Bus and Auxiliary Bus

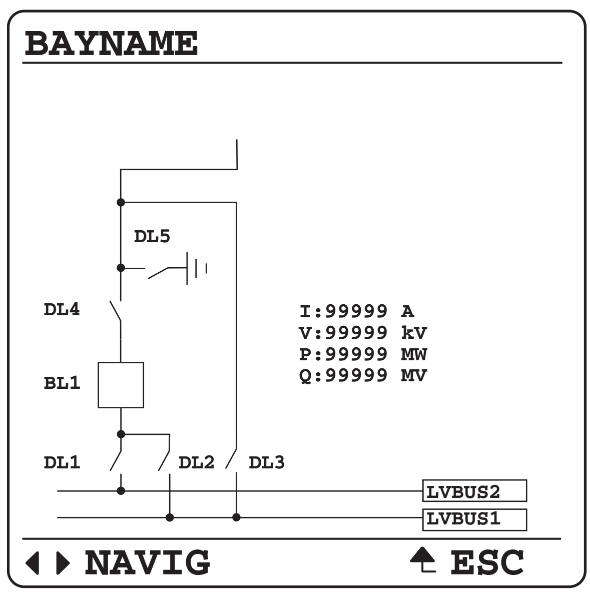


Figure 9.52 LV Bay With Ground SW (Option 1)

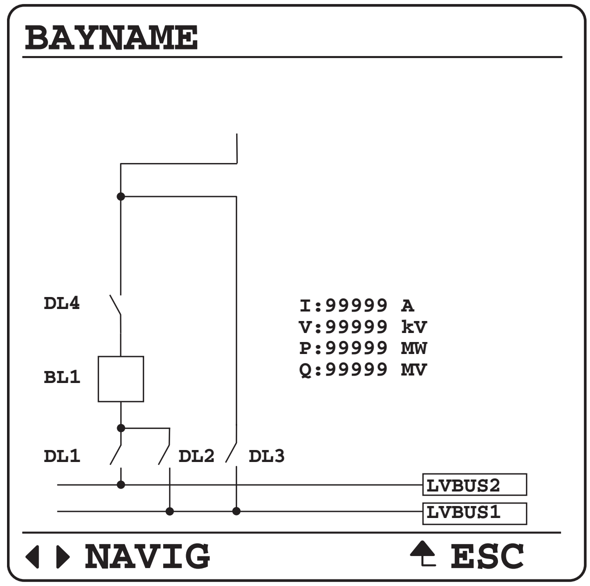


Figure 9.53 LV Bay Without Ground SW (Option 2)

Bus 1, Bus 2, and Transfer Bus

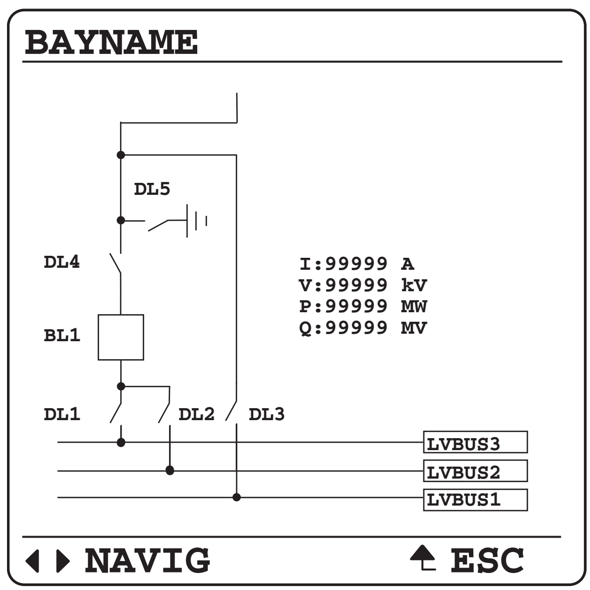


Figure 9.54 LV Bay With Ground SW (Option 3)

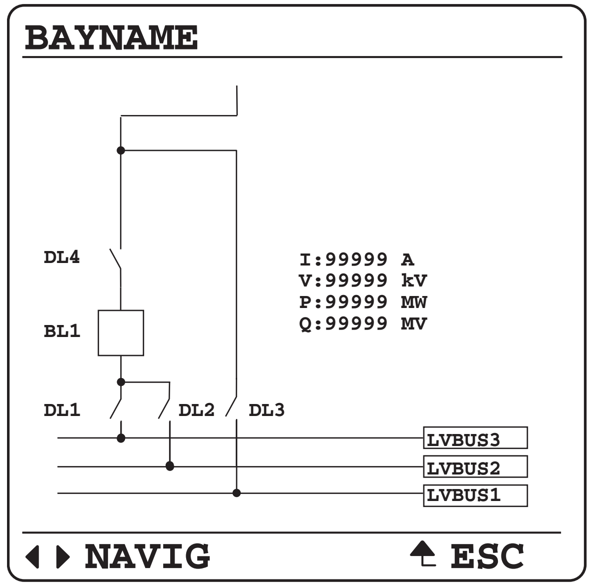


Figure 9.55 LV Bay Without Ground SW (Option 4)

Main Bus and Transfer Bus

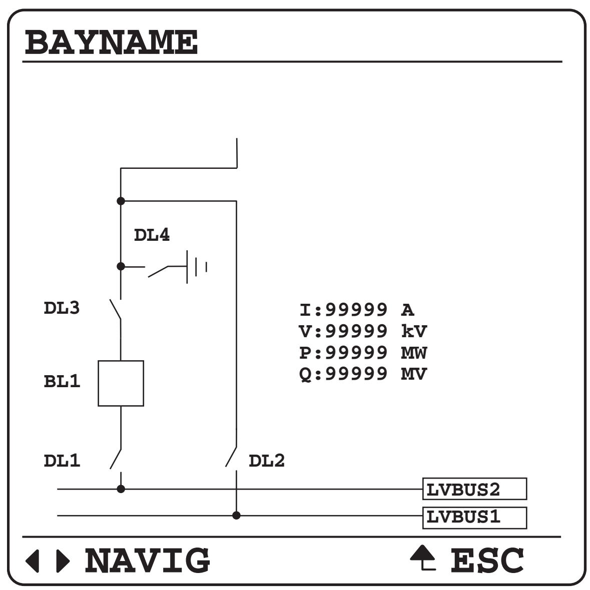


Figure 9.56 LV Bay With Ground SW (Option 5)

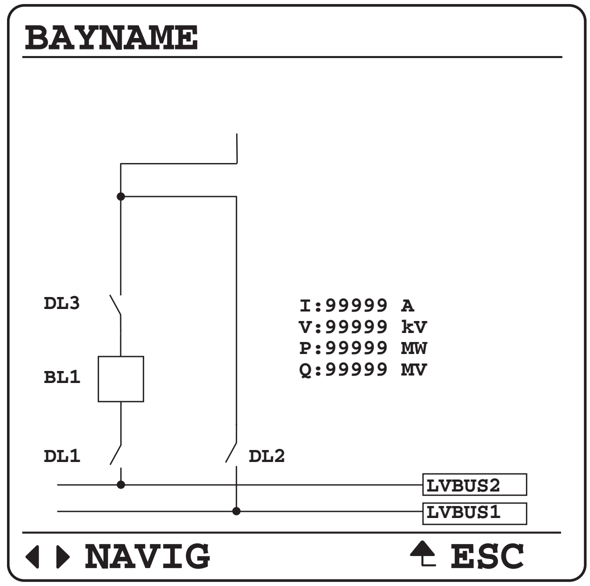


Figure 9.57 LV Bay Without Ground SW (Option 6)

Main Bus

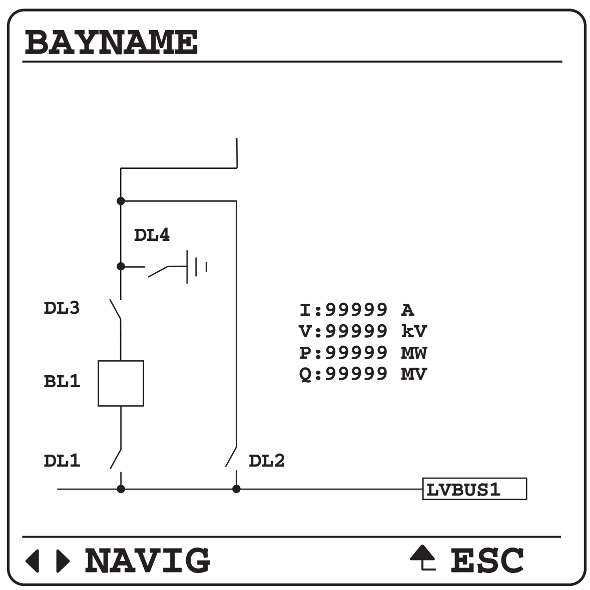


Figure 9.58 LV Bay With Ground SW (Option 7)

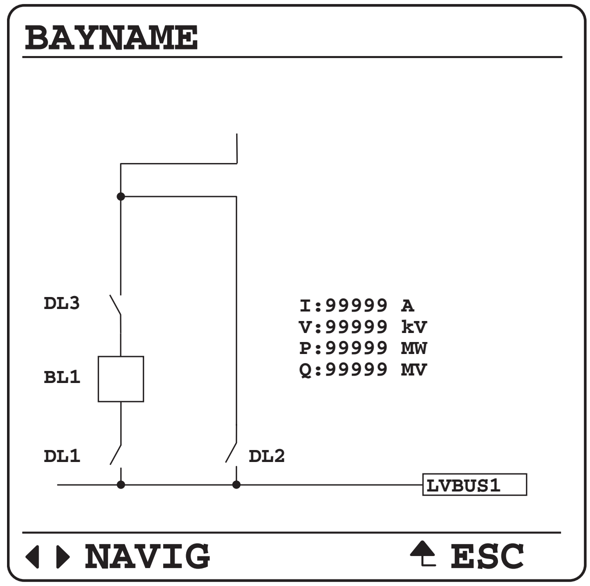


Figure 9.59 LV Bay Without Ground SW (Option 8)

Breaker-and-a-Half

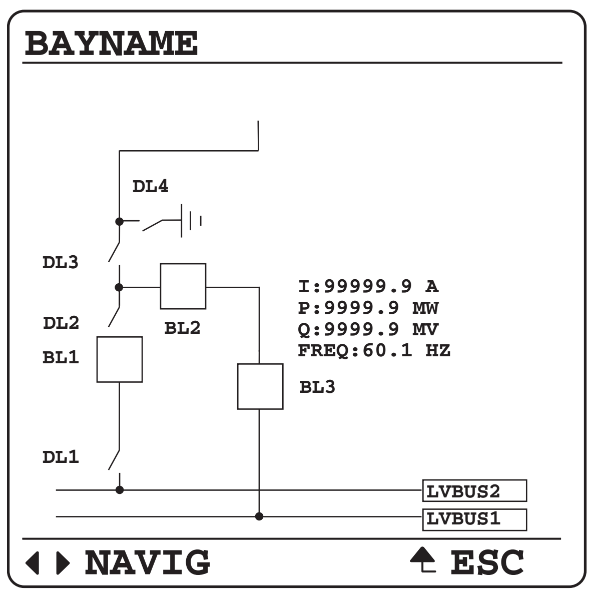


Figure 9.60 LV Left Breaker Bay With Ground SW (Option 9)

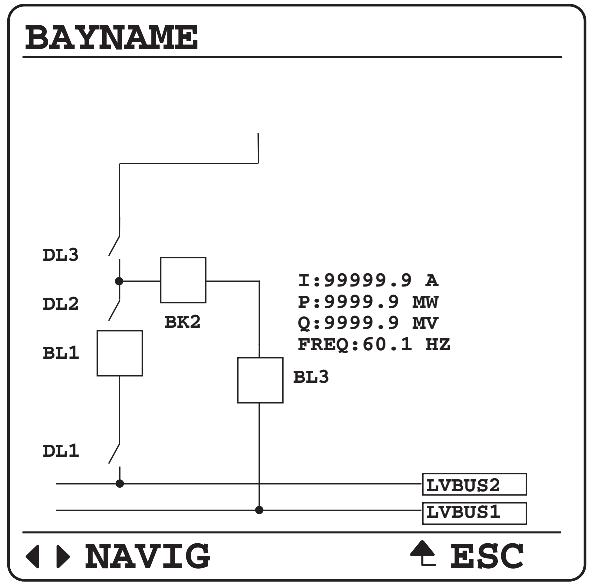


Figure 9.61 LV Left Breaker Bay Without Ground SW (Option 10)

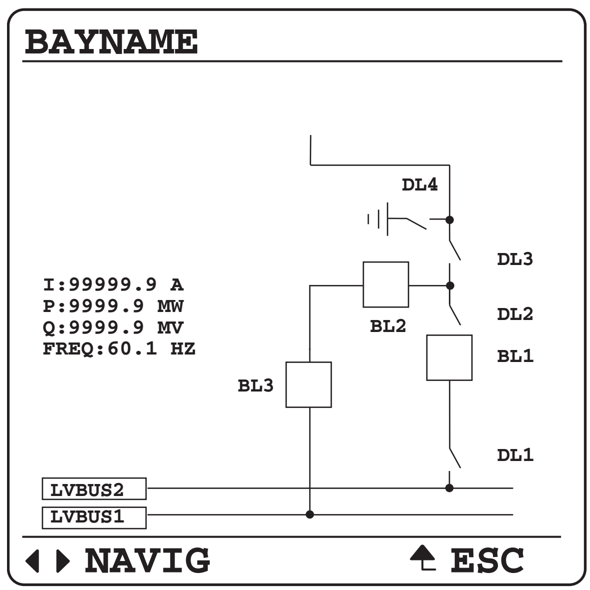


Figure 9.62 LV Right Breaker Bay With Ground SW (Option 11)

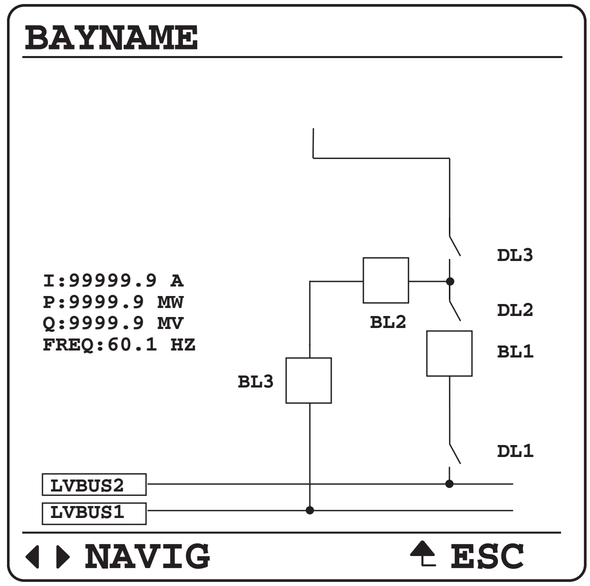


Figure 9.63 LV Right Breaker Bay Without Ground SW (Option 12)

Ring Bus

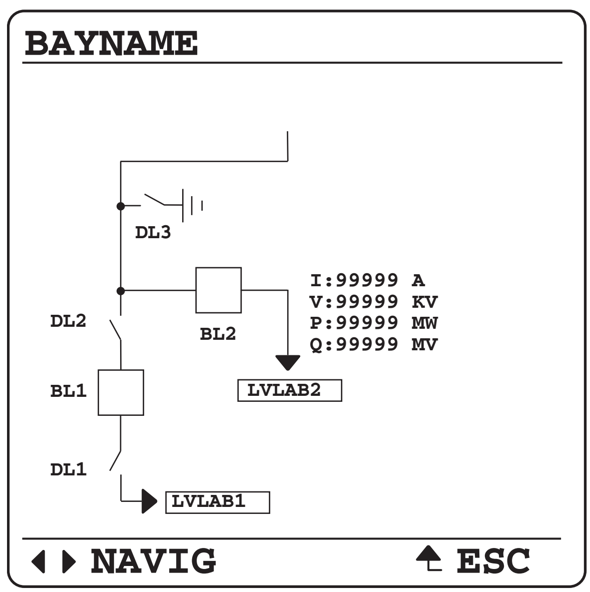


Figure 9.64 LV Bay With Ground SW (Option 13)

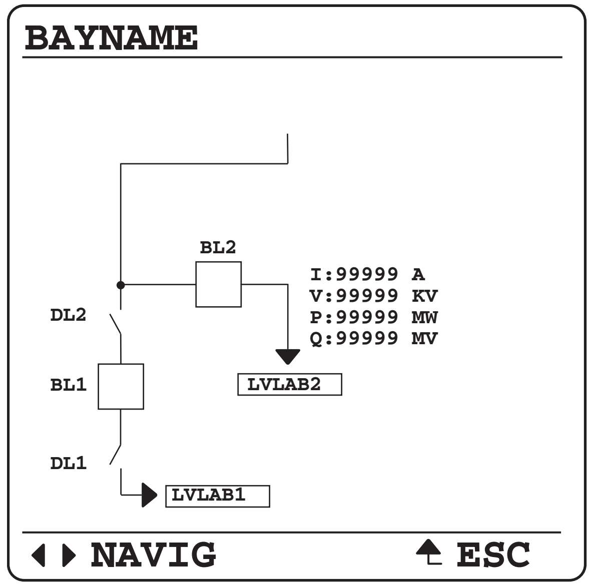


Figure 9.65 LV Bay Without Ground SW (Option 14)

Double Bus Double Breaker

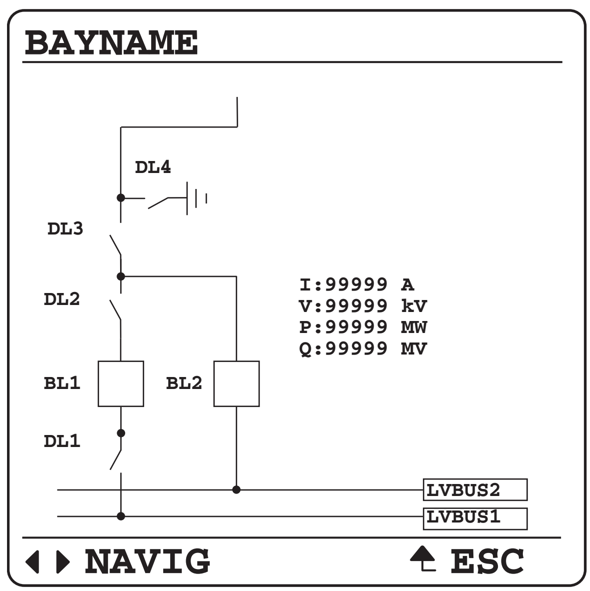


Figure 9.66 LV Left Breaker Bay With Ground SW (Option 15)

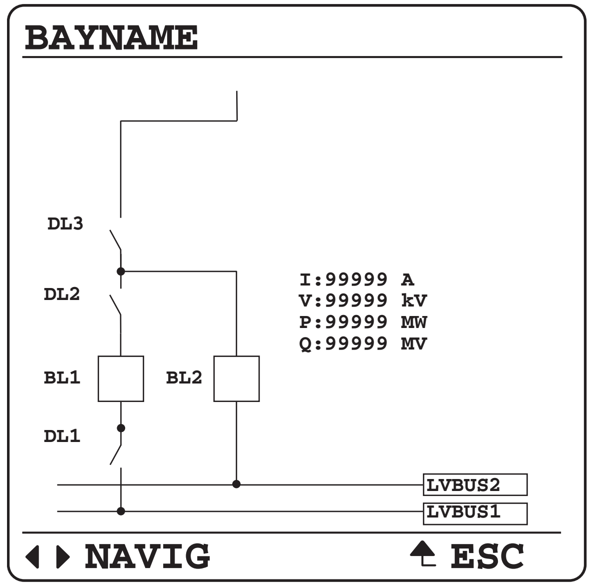


Figure 9.67 LV Left Breaker Bay Without Ground SW (Option 16)

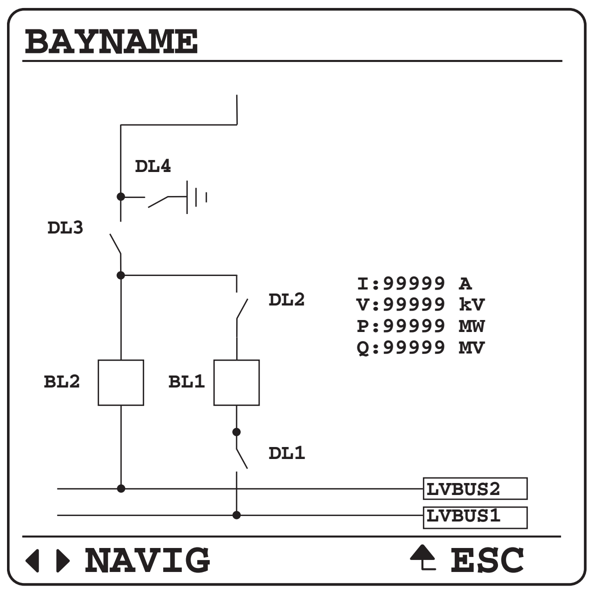


Figure 9.68 LV Right Breaker Bay With Ground SW (Option 17)

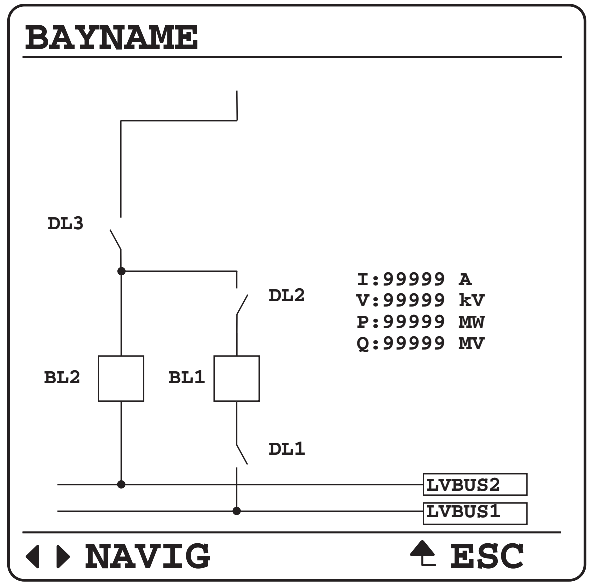


Figure 9.69 LV Right Breaker Bay Without Ground SW (Option 18)

Double Bus Single Breaker

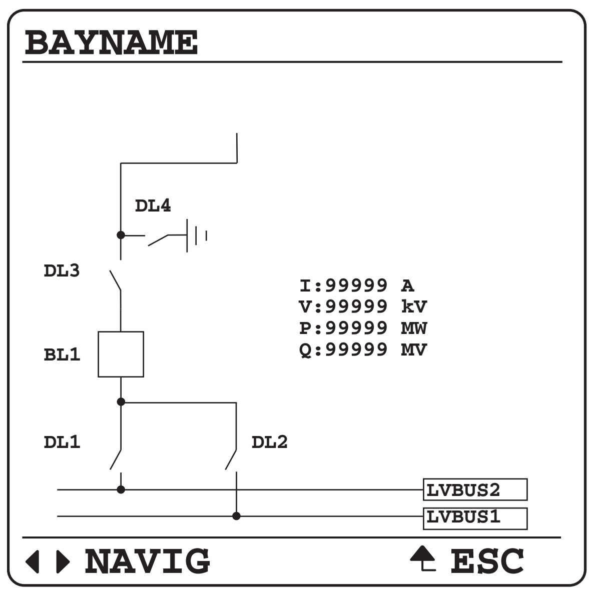


Figure 9.70 LV Right Breaker Bay With Ground SW (Option 19)

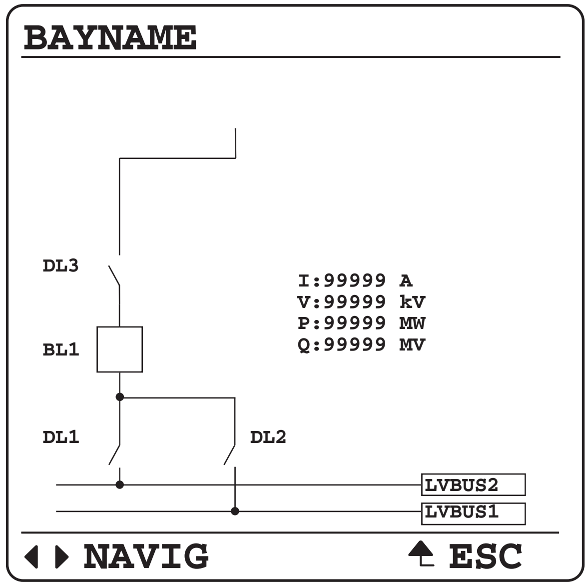


Figure 9.71 LV Right Breaker Bay Without Ground SW (Option 20)

Transformer Bay Type Configurations

The following pages illustrate all of the predefined transformer bay type configurations in the SEL-487E defined by the T_MIMIC setting. Select the configuration that exactly matches the bay configuration being implemented and controlled. *Figure 9.72* through *Figure 9.73* illustrates IEC transformer options I1–I7. and *Figure 9.74*–*Figure 9.75* illustrate ANSI transformer options A1–A7.

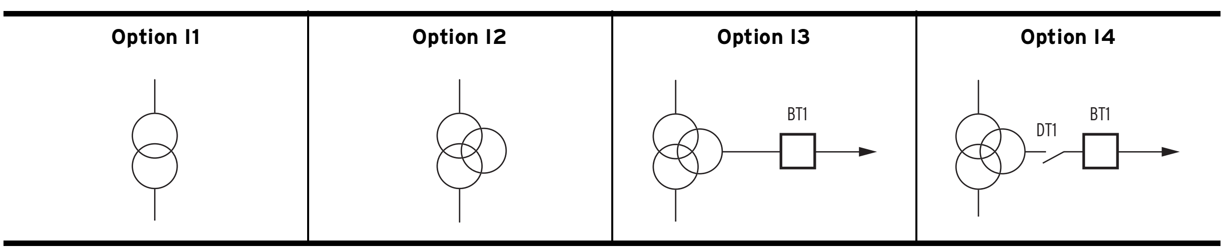


Figure 9.72 Options I1–I4

- ➤ Option I1: IEC two-winding transformer
- ➤ Option I2: IEC three-winding transformer
- ➤ Option I3: IEC three-winding transformer with tertiary circuit breaker
- ➤ Option I4: IEC three-winding transformer with tertiary disconnect and circuit breaker

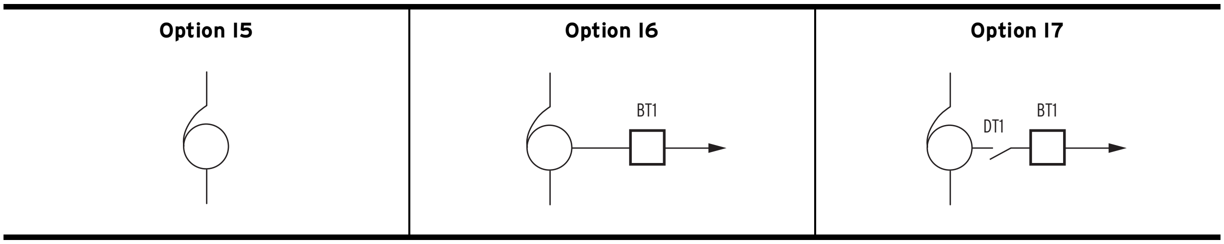


Figure 9.73 Options I5–I7

- ➤ Option I5: IEC autotransformer
- ➤ Option I6: IEC autotransformer, with tertiary circuit breaker
- ➤ Option I7: IEC autotransformer with tertiary disconnect and circuit breaker

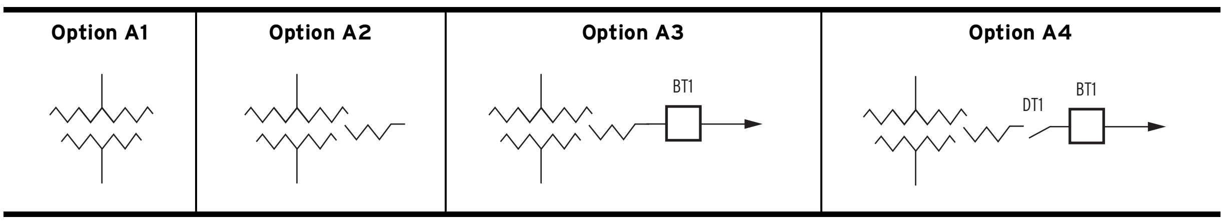


Figure 9.74 Options A1–A4

- ➤ Option A1: ANSI two-winding transformer
- ➤ Option A2: ANSI three-winding transformer
- ➤ Option A3: ANSI three-winding transformer with tertiary circuit breaker
- ➤ Option A4: ANSI three-winding transformer with tertiary disconnect and circuit breaker

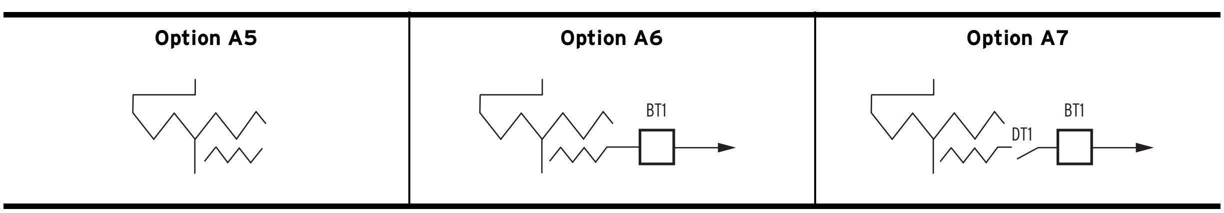


Figure 9.75 Options A5–A7

- ➤ Option A5: ANSI autotransformer
- ➤ Option A6: ANSI autotransformer, with tertiary circuit breaker
- ➤ Option A7: ANSI autotransformer with tertiary disconnect and circuit breaker

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Section 10
Event Reports and SER

Overview

An event is a representation of the operating conditions of the power system at a specific time. Events include instances such as a relay trip, an abnormal situation in the power system that triggers a relay element, or an event capture command.

Information from oscillograms, relay event reports, and SER (Sequential Events Recorder) data is very valuable if you are responsible for outage analysis, outage management, or relay settings coordination. The SEL-487E accepts an IRIG-B clock input for high-accuracy timing. When using a suitable external clock (such as the SEL-2407® Satellite-Synchronized Clock), the SEL-487E synchronizes the data acquisition system to the received signal. Knowledge of the precise time of sampling allows comparisons of data across the power system.

The SEL-487E Relay provides the following comprehensive data recording capabilities:

- Oscillography
- Event Reports, Event Summaries, and Event Histories
- SER (Sequential Events Recorder) with debounced and un-debounced data

The SEL-487E can also perform the PMU (Phasor Measurement Unit) function of gathering synchrophasor data when the relay is in high-accuracy timekeeping mode (HIRIG). See *Section 11: Synchrophasors*.

Data Processing

The SEL-487E is a numeric, or microprocessor-based, relay that obtains power system analog quantities via the CT and PT inputs. The relay converts these analog inputs to digital information for processing to determine relaying quantities for protection, control, and automation. *Figure 10.1* shows a general overview of the input processing diagram for the SEL-487E.

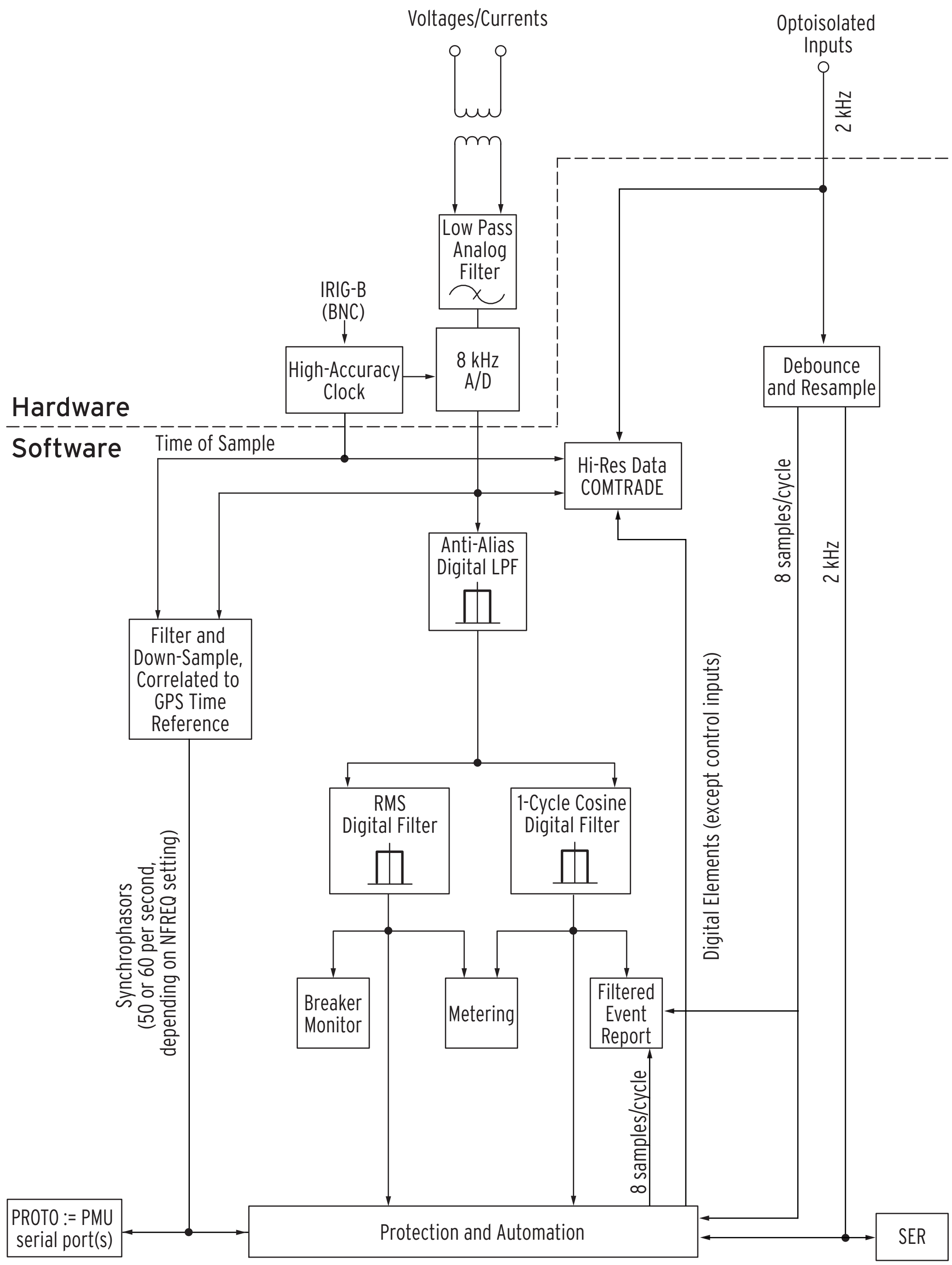

Figure 10.1 SEL-487E Input Processing

Raw and Filtered Data

The SEL-487E outputs two types of analytical data: high-resolution raw data and filtered data. *Figure 10.1* shows the path a power system signal takes through relay input processing. A CT or PT analog input begins at hardware acquisition and sampling, continues through software filtering, and progresses to protection and automation processing. The initial hardware low-pass filter half-power or –3 dB point is 3.0 kHz. Next, the relay samples the power system voltage or current with an 8000 samples/second A/D (analog to digital) converter. This is the tap point for high-resolution raw data captures. You can select 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second effective sampling rates for presentation and storage of the high-resolution raw data in binary COMTRADE format (see *Oscillography*).

The software portion of input signal processing receives the high-resolution raw data sampled quantities and passes these to the Anti-Aliasing Digital Filter. The half-power or –3 dB point of the anti-aliasing filter is 640 Hz. Subsequent processing decimates the sampled data to eight samples per power system cycle using additional digital filtering. This 8-samples/cycle information is the filtered data for event reports and other relay functions. The relay selects every other sample of 8-samples/cycle filtered data to present 4-samples/cycle event reports. The SEL-487E samples the control inputs at a rate of 2 kHz. *Table 10.1* summarizes the available analog quantities and the different processing rates for the COMTRADE oscillography files.

Table 10.1 COMTRADE Analog Quantities

Analog Quantity	Description	Sample Rate (power system cycle)
IA*k*, IB*k*, IC*k*[a]	S, T, U, W, X, and Y phase/neutral currents	8/4/2/1 kHz
VAV, VBV, VCV	“V” phase voltages	8/4/2/1 kHz
VAZ, VBZ, VCZ	“Z” phase voltages	8/4/2/1 kHz

[a] k = S, T, U, W, X, Y.

The SEL-487E main and interface boards INT2, INT4, INT7, and INT8 have optoisolated control inputs with fixed pickup voltages. Optoisolated inputs are ordered with one of six available pickup voltage ratings. No analog voltage information is available from these inputs. Un-debounced raw input digital status is available in high-resolution (COMTRADE) data files, recorded at 2 kHz. Contact bounce may be visible when the raw data is viewed.

Event reports can include the filtered control input Relay Word bits. Control input state changes will appear to occur faster in COMTRADE oscillography files than in event reports (**EVE** command) or Sequential Events Recorder reports (**SER** command) because of the control input debounce time delays. See *Control Inputs on page 2.5* for details on control inputs.

After the full-cycle cosine filter, the Analog quantities are processed at 1/8 spc (samples per cycle), and are inputs to the protection elements. All protection elements however, except for the differential and REF elements, are processed at 1/4 of a cycle. *Table 10.2* summarizes the available analog quantities from protection elements and the processing rate of each. Notice that the relay processes the protection elements at three different rates:

- Differential element and REF, filtered = 1/8
- Harmonics = 1/8
- All other protection elements = 1/4

Table 10.2 Protection Element Analog Quantities and Processing Rates

Analog Quantity	Description	Sample Rate (power system cycle)
IOPFA, IOPFB, IOPFA	Differential, filtered operating current	1/8
IRTFA, IRTFB, IRTFA	Differential, filtered restraint current	1/8
IAH2, IBH2, ICH2	2nd Harmonic current	1/8
IAH4, IBH4, ICH4	4th Harmonic current	1/8
IAH5, IBH5, ICH5	5th Harmonic current	1/8
REF1, REF2, REF3	Restricted earth fault	1/8
Other	All output analog quantities from other protection elements	1/4

Table 10.3 summarizes the available digital inputs and the processing rate of each.

Table 10.3 Processing Rates of Digital Inputs

Digitals	Sample Rate (power system cycle)
100 rows of Event Reporting Digital Elements	1/8
Un-debounced Digital Inputs	2 kHz

Triggering Data Captures and Event Reports

The SEL-487E displays power system data from oscillograms, event reports, event summaries, event histories, and SER data. All of these features, except the SER, require sampled or filtered data from the power system, and are triggered both internally and externally depending on the event trigger that you program in the relay. Both high resolution raw data oscillography and event reports use the same triggering methods. Trigger data captures from one of the following three possible sources:

- Rising edge of Relay Word bit TRIP
- Rising edge of SELOGIC® control equation ER (event report trigger)
- Execution of the **TRIGGER** (**TRI**) command (manually triggered)

In previous SEL relays, the **PUL** command initiated event recording. If you want the **PUL** command to initiate data capture, add the Relay Word bit TESTPUL to the SELOGIC control equation ER.

SELOGIC Control Equation ER

Program the SELOGIC control equation ER to trigger high-resolution raw data oscillography and standard event reports for conditions other than TRIP conditions. When ER asserts, the SEL-487E begins recording data if the relay is not already capturing data initiated by another trigger.

Relay Word Bit TRIP

If Relay Word bit TRIP asserts, the relay automatically triggers an event trigger on the rising edge of the TRIP Relay Word bit state change. In every instance, TRIP causes the relay to begin recording data. You therefore do not need to enter any condition that causes a trip in the ER SELOGIC control equation. For information on Relay Word bit TRIP see *Trip Logic on page 4.100*.

EXAMPLE 10.1 Triggering Event Report/Data Capture Using the ER SELogic Control Equation

This example shows how the elements in the ER SELogic control equation initiate relay data capture. The factory default setting for Group setting SELogic control equation ER is:

ER := **R_TRIG 87RA OR R_TRIG 87RB OR R_TRIG 87RC** (Event Report Trigger Equation (SELogic Control Equation))

The element transitions in this setting are from the following Relay Word bits:

87RA, 87RB, 87RC differential elements

The rising-edge operator, R_TRIG, occurs in front of each of the elements ER equation. Rising-edge operators are especially useful for generating an event report at fault inception. The triggering element causes ER to assert, then clears the way for other elements to assert ER because the relay uses only the beginning of a long element assertion. The starting element in a continuously occurring fault does not mask other possible element triggers. This allows another rising-edge sensitive element to generate another event report later in that same continuously occurring fault (such as an overcurrent situation with the R_TRIG 51O01 element).

In the factory default ER SELogic control equation, if the 87RA element remains asserted for the duration of the ground fault, the rising-edge operator, R_TRIG, in front of 87RA causes ER to assert for only one processing interval (a 1/8-cycle pulse). Other elements in the ER SELogic control equation can trigger event reports while the 87RA element remains asserted throughout the fault duration. You can also use the falling-edge operator, F_TRIG, to initiate data captures.

TRI (Trigger Event Report) Command

Use the **TRI** command from any communications port to trigger the SEL-487E to begin recording high-resolution raw data and event report data. When testing with the **TRI** command, you can gain a glimpse of power system operating conditions that occur immediately after you issue the **TRI** command.

Duration of Data Captures and Event Reports

The SEL-487E stores high-resolution raw data and filtered data. The number of stored high-resolution raw data captures and event reports is a function of the amount of data contained in each capture. You can configure the relay to record long data captures at high sampling rates, although this reduces the total number of stored events you can retrieve from the relay.

To use the data capture functions, select the effective sampling rate and data capture times. Relay setting SRATE, listed in *Table 10.1*, determines the number of data points the relay records per second. You can set SRATE to 8 kHz, 4 kHz, 2 kHz, and 1 kHz. The effective sampling rate and the event report length are related:

- 8 kHz sampling—2.00 seconds total event report
- 4 kHz sampling—3.00 seconds total event report
- 2 kHz sampling—4.00 seconds total event report
- 1 kHz sampling—5.00 seconds total event report

The LER setting is the overall length of the event report data capture; the PRE setting determines the time reserved in the LER period when the relay records pretrigger (prefault) data. Typically, you set the PRE time to 20 percent of the total LER period. *Table 10.4* shows the relay settings for the data capture recording times at each effective sampling rate.

Table 10.4 Report Settings

Label	Description	Range	Default
SRATE	Effective sample rate of event report	1, 2, 4, 8 kHz	2 kHz
SRATE = 8 kHz			
LER	Length of event report	0.25–2.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–1.95 seconds	0.1 seconds
SRATE = 4 kHz			
LER	Length of event report	0.25–3.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–2.95 seconds	0.1 seconds
SRATE = 2 kHz			
LER	Length of event report	0.25–4.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–3.95 seconds	0.1 seconds
SRATE = 1 kHz			
LER	Length of event report	0.25–5.00 seconds	0.5 seconds
PRE	Length of prefault	0.05–4.95 seconds	0.1 seconds

Figure 10.2 shows how the length of the data capture/event report (setting LER) and the pre-trigger or pre-fault time (setting PRE) are related.

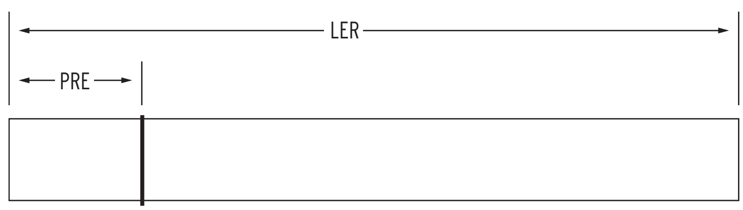

Figure 10.2 Data Capture/Event Report Times

NOTE: Consider the total capture time when choosing a value for setting LER at the SRATE := 8 kHz. At LER := 0.5 or LER := 1.0 the relay records at least two data captures. These and smaller LER settings are sufficient for most power system disturbances.

The relay stores all data captures to volatile RAM and then moves these data to nonvolatile memory storage. There is enough volatile RAM to store one maximum length capture (maximum LER time) for a given SRATE. No data captures can be triggered while the volatile RAM is full; the relay must move at least one data capture to non-volatile storage to reenable data capture triggering. Thus, to record sequential events, you must set LER to half or less than half of the maximum LER setting. The relay stores more sequential data captures as you set LER smaller. *Table 10.5* lists the maximum number of data captures/event reports the relay stores in nonvolatile memory for various report lengths and sample rates. The relay automatically overwrites the oldest events with the newest events when the nonvolatile storage capacity is exceeded.

The relay stores approximately five seconds of high-resolution raw or filtered data in nonvolatile memory at the maximum resolution (8000 samples/second effective sampling rate). If you have selected LER at 0.5 seconds (30 cycles at 60 Hz or 25 cycles at 50 Hz), you can store eleven 1/2-second reports. These 11 reports are at 8000 samples/second resolution (approximately eight times more resolution than the SEL-300 series relays.)

The lower rows of *Table 10.5* show the number of event reports the relay stores at the maximum data capture times for each SRATE sampling rate setting. Table entries are the maximum number of stored events; these can vary by 10 percent according to relay memory usage.

Table 10.5 Event Report Nonvolatile Storage Capability

Event Report Length	Maximum Number of Stored Reports			
	8 kHz	4 kHz	2 kHz	1 kHz
0.25 seconds	41	55	65	76
0.50 seconds	23	32	39	47
1.0 seconds	12	17	21	26
2.0 seconds	6	9	11	14
3.0 seconds	N/A	4	7	9
4.0 seconds	N/A	N/A	5	7
5.0 seconds	N/A	N/A	N/A	6

Oscillography

The SEL-487E features the following three types of oscillography:

- Raw data oscillography—24 fixed analog quantities, with an effective sampling rate as fast as 8000 samples/second
- Event report oscillography from filtered data—24 fixed analog quantities, with a sampling rate of either 8 samples/cycle or 4 samples/cycle
- Event report oscillography from filtered data—20 settable analog quantities, with a sampling rate of either 8 samples/cycle or 4 samples/cycle

Raw Data Oscillography

Use high-resolution raw data oscillography to view transient conditions in the power system. You can set the relay to report these high-resolution oscillograms at 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second effective sampling rates (see *Duration of Data Captures and Event Reports*). The high-resolution raw data oscillograms are available as files through the use of Ymodem file transfer and FTP (file transfer protocol) in the binary COMTRADE file format output (*IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111-1999*). The filtered data oscillograms at 8 samples/cycle and 4 samples/cycle give you accurate information on the relay protection and automation processing quantities. The relay outputs 8-samples/cycle and 4-samples/cycle filtered event reports through a terminal or as files in ASCII format, Compressed ASCII format, and binary FTP and Ymodem file outputs. *Figure 10.3* shows a sample filtered-data oscillogram

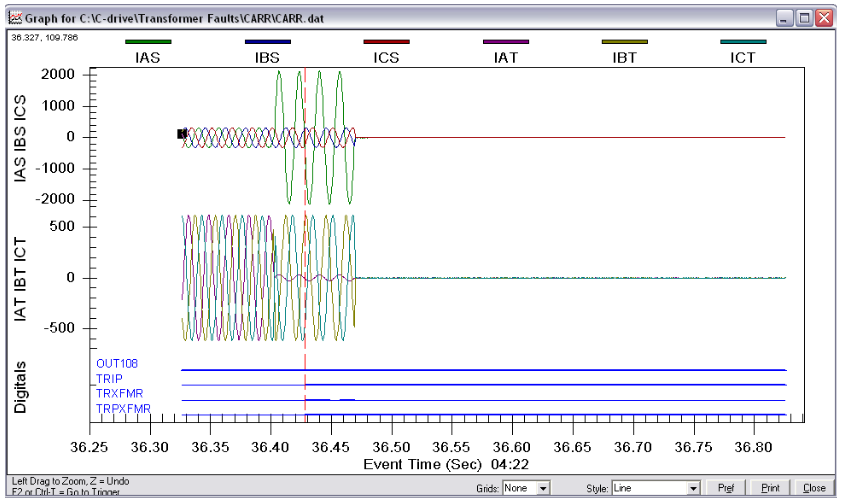

Figure 10.3 Sample SEL-487E Oscillogram

Raw data oscillography produces oscillograms that record power system phenomena that occur at frequencies that the relay filters out for normal protection element operation. Raw data oscillography captures data with content ranging from dc to greater than 3.0 kHz; the –3 dB point of the first-order low-pass analog input filter is 3.0 kHz (with response rolling off at –20 dB per decade). COMTRADE files include all selected Relay Word bits (up to 800 Relay Word bits from 100 rows).

The SEL-487E stores high-resolution raw data oscillography in binary format and uses COMTRADE file types to output these data:

- .HDR-header file
- .CFG-configuration file
- .DAT-data file

The .HDR file contains summary information about the event in ASCII format settings. The .CFG file is an ASCII configuration file that describes the layout of the .DAT file. The .DAT file is in binary format and contains the values for each input channel for each sample in the record. These data conform to the IEEE C37.111-1999 COMTRADE standard.

.HDR File

The .HDR file contains the summary and relay settings information that appears in the event report for the data capture (see *Event Summary Section of the Event Report* and *Settings Section of the Event Report*). *Figure 10.4* shows a sample COMTRADE .HDR file.

```
Relay 1                                      Date: 04/16/2008  Time: 03:24:59.245
Station A                                    Serial Number: 2008030645

Event: TRIP                                                    Time Source: OTHER
Event Number: 10001                   Frequency: 60.000              Group: 1
Targets: TLED_14

Breaker S: OPEN

Fault Analog Data

         IAS    IBS    ICS    IAT    IBT    ICT    IAU    IBU    ICU
MAG(A)     220    219    220    436    436    437      0      0      0
ANG(DEG)    0.0 -120.0  120.2 -179.8   60.5  -59.5  102.4   94.9  -21.8

         IAW    IBW    ICW    IAX    IBX    ICX    IY1    IY2    IY3
MAG(A)       0      0      0      0      0      0      0      0      0
ANG(DEG) -101.7  156.5  -55.8   34.4  167.2  -96.7 -139.1   26.0  134.2

         VAV    VBV    VCV    VAZ    VBZ    VCZ
MAG(kV)      0      0      0      0      0      0
ANG(DEG)   38.5   92.9   68.2   14.5 -155.8   19.6

         IOPA   IRTA   IOPB   IRTB   IOPC   IRTC
MAG(p.u)  0.05   2.04   0.05   2.04   0.05   2.05
SET_G1.TXT
[INFO]
RELAYTYPE=SEL-487E
FID=SEL-487E-R100-V0-Z001001-D20080403
BFID=SLBT-4XX-X025-V0-Z001002-D20080211
PARTNO=0487E0X41111XXB4H74424X
[IOBOARDS]
.
.
.
"AR195",
"AR196",
"AR197",
"AR198",
"AR199",
"AR200",
```

Summary Event Information

Relay Settings

Figure 10.4 Sample COMTRADE .HDR Header File

.CFG File

The .CFG file contains data such as sample rates, number of channels, line frequency, channel information, and transformer ratios (see *Figure 10.5*). A <CR><LF> follows each line.

The relay divides the CT ratio in the .cfg file for delta-connected CTs. See *Delta-Connected CTs on page 4.28*.

```
Station A,FID=SEL-487E-R100-V0-Z001001-D20080403,2008      COMTRADE Standard
361,25A,336D                                                Total Channels, Analog, Digital
1,IAS,A,,A,0.757147,0,0,-32767,32767,100.0,1,P
2,IBS,B,,A,0.757147,0,0,-32767,32767,100.0,1,P
3,ICS,C,,A,0.757147,0,0,-32767,32767,100.0,1,P
4,IAT,A,,A,0.757147,0,0,-32767,32767,100.0,1,P
5,IBT,B,,A,0.757147,0,0,-32767,32767,100.0,1,P
6,ICT,C,,A,0.757147,0,0,-32767,32767,100.0,1,P
7,IAU,A,,A,0.757147,0,0,-32767,32767,100.0,1,P
8,IBU,B,,A,0.757147,0,0,-32767,32767,100.0,1,P
9,ICU,C,,A,0.757147,0,0,-32767,32767,100.0,1,P
10,IAW,A,,A,0.757147,0,0,-32767,32767,100.0,1,P
11,IBW,B,,A,0.757147,0,0,-32767,32767,100.0,1,P            Analog Channel Data
12,ICW,C,,A,0.757147,0,0,-32767,32767,100.0,1,P
13,IAX,A,,A,0.757147,0,0,-32767,32767,100.0,1,P
14,IBX,B,,A,0.757147,0,0,-32767,32767,100.0,1,P
15,ICX,C,,A,0.757147,0,0,-32767,32767,100.0,1,P
16,IY1,1,,A,0.757147,0,0,-32767,32767,100.0,1,P
17,IY2,2,,A,0.757147,0,0,-32767,32767,100.0,1,P
18,IY3,3,,A,0.757147,0,0,-32767,32767,100.0,1,P
19,VAV,A,,kV,0.030286,0,0,-32767,32767,2000.0,1,P
20,VBV,B,,kV,0.030286,0,0,-32767,32767,2000.0,1,P
21,VCV,C,,kV,0.030286,0,0,-32767,32767,2000.0,1,P
22,VAZ,A,,kV,0.030286,0,0,-32767,32767,2000.0,1,P
23,VBZ,B,,kV,0.030286,0,0,-32767,32767,2000.0,1,P
24,VCZ,C,,kV,0.030286,0,0,-32767,32767,2000.0,1,P
25,VDC,,,V,0.011153,0.000000,0,-32767,32767,1,1,P
1,TLED_8,,,0
2,TLED_7,,,0
3,TLED_6,,,0
4,TLED_5,,,0
5,TLED_4,,,0
6,TLED_3,,,0
7,TLED_2,,,0                                                 Digital (Status)
8,TLED_1,,,0                                                  Channel Data
9,TLED_16,,,0
10,TLED_15,,,0
11,TLED_14,,,0
12,TLED_13,,,0
13,TLED_12,,,0
.
.
.
329,OCX,,,0
330,CCX,,,0
331,UNUSED331,,,0
332,UNUSED332,,,0
333,UNUSED333,,,0
334,UNUSED334,,,0
335,UNUSED335,,,0
336,UNUSED336,,,0
60
1
2000,1000
16/04/2008,03:24:59.143183
16/04/2008,03:24:59.245235
ASCII
1
```

Figure 10.5 COMTRADE .CFG Configuration File Data

The configuration file has the following format:

- Station name, device identification, COMTRADE standard year
- Number and type of channels
- Channel name units and conversion factors
- Line frequency
- Sample rate and number of samples
- Date and time of first data point
- Date and time of trigger point
- Data file type
- Time stamp multiplication factor

.DAT File

The .DAT file follows the COMTRADE binary standard. The format of the binary data files comply with IEEE Standard C37.111-1999. Refer to the *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111-1999* for more information. Many programs read the binary COMTRADE files. These programs include the SEL-5601 Analytic Assistant and the ACSELERATOR QuickSet® SEL-5030 Software program.

Generating Raw Data Oscillograms

To use high-resolution raw data oscillography, select the type of triggering event and use a trigger event method described in *Triggering Data Captures and Event Reports*. Use the settings SRATE, LER, and PRE to set the SEL-487E for the appropriate data sampling rate and data capture time (see *Duration of Data Captures and Event Reports*).

Retrieving Raw Data Oscillograms

Use a computer terminal emulation program and the **FILE** commands at any communications port to retrieve the stored high-resolution raw data capture from the relay file structure. You can also use ACSELERATOR QuickSet (see *Analyze Events on page 3.22*) or the Ethernet card (using FTP).

Event Report Oscillography

Use a terminal or SEL-supplied PC software to retrieve filtered event report files stored in the relay and transfer these files to your computer. Both ACSELERATOR QuickSet and the SEL-5601 Analytic Assistant read the compressed event files that the relay generates for an event. See *Analyze Events on page 3.22* for instructions on viewing event report oscillography with ACSELERATOR QuickSet.

Event Reports, Event Summaries, and Event Histories

Event Report Oscillography From Filtered Data

Event reports simplify postfault analysis and help you improve your understanding of protection element operations. Event reports also aid in testing and troubleshooting relay settings and protection schemes because these reports contain detailed data on voltage, current, and relay element status. For further analysis assistance, the relay appends the active relay settings to each event report. The relay stores event reports in nonvolatile memory, and you can clear the event report memory on a port-by-port basis (see the **EVE** command in *EVENT on page 13.17*). You decide the amount of information and length in an event report (see *Duration of Data Captures and Event Reports*).

NOTE: The relay compensates for delta-connected CTs when reporting primary values. (See *Delta-Connected CTs on page 4.28*.)

The SEL-487E records the filtered power system data that the relay uses in protection and automation processing. You can view filtered information about an event in one or more of the following forms:

- Event report
- Event summary
- Event history

Alias Names

To customize your event report, rename (alias) any Relay Word bit, analog quantity, or default terminal name with more meaningful names to improve the readability of fault analysis and customized programming. After renaming

NOTE: If Alias names were changed after an event was recorded, the relay uses the present alias names in subsequent event reports.

the primitive quantities, the alias names rather than the primitive names appear in the event reports and SER. The primitive names of the analog channels still appear in the event reports.

Event Report

The relay generates event reports to display settable analog data, digital data (control inputs, control outputs, and the state of Relay Word bits), and relay settings. The event report is a complete description of the data that the relay recorded in response to an event trigger. Each event report includes these components:

- Report header and analog section
- Phase currents and voltages
- Differential currents
- Digital section
  - Relay Word bit elements
  - Control outputs
  - Control inputs
- Event summary
- Settings
  - Group settings
  - Global settings
  - Output settings
  - SELOGIC control equations protection logic

Viewing the Event Report

Access event reports from the communications ports and communications cards at Access Level 1 and higher. (You cannot view event reports at the front panel, although you can view event summary information at the front-panel display). You can independently acknowledge the oldest event report at each communications port (**EVE ACK** command) so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete sets of event reports. To acknowledge the oldest event report, you must first view that event report at a particular port by using the **EVE N(EXT)** command. You can use the **EVE** command and a terminal to retrieve event reports by event order or by event serial number. (The relay labels each new event with a unique serial number as reported in the **HIS** command history report; see *Event History*.)

Event Numbering

Use the **EVE *n*** command to access particular event reports. When parameter *n* is 1 through 9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

You can retrieve only analog or digital information, and you can exclude the summary or settings portions of the report. The default **EVE** command event report data resolution is 4 samples/cycle and the default report length is 0.5 seconds (30 cycles at 60 Hz or 25 cycles at 50 Hz) with the factory default setting for LER. *Table 10.7* lists a summary of **EVE** commands (see *EVENT* for complete information on the **EVE** command), in response to the **HELP EVE** command. *Table 10.7* shows a few examples of command options that you can use with the **EVE** command. The **EVE L** and **EVE C** commands provide compatibility with older command sets.

Table 10.6 EVE Command[a,b,c]

Command	Description
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.
EVE *n*	Return a particular *n* event report (including settings and summary) at full length with 4-samples/cycle data.
EVE A	Return only the analog information for the most recent event report.
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.
EVE C *n*	Return a particular *n* event report at a 15-cycle length with 8-samples/cycle data.
EVE D *n*	Return only the digital information for a particular *n* event report.
EVE *n* L	Return a particular *n* event report at full length with 8-samples/cycle sampling.
EVE *n* *Lyyy*	Return *yyy* cycles of a particular *n* *e*vent report with 4-samples/cycle data.
EVE N	Return the oldest unacknowledged event report with 4-samples/cycle data (N = next).
EVE *n* NSET	Return a particular *n* event report without settings at full length with 4-samples/cycle data.
EVE *n* NSUM	Return a particular *n* event report without the event summary at full length with 4-samples/cycle data.
EVE *n* Sx	Return a particular *n* event report at full length with *x*-samples/cycle data.
EVE *n* TE	Return a particular *n* event report at full length without the report header with 4-samples/cycle data.

[a] The optional parameter n indicates event order or serial number (see Event Numbering).
[b] The parameter x is 4 or 8 to represent data resolution of 4 samples/cycle and 8 samples/cycle, respectively.
[c] The parameter yyy represents an event length in cycles.

Table 10.7 EVE Command Examples

Example	Description
EVE L10 S8	Return 10 cycles of an 8-samples/cycle event report for the most recent event.
EVE L010 A	Return 10 cycles of the analog portion only of the most recent event report at 4-samples/cycle resolution.
EVE 2 NSET	For the second most recent event, return the event report with no settings at 4-samples/cycle data.

You can retrieve event reports with the ACSELERATOR QuickSet **Analysis > View Event History** menu. The **Analysis > View Event Files** menu gives you oscillogram/element displays, phasor displays, harmonic analysis, and an event summary for each event you select in the **Event History** dialog box. See *Analyze Events on page 3.22* and *Read History on page 3.22* for more information on viewing event reports with ACSELERATOR QuickSet.

You can also download event report files from the relay. Use a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher, type **FILE READ EVENTS E8_*nnnnn*.TXT <Enter>** for the 8-samples/cycle event report and type **FILE READ EVENTS E4_*nnnnn*.TXT <Enter>** for the 4-samples/cycle event report (*nnnnn* is the event serial number). Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, use the

C8_nnnnn.TXT and C4_nnnnn.TXT file names for the 8-samples/cycle and 4-samples/cycle Compressed ASCII event reports, respectively. See *Get Event on page 3.22* for file download procedures.

The following discussion shows sample portions of an event report that you download from the relay using a terminal and the **EVE** command. An event report contains analog, digital, summary, and settings sections without breaks.

Report Header and Analog Section of the Event Report

The first portion of an event report is the report header and the analog section. See *Figure 10.6* for the location of items included in a sample analog section of an event report. If you want to view only the analog portion of an event report, use the **EVE A** command.

The report header is the standard SEL-487E header listing the relay identifiers, date, and time. Report headers help you organize report data. Each event report begins with information about the relay and the event, such as the RID setting (Relay ID), the SID setting (Station ID), and the firmware checksum (CID). The FID string identifies the relay model, flash firmware version, and the date code of the firmware. See *Firmware on page A.1* for a description of the FID string. To complete the header, the relay reports a date and time stamp to indicate the internal clock time when the relay triggered the event.

The event report column labels follow the header. The data underneath the analog column labels contain samples of power system voltages and currents in primary kilovolts and primary amps, respectively. These quantities are instantaneous values scaled by $\sqrt{2}/2$ (0.707). Although you may not use all 24 channels of the SEL-487E in your application, all 24 channels are always displayed in the event report. To display all 24 channels, the event report consists of two groups of 12 channels. Current channels IAS through ICU and voltage channels VAV through VCV are displayed in the first group, and analogs IAW though IY3 and VAZ through VCZ immediately follow IAS through ICU and VAV through VCV, separated by one blank row. *Figure 10.6* shows an example of the first 12 channels.

Figure 10.6 contains selected data from the analog section of a 4-samples/cycle event report for a transformer fault. The bracketed numbers at the left of the report (for example, [11]) indicate the cycle number; *Figure 10.6* presents seven cycles of 4-samples/cycle data. The trigger row includes a > character to indicate the trigger point. This is the dividing point between the prefault or PRE time and the fault or remainder of the data capture.

The row that the relay uses for the currents in the event summary is the row 1.25 cycles after the event trigger; the relay marks this row on the event report with an asterisk (*) character.

```
Relay 1                                       Date: 04/21/2008  Time: 02:03:38.102
Station A                                     Serial Number: 2008030645               Header
FID=SEL-487E-R100-V0-Z001001-D20080407        Event Number = 10020     CID=0xE905
                                                                                      Firmware ID
                   Currents (Pri. Amps)
  IAS    IBS    ICS    IAT    IBT    ICT    IAU    IBU    ICU
[1]
   190    -39   -150   -416     84    331      0      0      0
   -64    195   -132    141   -431    289      0      0      0
  -190     39    150    416    -84   -331      0      0      0        One Cycle
    63   -195    132   -141    431   -289      0      0      0         of Data
[2]
   190    -39   -150   -416     84    331      0      0      0
   -63    195   -132    141   -432    289      0      0      0
  -190     39    150    416    -84   -331      0      0      0
    64   -195    132   -141    431   -289      0      0      0
[3]
   190    -39   -150   -416     84    331      0      0      0
   -64    195   -132    141   -431    289      0      0      0
  -190     39    150    416    -84   -331      0      0      0
    63   -195    132   -141    431   -289      0      0      0
[4]
   190    -39   -150   -416     84    331      0      0      0
   -63    195   -132    141   -431    289      0      0      0
  -190     39    150    416    -84   -331      0      0      0
    63   -195    132   -141    432   -289      0      0      0
[5]
   189    -39   -150   -416     84    331      0      0      0
   -63    195   -132    141   -432    289      0      0      0
  -190     39    150    416    -84   -331      0      0      0
    85   -195    132   -135    427   -285      0      0      0
[6]
   561    -39   -150   -319     77    327      0      0      0
  -291    195   -132     81   -408    272      0      0      0
 -1177     39    150    158    -73   -312      0      0      0
   475   -195    132    -32    392   -263      0      0      0
[7]
  1422    -39   -150    -94     77    301      0      0      0>       Trigger
  -475    195   -132     32   -393    263      0      0      0
 -1422     39    150     94    -77   -301      0      0      0
   534   -195    132    -37    392   -263      0      0      0
[8]
  2421    -39   -150   -180     77    301      0      0      0
 -1088    195   -132     85   -392    263      0      0      0*       1.25 cycles after trigger
 -4079     39    150    322    -77   -301      0      0      0        (to Event Summary)
  1583   -195    132   -128    392   -263      0      0      0
[9]
  4740    -39   -150   -378     77    301      0      0      0
 -1583    195   -132    128   -392    263      0      0      0
 -4740     39    150    378    -77   -301      0      0      0
  1583   -195    132   -128    392   -263      0      0      0
[10]
  4739    -39   -150   -378     77    301      0      0      0
 -1583    195   -132    128   -392    263      0      0      0
 -4739     39    150    378    -77   -301      0      0      0
  1517   -185    125   -123    372   -248      0      0      0
[11]
  3308      1   -133   -264     -3    266      0      0      0
  -726     87    -58     59   -175    116      0      0      0
  -939    -20     58     75     42   -115      0      0      0
     0      1      0      0     -1      1      0      0      0        Circuit Breaker Open
```

Figure 10.6 Analog Section of the Event Report

IAS through ICU and voltage channels VAV through VCV are displayed in the first group, and analogs IAW through IY3 and VAZ through VCZ immediately follow IAS through ICU and VAV through VCV.

Table 10.8 Event Report Metered Analog Quantities

Quantity	Description
IAS, IBS, ICS	Winding S, filtered phase current vector
IAT, IBT, ICT	Winding T, filtered phase current vector
IAU, IBU, ICU	Winding U, filtered phase current vector
VAV, VBV, VCV	Voltage V, filtered phase voltage vector
IAW, IBW, ICW	Winding W, filtered phase current vector
IAX, IBX, ICX	Winding X, filtered phase current vector
IY1, IY2, IY3	Windings Y1, Y2, and Y3, filtered phase current vectors
VAZ, VBZ, VCZ	Voltage Z, filtered phase voltage vector

For the event report (different from the raw data oscillography), you can select up to 20 additional analog quantities from the available analog quantities in the relay (see *Appendix H: Analog Quantities*). These user-defined analog quantities follow the 24 fixed channels.

Differential Report

The differential report is not a part of the event report unless specified to be included. Use the **EVE DIF[F]** command (add **DIF[F]** to the **EVE** command) to specify the differential report is part of the event report. If so specified, then the differential data is displayed after the user-configurable analog quantities. The analog differential report displays operate and restraint quantities for each differential element, and the percentage second, fourth, and fifth harmonic currents in each element, as shown in *Figure 10.7*.

```
Relay 1                                     Date: 04/21/2008  Time: 02:03:38.102
Station A                                   Serial Number: 2008030645
FID=SEL-487E-R100-V0-Z001001-D20080407      Event Number = 10020     CID=0xE905

   Differential Quantities     2nd Harmonic   4th Harmonic  5th Harmonic
IOPA  IRTA  IOPB  IRTB  IOPC  IRTC  IAH2 IBH2 ICH2 IAH4 IBH4 ICH4 IAH5 IBH5 ICH5

[1]
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    1    1    0    1    1    1    1
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    2    2    1    1    1    1    1
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    2    1    1    1    1    1    2
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    2    1    1    1    1    1    2
[2]
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    2    1    1    1    1    2    1
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    2    1    1    0    1    2    2
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    1    2    2    1    1    2    2
 0.05  1.96  0.06  1.95  0.05  1.96  3    2    1    2    2    1    1    2    2
[3]
 0.05  1.96  0.06  1.95  0.05  1.96  1    2    2    2    2    1    1    1    2
 0.05  1.96  0.06  1.95  0.05  1.96  1    3    2    1    2    1    1    1    1
 0.05  1.96  0.06  1.95  0.05  1.96  1    1    2    2    2    1    0    1    1
 0.05  1.96  0.06  1.95  0.05  1.96  1    1    2    1    1    1    1    1    2
[4]
 0.05  1.96  0.06  1.95  0.05  1.96  1    3    1    1    0    0    1    0    2
 0.05  1.96  0.06  1.95  0.05  1.96  1    1    2    1    1    0    1    1    2
 0.05  1.96  0.06  1.95  0.05  1.96  1    1    2    1    1    0    1    2    2
 0.05  1.96  0.05  1.95  0.05  1.96  2    3    1    1    1    1    1    1    2
[5]
 0.05  1.96  0.05  1.95  0.05  1.96  0    0    0    1    0    0    1    1    2
 0.05  1.96  0.06  1.95  0.05  1.96  0    2    1    1    1    1    1    1    1
 0.05  1.96  0.06  1.95  0.05  1.96  2    2    1    1    2    1    0    1    1
 0.07  1.98  0.01  1.97  0.08  1.93  2    3    1    1    1    1    1    1    2
[6]
 1.29  2.97  0.67  2.22  0.62  2.38  1    2    3    1    1    1    1    1    1
 1.51  3.14  0.78  2.40  0.74  2.28  1    3    3    1    1    0    0    1    0
 3.59  4.74  1.81  3.07  1.79  3.15  1    2    3    1    1    1    1    1    1
 3.79  4.90  1.92  3.19  1.88  3.15  0    0    0    0    0    0    1    6    8
[7]
 4.62  5.53  2.31  3.49  2.31  3.50  0    0    0    0    0    0    0    0    0
 4.62  5.53  2.31  3.49  2.31  3.50  0    0    0    0    0    0    0    0    0
 4.62  5.53  2.31  3.49  2.31  3.50  0    0    0    0    0    0    0    0    0
 4.68  5.60  2.34  3.55  2.34  3.49  0    0    1    1    1    0    0    0    1
[8]
 7.60  8.77  3.80  4.92  3.80  5.12  1    2    3    1    1    1    1    1    1
 8.14  9.35  4.07  5.39  4.06  5.20  1    2    3    1    1    1    1    1    1
12.91 14.53  6.46  7.73  6.45  7.87  1    2    3    1    1    1    1    1    1
13.38 15.04  6.69  8.09  6.68  8.00  1    2    3    1    1    1    1    1    1
[9]
15.27 17.10  7.64  9.04  7.63  9.05  0    0    0    0    0    0    0    0    0
15.27 17.10  7.64  9.04  7.63  9.05  0    0    0    0    0    0    0    0    0
15.27 17.10  7.64  9.04  7.63  9.05  0    0    0    0    0    0    0    0    0
15.27 17.10  7.64  9.04  7.63  9.05  0    0    0    0    0    0    0    0    0
[10]
15.27 17.10  7.64  9.04  7.63  9.05  0    0    0    0    0    0    0    0    0
15.27 17.10  7.64  9.04  7.63  9.05  0    0    0    0    0    0    0    0    0
15.27 17.09  7.64  9.04  7.63  9.05  0    0    0    0    0    0    0    0    0
15.21 17.02  7.61  8.94  7.60  9.01  1    1    1    1    1    1    1    0    1
[11]
11.12 12.45  5.56  6.82  5.56  6.76  1    2    3    1    1    1    1    1    1
10.35 11.59  5.17  5.66  5.18  6.40  0    0    1    1    1    0    0    0    1
 3.63  4.06  1.82  2.43  1.81  2.27  0    0    1    1    1    0    0    0    1
 2.87  3.21  1.43  1.43  1.44  1.97  0    0    1    1    1    0    0    0    1
[12]
 0.00  0.00  0.00  0.00  0.00  0.00  0    0    0    0    0    0    0    0    0
```

Figure 10.7 Differential Report

Digital Section of the Event Report

The second portion of an event report is the digital section. Inspect the digital data to evaluate relay element response during an event. See *Figure 10.8* for the locations of items in a sample event report digital section. If you want to view only the digital portion of an event report, use the **EVE D** command (see *Table 10.6* or *Section 13: ASCII Command Reference* for details). In the digital portion of the event report, the relay indicates deasserted elements with a period (.) and asserted elements with an asterisk (*) character.

The element and digital information labels are single character columns. Read these columns from top to bottom. The trigger row includes a > character following immediately after the last digital element column to indicate the trigger point. The relay marks the row used to report the maximum fault current with an asterisk (*) character at the right of the last digital element column. Event reports that are 4-samples/cycle reports show the OR combination of digital elements in the two 8-samples/cycle rows to make the quarter-cycle entry.

The digital report arranges the event report digital settings into 79 column pages. For every 79 columns, the relay generates a new report that follows the previous report. The report displays the digital label header for each column in a vertical fashion, aligned on the last character. For example, if the first digital section elements are IN101, #, RMBA5, FBFS, LOKA, #, OUT203, OUT204, and HALARM, the header appears as in *Figure 10.9*. If the Relay Word bits included in the header were assigned aliases, the alias names appear in the report.

```
T
R                                                                          000000
PTTTTT      RRRRRR VV   SSSSSS TTTTTT UUUUUU WWWWWW XXXXXX       IIIIIII UUUUUU
XRRRRR 888  EEEEEE PPLL FRFRFR FRFRFR FRFRFR FRFRFR FRFRFR FFFFF NNNNNNN TTTTTT
FIIIII 7778 FFFFFF 0000 333333 333333 333333 333333 333333 BBBBB 1111111 111111
MPPPPP RRR7 FFFRRR LLPP 222222 222222 222222 222222 222222 FFFFF 0000000 000000
RSTUWX ABCQ 123123 VZVZ PPQQGG PPQQGG PPQQGG PPQQGG PPQQGG STUWX 1234567 123456

[1]
...... .... ...... .... ...... ...... ...... ...... ...... ..... ....... ......
...... .... ...... .... ...... ...... ...... ...... ...... ..... ....... ......
...... .... ...... .... ...... ...... ...... ...... ...... ..... ....... ......
...... .... ...... .... ...... ...... ...... ...... ...... ..... ....... ......
.
.
.
[7]
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....>
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
[8]
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....*
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
[9]
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
*..... *... ...... .... ...... ...... ...... ...... ...... ..... ....... *.....
```

Digital Column Labels

One Cycle of Data

Trigger

Figure 10.8 Digital Section of the Event Report

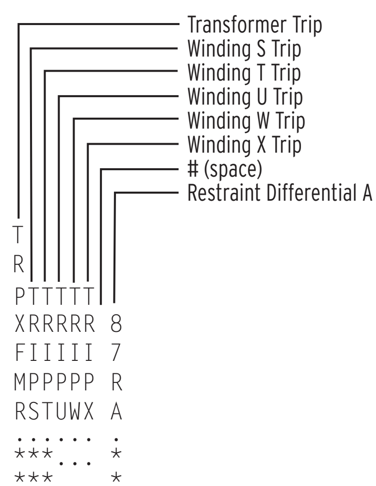

Figure 10.9 Sample Digital Portion of the Event Report

EXAMPLE 10.2 Reading the Digital Portion of the Event Report

This example shows how to read the digital event report shown in Figure 10.9. The sample digital event report shows seven cycles of 4-samples/cycle data for an internal transformer fault.

In this particular report, Restraint Differential element 87RA operated, causing, Relay Word bits TRPXFMR (transformer trip), TRIPS (Winding S trip) and TRIPT (Winding T trip) to assert.

Selecting Event Digital Elements

Specify the digital elements in the digital section of the event report by using the Event Reporting Digital Elements settings found in the Report settings (the **SET R** command from a terminal or the **Report** branch of the **Settings** tree view of ACSELERATOR QuickSet). You can enter as many as 800 Relay Word bits from 100 target rows. However, the rows containing the following elements are always included as part of the 100 rows: TLED_1, TLED_2, TLED_3, TLED_4, TLED_5, TLED_6, TLED_7, TLED_8, TLED_9, TLED_10, TLED_11, TLED_12, TLED_13, TLED_14, TLED_15, TLED_16, TLED_17, TLED_18, TLED_19, TLED_20, TLED_21, TLED_22, TLED_23, TLED_24 (rows 1–3), 87RA, 87RB, 87RC, 87Q (rows 10–11), RMB*n*A, TMB*n*A, RMB*n*B, TMB*n*B, ROKA, RBADA, CBADA, LBOKA, ROKB, RBADB, CBADB, LBOKB, (rows 312–314), and TRIP (row 111).

The # symbol places a blank column in the digital report. Use the # symbol to organize the digital section of the event report. See *Figure 10.9* for a list of the default programmed digital elements.

Digital Section INnnn Times

Reported assertion times for input digital elements differ, although these elements have the same name in both high-resolution raw data reports and in the filtered event reports. When you enter an input (IN*nnn*) in the event digitals list, the relay displays the filtered input with time latency in the event report and the Compressed ASCII event report. However, in the binary COMTRADE file event report, the relay reports the actual high-sample rate capture time (raw) for relay inputs, i.e., the non-debounced inputs.

Event Summary Section of the Event Report

The third portion of an event report is the summary section. See *Figure 10.10* for the locations of items included in a sample summary section of an event report. If you want to exclude the summary portion from an event report, use the **EVE NSUM** command.

Table 10.9 shows the order of valid reference quantities that the relay uses to display the angular relationship among the metering values. Notice that the SEL-487E does not adjust the angle of the current values for delta-connected CTs.

Table 10.9 Valid Reference Quantities (Sheet 1 of 2)

Reference Quantity	Source	Y-Connected	Delta-Connected
Fundamental voltage magnitude	PT V[a]	VAVFAC	VABVFAC
Fundamental voltage magnitude	PT Z[b]	VAZFAC	VABZFAC
Positive-sequence current	Winding S[c]	IASFAC	Not calculated
Positive-sequence current	Winding T[c]	IATFAC	Not calculated

Table 10.9 Valid Reference Quantities (Sheet 2 of 2)

Reference Quantity	Source	Y-Connected	Delta-Connected
Positive-sequence current	Winding U[c]	IAUFAC	Not calculated
Positive-sequence current	Winding W[c]	IAWFAC	Not calculated
Positive-sequence current	Winding X[c]	IAXFAC	Not calculated

[a] VAVFMC > 5 V
[b] VAZFMC > 5 V
[c] IAkFMC > 0.25 A (k = S, T, U, W, X)

For example, the A-phase voltage measured from the PT V voltage inputs is reference for all metering quantities provided this voltage magnitude is greater than 5 V. If PT V is not available, then the A-phase voltage measured from the PT Z voltage inputs is reference for all metering quantities provided this voltage magnitude is greater than 5 V. This sequence continues for all other reference quantities.

The information in the summary portion of the event report is the same information in the event summary, except that the report header does not appear immediately before the event information when you view a summary in the event report.

```
Event: TRIP                                                 Time Source: OTHER
Event Number: 10014                    Frequency: 60.003          Group: 1
Targets: TLED_13 TLED_20

Breaker S: OPEN

Fault Analog Data

         IAS    IBS    ICS    IAT    IBT    ICT    IAU    IBU    ICU
MAG(A)     426    426    426    428    428    427      0      0      0
ANG(DEG)  -1.0 -120.8  119.3  179.4   59.5  -60.5 -118.1  -90.9   29.7

         IAW    IBW    ICW    IAX    IBX    ICX    IY1    IY2    IY3
MAG(A)     426      1      0      0      0      0      0      0      0
ANG(DEG)  -0.9 -122.8 -152.1 -137.8 -118.8 -169.8 -143.6 -139.8 -138.1

         VAV    VBV    VCV    VAZ    VBZ    VCZ
MAG(kV)    134    134    134      0      0      0
ANG(DEG)   0.0 -119.9  120.3 -136.1 -112.0 -165.2

         IOPA   IRTA   IOPB   IRTB   IOPC   IRTC
MAG(p.u)  1.05   3.01   1.05   3.00   1.05   3.01
```

Event Information

Fault Data

Figure 10.10 Summary Section of the Event Report

Settings Section of the Event Report

The final portion of an event report is the settings section. See *Figure 10.11* for the locations of items included in a sample settings section of an event report. If you want to exclude the settings portion from an event report, use the **EVE NSET** command.

The settings portion of the event report lists important relay settings at the time the relay event triggered. The event report shows group, global, output, protection SELOGIC control equation settings and alias settings. For the group settings and the protection SELOGIC settings, the relay reports only the active group. The settings order in the event report is the same order as when you issue a **SHOW** command from a terminal.

```
Group 1

Relay Configuration

ECTTERM := "S,T"    EPTTERM := "V"      E87     := "S,T"    EREF    := N
E50     := OFF      E51     := N        E46     := OFF      E59     := N
E27     := N        E81     := N        E24     := Y        EBFL    := OFF
EPCAL   := OFF      EDEM    := N

Current Transformer Data

CTRS    := 100      CTCONS  := Y        CTRT    := 100      CTCONT  := Y


Potential Transformer Data

PTRV    := 2000     PTCONV  := Y        PTCOMPV := 0.00     VNOMV   := 110


Voltage Reference Terminal Selection

VREFS   := V        VREFT   := V

Differential Element Configuration and Data

E87TS   := 1
E87TT   := 1
ICOM    := Y        TSCTC   := 12       TTCTC   := 12       MVA     := 100
VTERMS  := 275.00   VTERMT  := 132.00   TAPS    := 2.10     TAPT    := 4.37
O87P    := 1.00     SLP1    := 35.00    SLP2    := 75.00    U87P    := 8.00
DIOPR   := 1.20     DIRTR   := 1.20     E87HB   := Y        E87HR   := Y
PCT2    := 15       PCT4    := 15       PCT5    := 35       TH5P    := OFF
87QP    := 0.10     SLPQ1   := 10       87QD    := 5.000

Volts per Hertz Element
.
.
.

Close Logic

CLS     := LB10
ULCLS   := 52CLS
CLT     := LB10
ULCLT   := 52CLT
CFD     := 4.00

Global

General Global Settings

SID     := "Station A"
RID     := "Relay 1"
NFREQ   := 60       PHROT   := ABC
```

Active Group Settings

```
Global Enables

EICIS   := N        EPMU    := N

Frequency Source Selection

FRQST   := V

Control Inputs

IN1XXD  := 2.0      IN2XXD  := 2.0      IN3XXD  := 2.0

Settings Group Selection

SS1     := PB3_PUL AND NOT SG1
SS2     := NA
SS3     := NA
SS4     := NA
SS5     := NA
SS6     := NA
TGR     := 180

Time and Date Management

DATE_F  := MDY      IRIGC   := NONE

Data Reset Control

RST_DEM := NA
RST_PDM := NA
RST_ENE := NA
RSTTRGT := NA
RSTDNPE := TRGTR
```

Global Settings

```
Output

Main Board

OUT101  := TRIPS OR PCT01Q
.
.
.

Interface Board #1

OUT201  := NA
.
.
.

Interface Board #2

OUT301  := NA
.
.
.
```

Output Settings

```
Mirrored Bits Transmit Equations

TMB1A   := NA
.
.
.
TMB8B   := NA
```

MIRRORED BITS Settings

```
Protection 1

1: # BREAKER S OPEN AND CLOSE CMD
.
.
.
```

Protection Logic Settings

```
Alias

Relay Aliases
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,"EN_RLY"
```

Alias Settings

Figure 10.11 Settings Section of the Event Report

CEVENT

The relay provides a Compressed ASCII event report for SCADA and other automation applications. ACSELERATOR QuickSet uses Compressed ASCII commands to gather event report data. If you want to view the Compressed ASCII event report data, use a terminal to issue ASCII command **CEV**. A sample of the report appears in *Figure 10.12*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII event report are similar to the event report, although the relay reports the items in a special order. CEV files (and COMTRADE files) include all eight Relay Word bits from each row of the Relay Word that has at least one element included in the event report digital elements setting. For the purpose of improving products and services, SEL sometimes changes the items and item order.

```
"FID","RID","SID","03E2"
"FID=SEL-487E-R100-V0-Z001001-D20080411","Relay 1","Station A","0F67"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","0C6A"
4,24,2008,2,33,7,340,103,"04BE"
"EVENT_NUM","FREQ","NFREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","SER_NUM","PRIM_
VAL","IAS","IBS","ICS","IAT","IBT","ICT","IAU","IBU","ICU","IAW","IBW","ICW","IA
X","IBX","ICX","IY1","IY2","IY3","VAV","VBV","VCV","VAZ","VBZ","VCZ","ERAQ01","E
RAQ02","ERAQ03","ERAQ04","ERAQ05","ERAQ06","ERAQ07","ERAQ08","ERAQ09","ERAQ10","
ERAQ11","ERAQ12","ERAQ13","ERAQ14","ERAQ15","ERAQ16","ERAQ17","ERAQ18","ERAQ19",
"ERAQ20","EVENT","TIME_SOURCE","FREQUENCY","GROUP","BKR_S","HOUR_T1","MIN_T1","S
EC_T1","MSEC_T1","HOUR_C1","MIN_C1","SEC_C1","MSEC_C1","BKR_T","HOUR_T2","MIN_T2
","SEC_T2","MSEC_T2","HOUR_C2","MIN_C2","SEC_C2","MSEC_C2","BKR_U","HOUR_T3","MI
N_T3","SEC_T3","MSEC_T3","HOUR_C3","MIN_C3","SEC_C3","MSEC_C3","BKR_W","HOUR_T4"
,"MIN_T4","SEC_T4","MSEC_T4","HOUR_C4","MIN_C4","SEC_C4","MSEC_C4","BKR_X","HOUR
_T5","MIN_T5","SEC_T5","MSEC_T5","HOUR_C5","MIN_C5","SEC_C5","MSEC_C5","T_LED1",
"T_LED2","TARGETS","IAS","IAS_DEG","IBS","IBS_DEG","ICS","ICS_DEG","IAT","IAT_DE
G","IBT","IBT_DEG","ICT","ICT_DEG","IAU","IAU_DEG","IBU","IBU_DEG","ICU","ICU_DE
G","IAW","IAW_DEG","IBW","IBW_DEG","ICW","ICW_DEG","IAX","IAX_DEG","IBX","IBX_DE
G","ICX","ICX_DEG","IY1","IY1_DEG","IY2","IY2_DEG","IY3","IY3_DEG","VAV","VAV_DE
G","VBV","VBV_DEG","VCV","VCV_DEG","VAZ","VAZ_DEG","VBZ","VBZ_DEG","VCZ","VCZ_DE
G","IOPA","IRTA","IOPB","IRTB","IOPC","IRTC","06D3"
10014,60.00,60,4,4,30,"0000000000","YES",100,100,100,100,100,100,100,100,100,100
,100,100,100,100,100,100,100,100,2000,2000,2000,2000,2000,2000," "," "," "," ","
 "," "," "," "," "," "," "," "," "," "," "," "," "," "," ","TRIP","OTHER",60
.003,1,"OPEN", , , , , , , , ,"OPEN", , , , , , , , ,"OPEN", , , , , , , , ,"OPE
N", , , , , , , , ,"OPEN", , , , , , , , ,2048,16,"TLED_13 TLED_20",426,-1.0,426
,-120.8,426,119.3,428,179.4,428,59.5,427,-60.5,0,-118.1,0,-90.9,0,29.7,426,-0.9,
1,-122.8,0,-152.1,0,-137.8,0,-118.8,0,-169.8,0,-143.6,0,-139.8,0,-138.1,134,0.0,
134,-119.9,134,120.3,0,-136.1,0,-112.0,0,-165.2,1.05,3.01,1.05,3.00,1.05,3.01,"7
4A4"
"IAS(A)","IBS(A)","ICS(A)","IAT(A)","IBT(A)","ICT(A)","IAU(A)","IBU(A)","ICU(A)"
,"IAW(A)","IBW(A)","ICW(A)","IAX(A)","IBX(A)","ICX(A)","IY1(A)","IY2(A)","IY3(A)
","VAV(kV)","VBV(kV)","VCV(kV)","VAZ(kV)","VBZ(kV)","VCZ(kV)","IOPA","IRTA","IOP
B","IRTB","IOPC","IRTC","IAH2","IBH2","ICH2","IAH4","IBH4","ICH4","IAH5","IBH5",
"ICH5","ANA01","ANA02","ANA03","ANA04","ANA05","ANA06","ANA07","ANA08","ANA09","
ANA10","ANA11","ANA12","ANA13","ANA14","ANA15","ANA16","ANA17","ANA18","ANA19","
ANA20","TRIG","TRPXFMR TRIPS TRIPT TRIPU TRIPW TRIPX 87RA 87RB 87RC 87Q REFF1 RE
FF2 REFF3 REFR1 REFR2 REFR3 VPOLV VPOLZ LOPV LOPZ SF32P SR32P SF32Q SR32Q SF32G
SR32G TF32P TR32P TF32Q TR32Q TF32G TR32G UF32P UR32P UF32Q UR32Q UF32G UR32G WF
32P WR32P WF32Q WR32Q WF32G WR32G XF32P XR32P XF32Q XR32Q XF32G XR32G FBFS FBFT
FBFU FBFW FBFX IN101 IN102 IN103 IN104 IN105 IN106 IN107 OUT101 OUT102 OUT103 OU
T104 OUT105 OUT106 OUT107 OUT108 RMB1A RMB2A RMB3A RMB4A RMB5A RMB6A RMB7A RMB8A
 TMB1A TMB2A TMB3A TMB4A TMB5A TMB6A TMB7A TMB8A ROKA RBADA CBADA LBOKA ANOKA DO
KA PSV01 PSV02 PSV03 PSV04 PSV05 PSV06 PSV07 PSV08 PLT01 PLT02 PLT03 PLT04 PLT05
 PLT06 PLT07 PLT08 PCT01Q PCT02Q PCT03Q PCT04Q PCT05Q PCT06Q PCT07Q PCT08Q CCS C
CT CCU CCW CCX OCS OCT OCU OCW OCX * *","20DA"
-10,-37,47,21,83,-104,0,0,0,-10,0,0,0,0,0,0,0,0,-24.4,-101.9,125.9,0.0,0.0,0.0,0
.02,0.49,0.02,0.49,0.01,0.49,0,0,0,0,0,0,0,0,0, , , , , , , , , , , , , , , ,
, , , , ,"E0000000000000000400000000000000","2436"
48,-33,-16,-108,72,36,0,0,0,48,0,0,0,0,0,0,0,0,131.6,-86.8,-45.5,0.0,0.0,0.0,0.0
2,0.49,0.02,0.49,0.01,0.49,0,0,0,0,0,0,0,0,0, , , , , , , , , , , , , , , , ,
, , , ,"E0000000000000000400000000000000","23F8"
10,37,-47,-21,-83,104,0,0,0,10,0,0,0,0,0,0,0,0,24.4,101.9,-125.9,0.0,0.0,0.0,0.0
2,0.49,0.02,0.49,0.01,0.49,0,0,0,0,0,0,0,0,0, , , , , , , , , , , , , , , , ,
, , , ,"E0000000000000000400000000000000","23DC"
```

Report Header

Summary Labels

Summary Data

Column Labels

Event Data

```
"SETTINGS","02E1"
"
Group 1

Relay Configuration

ECTTERM := S,T    EPTTERM := OFF      E87     := S,T    EREF    := N
E50     := OFF      E51     := N        E46     := OFF      EBFL    := OFF
EDEM    := N
.
.
.

Global

General Global Settings

SID     := Station A
RID     := Relay 1
NFREQ   := 60       PHROT   := ABC

.
.
.
```

Active Group Settings

Global Settings

```
Control Inputs

IN1XXD  := 2.0      IN2XXD  := 2.0      IN3XXD  := 2.0                    Control Inputs Settings

Settings Group Selection

SS1     := PB3_PUL AND NOT SG1                                            Settings Group Selection Settings
.
.
.
Time and Date Management

DATE_F  := MDY      IRIGC   := NONE                                       Time and Date Management Settings

Data Reset Control

RST_DEM := NA                                                             Data Reset Control Settings
.
.
.
Output

Main Board

OUT101  := TRIPS
OUT102  := TRIPT
.
.
.
Interface Board #1

OUT201  := NA                                                             Output Settings
.
.
.
Interface Board #2

OUT301  := NA
OUT302  := NA
.
.
.

Mirrored Bits Transmit Equations

TMB1A   := NA                                                             Mirrored Bits Settings
.
.
.
Protection 1

1: # BREAKER S OPEN AND CLOSE CMD                                         Active Protection Logic Settings
2: PCT01IN := PB1_PUL AND 52CLS #CMD TO OPEN BKR S
.
.
.
Alias

Relay Aliases                                                             Alias Settings
(RW Bit or Analog Qty. 7 Character Alias [0-9 A-Z _])

1: EN,EN_RLY
","2D56"
```

Figure 10.12 Sample Compressed ASCII Event Report

The order of the labels in the digital portion of the Column Labels field matches the order of the HEX-ASCII Relay Word. Each numeral in the HEXASCII Relay Word reflects the status of four Relay Word bits from the Digital Column Labels field of the Compressed ASCII event report. The HEX-ASCII Relay Word from the sample shown is the following:

```
"E000000000000000004000000000000000
```

In this HEX-ASCII Relay Word, the first numeral in the HEX-ASCII Relay Word is E. In binary, this is 1110. Mapping the labels to the digital Column Labels yields the following:

```
TRPXFMR  TRIPS    TRIPT    TRIP U
1        1        1        0
```

TRIPXFMR, TRIPS, and TRIPT are elements that picked up at the first sample.

Event Files Download

You can download the event file from the relay and save these files to a PC to keep as a record or examine later. Use a terminal emulation program with file transfer capability. For example, type **FILE READ EVENTS E4_10007.TXT <Enter>** at an Access Level 1 prompt or higher to download a 4-samples/cycle event report with serial number 10007. Start the terminal download routine to store the file on your computer. Use Ymodem protocol. If you want the Compressed ASCII file, type **FILE READ EVENTSC4_10007.TXT <Enter>**. In addition, you can use ACSELERATOR QuickSet to download event files.

Event Summary

You can retrieve a shortened version of stored event reports as event summaries. These short-form reports present vital information about a triggered event. The relay generates an event in response to power system faults and other trigger events (see *Triggering Data Captures and Event Reports*). See *Figure 10.13* for a sample event summary. The SEL-487E can be configured to automatically send an event summary—see *Automatic Messages on page 7.10*.

```
Relay 1                                      Date: 04/24/2008  Time: 08:15:52.452     Report Header
Station A                                    Serial Number: 2008030645

Event: TRIP                                                 Time Source: OTHER        Event Information
Event Number: 10015                   Frequency: 60.000           Group: 1
Targets: TLED_13 TLED_14 TLED_15

Breaker S: OPEN                                                                       Breaker Status

Fault Analog Data                                                                     Fault Data

         IAS    IBS    ICS    IAT    IBT    ICT    IAU    IBU    ICU
MAG(A)    629    629    629      0      0      0      0      0      0
ANG(DEG)  -16.1 -135.8  104.3  -75.9  136.1  161.7  -90.1  -51.3   93.8

         IAW    IBW    ICW    IAX    IBX    ICX    IY1    IY2    IY3
MAG(A)    630      0      0      0      0      0      1      0      0
ANG(DEG)  -15.9  -40.2  -63.6 -101.0 -109.8  -52.7  -74.2  -68.2  -97.0

         VAV    VBV    VCV    VAZ    VBZ    VCZ
MAG(kV)   126    126    126      0      0      0
ANG(DEG)    0.0 -119.9  120.3  -55.9  -52.0  -84.5

         IOPA   IRTA   IOPB   IRTB   IOPC   IRTC
MAG(p.u)  3.00   3.00   2.99   2.99   3.00   3.00
```

Figure 10.13 Sample Event Summary Report

The event summary contains the following information:

- Standard report header
  - Relay and terminal identification
  - Event date and time
- Event type
- Time source (HIRIG or OTHER)

- Event number
- System frequency
- Active group at trigger time
- Targets
- Circuit breaker trip and close times; and auxiliary contact(s) status
- Prefault and fault voltages, currents, and sequence current (from the event report row with the largest current)
- MIRRORED BITS® communications channel status (if enabled)

The relay derives the summary target information and circuit breaker trip and close times from the rising edge of relevant Relay Word bits during the event. If no trip or circuit breaker element asserted during the event, the relay uses the last row of the event.

The SEL-487E reports the event type according to the output of the fault location algorithm. *Table 10.10* lists event types in fault reporting priority. Differential and restricted earth-fault indications have reporting priority over indeterminate fault events. For example, you can trigger an event when there is no fault condition on the power system by using the **TRI** command. In this case, when there is no fault, the relay reports the event type as TRIG.

Table 10.10 Event Types

Event	Description
87RA, 87RB, 87RC, REF	Differential elements involvement for event reports generated by 87RA, 87RB, or 87RC. REF is the OR combination of REFF1, REFF2, and REFF3
TRIP	Rising edge of Relay Word bit TRIP
ER (event report trigger)	Rising edge of ER (SELOGIC control equation)
TRIG	Execution of the TRIGGER (**TRI**) command (manually triggered)

Viewing the Event Summary

Access the event summary from the communications ports and communications cards. View and download history reports from Access Level 1 and higher. You can independently acknowledge a summary (with the **SUM ACK** command) at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve a complete set of summary reports. To acknowledge and remove a summary, you must first use the **SUM N(EXT)** command to view that summary.

You can use the **SUM** command to retrieve event summaries by date or date range, and by event number. (The relay labels each new event with a unique number as reported in the **HIS** command history report; see *Event History*). *Table 10.11* lists the **SUM** commands. See *SUMMARY on page 13.48* for complete information on the **SUM** command.

Table 10.11 SUM Command (Sheet 1 of 2)

Command	Description
SUM	Return the most recent event summary (with header).
SUM *n*	Return a particular *n*[a] event summary (with header).

Table 10.11 SUM Command (Sheet 2 of 2)

Command	Description
SUM ACK	Acknowledge the event summary on the present communications port.
SUM N	View the oldest unacknowledged event summary (N = next).

[a] The parameter n indicates event order or serial number.

You can retrieve event summaries with ACSELERATOR QuickSet. The **Event Waveform View** > **Summary Data** menu item gives you summary information for each event you select in the **Event History** dialog box. Access the Relay Event History dialog box via the **Analysis** > **View Event Files** menu. See *Analyze Events on page 3.22* for information and examples.

CSUMMARY

The relay outputs a Compressed ASCII summary report for SCADA and other automation applications. Issue ASCII command CSU to view the Compressed ASCII summary report. A sample of the summary report appears in *Figure 10.14*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII summary report are similar to those included in the summary report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","FID=SEL-487E-R100-V0-Z001001-D20080407","0F68"
"EVENT_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT","TIME_
SOURCE","FREQUENCY","GROUP","BKR_S","HOUR_T1","MIN_T1","SEC_T1","MSEC_T1","HOUR_
C1","MIN_C1","SEC_C1","MSEC_C1","BKR_T","HOUR_T2","MIN_T2","SEC_T2","MSEC_T2","H
OUR_C2","MIN_C2","SEC_C2","MSEC_C2","BKR_U","HOUR_T3","MIN_T3","SEC_T3","MSEC_T3
","HOUR_C3","MIN_C3","SEC_C3","MSEC_C3","BKR_W","HOUR_T4","MIN_T4","SEC_T4","MSE
C_T4","HOUR_C4","MIN_C4","SEC_C4","MSEC_C4","BKR_X","HOUR_T5","MIN_T5","SEC_T5",
"MSEC_T5","HOUR_C5","MIN_C5","SEC_C5","MSEC_C5","T_LED1","T_LED2","TARGETS","IAS
","IAS_DEG","IBS","IBS_DEG","ICS","ICS_DEG","IAT","IAT_DEG","IBT","IBT_DEG","ICT
","ICT_DEG","IAU","IAU_DEG","IBU","IBU_DEG","ICU","ICU_DEG","IAW","IAW_DEG","IBW
","IBW_DEG","ICW","ICW_DEG","IAX","IAX_DEG","IBX","IBX_DEG","ICX","ICX_DEG","IY1
","IY1_DEG","IY2","IY2_DEG","IY3","IY3_DEG","VAV","VAV_DEG","VBV","VBV_DEG","VCV
","VCV_DEG","VAZ","VAZ_DEG","VBZ","VBZ_DEG","VCZ","VCZ_DEG","IOPA","IRTA","IOPB"
,"IRTB","IOPC","IRTC","EEA4"
10020,4,21,2008,2,3,38,102,182,"TRIP","OTHER",60.004,1,"CLOSED", , , , , , , , ,
"OPEN", , , , , , , , , ,"OPEN", , , , , , , , , ,"OPEN", , , , , , , , , ,"OPEN", , ,
 , , , , , ,1056,64,"TLED_3 TLED_14 TLED_18",0,102.7,0,39.8,0,44.2,0,41.4,0,163.
8,0,-177.5,0,33.8,0,87.3,0,-179.2,0,21.5,0,36.6,1,39.2,0,34.8,0,161.5,0,161.3,0,
35.3,0,47.6,0,-149.5,134,0.0,134,-119.9,134,120.3,80,0.1,80,-119.9,80,120.3,0.00
,0.00,0.00,0.00,0.00,0.00,"5151"
```

Report Header

Report Labels

Report Data

Figure 10.14 Sample Compressed ASCII Summary

Event History

The event history gives you a quick look at recent relay activity. The relay labels each new event with a unique number from 10000 to 42767. (At 42767, the top of the numbering range, the relay returns to 10000 for the next event number and then continues to increment.) See *Figure 10.15* for a sample event history.

The event history contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report

- Event number
- Event date and time
- Event type
- Maximum phase current from summary fault data
- Active group at the trigger instant
- Targets

```
=>>HIS <Enter>

Relay 1                                     Date: 05/01/2008  Time: 13:33:45.446
Station A                                   Serial Number: 2008004045

#        DATE         TIME         EVENT  GRP  TARGETS
10052 05/01/2008 13:31:56.835  TRIG    1
10051 04/30/2008 14:41:22.578  TRIP    1    TLED_4 TLED_14 TLED_23
10050 04/30/2008 14:21:40.909  TRIP    1    TLED_3 TLED_4 TLED_5 TLED_14
10049 04/30/2008 13:46:00.070  TRIP    1    TLED_4 TLED_5 TLED_14
10048 04/30/2008 13:45:47.322  TRIP    1    TLED_3 TLED_5 TLED_14
10047 04/30/2008 13:14:31.581  TRIP    1    TLED_3 TLED_4 TLED_14
10046 04/30/2008 13:08:34.195  TRIP    1    TLED_5 TLED_14
10045 04/30/2008 12:01:31.334  TRIP    1    TLED_3 TLED_4 TLED_14
10044 04/30/2008 11:59:06.446  TRIP    1    TLED_4 TLED_5 TLED_14
10043 04/30/2008 11:54:23.451  TRIP    1    TLED_4 TLED_5 TLED_14
10042 04/30/2008 11:29:43.809  TRIP    1    TLED_3 TLED_4 TLED_5 TLED_14
10041 04/30/2008 11:04:18.573  TRIP    1    TLED_3 TLED_4 TLED_5 TLED_14
10040 04/30/2008 11:00:10.292  TRIP    1    TLED_3 TLED_4 TLED_5 TLED_14
10039 04/30/2008 10:59:29.753  TRIP    1    TLED_3 TLED_4 TLED_5 TLED_14
```

Event Number
Event Type
Active Group
Targets

Figure 10.15 Sample Event History From a Terminal

The event types in the event history are the same as the event types in the event summary (see *Table 10.6* for event types). The event history report indicates events stored in relay nonvolatile memory. The relay places a blank row in the history report output; items that are above the blank row are available for viewing (use the **EVE** and **CEV** commands). Items that are below the blank row are no longer in relay memory; these events appear in the history report to indicate past power system performance.

The relay does not ordinarily modify the numerical or time order in the history report. However, if an event report is corrupted (power was lost during storage, for example), the relay lists the history report line for this event after the blank row.

Viewing the Event History

Access the history report from the communications ports and communications cards. View and download history reports from Access Level 1 and higher. You can also clear or reset history data from Access Levels 1 and higher. You can independently clear/reset history data at each communications port so that you and users at other ports (SCADA, Engineering, etc.) can retrieve complete history reports. You can also clear all history data from all ports (with the **HIS CA** and **HIS RA** commands).

Use the **HIS** command from a terminal to obtain the event history. You can view event histories by date or by date range, or you can specify the number of the most recent events that the relay returns.

Table 10.12 HIS Command

Command	Description
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *k*	Return the *k* most recent event summaries with the oldest at the bottom of the list and the most recent at the top of the list.
HIS *date1*	Return the event summaries on date *date1*[a].
HIS *date1 date2*	Return the event summaries from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.
HIS C	Clear all event data on the present port.
HIS R	Clear all event data on the present port.
HIS CA	Clear event data for all ports.
HIS RA	Clear event data for all ports.

[a] Use the same date format as Global setting DATE_F.

You can use ACSELERATOR QuickSet to retrieve the relay event history. Use the **Analysis** > **View Event History** menu to view the **Event History** dialog box.

```
=>>CHI <Enter>
"RID","SID","FID","03E2"
"Relay 1","Station A","FID=SEL-487E-X077-V0-Z001001-D20080424","0F6E"
"REC_NUM","REF_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","EVENT",
"GROUP","TARGETS","1818"
1,10052,5,1,2008,13,31,56,835,862,"TRIG",1," ","0917"
2,10051,4,30,2008,14,41,22,578,654,"TRIP",1,"TLED_4 TLED_14 TLED_23","0F05"
3,10050,4,30,2008,14,21,40,909,590,"TRIP",1,"TLED_3 TLED_4 TLED_5 TLED_14","10AB"
4,10049,4,30,2008,13,46,0,70,499,"TRIP",1,"TLED_4 TLED_5 TLED_14","0E78"
5,10048,4,30,2008,13,45,47,322,540,"TRIP",1,"TLED_3 TLED_5 TLED_14","0ED4"
6,10047,4,30,2008,13,14,31,581,724,"TRIP",1,"TLED_3 TLED_4 TLED_14","0ED3"
7,10046,4,30,2008,13,8,34,195,7,"TRIP",1,"TLED_5 TLED_14","0C6A"
8,10045,4,30,2008,12,1,31,334,993,"TRIP",1,"TLED_3 TLED_4 TLED_14","0EA2"
9,10044,4,30,2008,11,59,6,446,178,"TRIP",1,"TLED_4 TLED_5 TLED_14","0EB1"
10,10043,4,30,2008,11,54,23,451,916,"TRIP",1,"TLED_4 TLED_5 TLED_14","0EFE"
11,10042,4,30,2008,11,29,43,809,908,"TRIP",1,"TLED_3TLED_4TLED_5TLED_14","10E5"
12,10041,4,30,2008,11,4,18,573,69,"TRIP",1,"TLED_3 TLED_4 TLED_5 TLED_14","107C"
13,10040,4,30,2008,11,0,10,292,560,"TRIP",1,"TLED_3TLED_4TLED_5TLED_14","109A"
14,10039,4,30,2008,10,59,29,753,52,"TRIP",1,"TLED_3TLED_4TLED_5TLED_14","10B8"
15,10038,4,30,2008,9,51,13,421,801,"TRIP",1," ","094A"
16,10037,4,30,2008,9,50,29,758,760,"TRIP",1,"TLED_3TLED_4TLED_5TLED_14","10C2"
17,10036,4,30,2008,9,49,32,639,632,"TRIP",1," ","095F"
18,10035,4,30,2008,9,46,50,160,516,"TRIP",1,"TLED_3TLED_4TLED_5TLED_14","10B3"
19,10034,4,30,2008,8,28,25,352,909,"TRIP",1,"TLED_3TLED_4TLED_5TLED_14","10BD"
20,10033,4,30,2008,8,22,35,532,942,"TRIP",1,"TLED_3TLED_4TLED_5TLED_14","10AC"

=>>
```

Figure 10.16 Sample Compressed ASCII History Report

CHISTORY

The relay outputs a Compressed ASCII history report for SCADA and other automation applications. Issue the **CHI** command to view the Compressed ASCII history report. A sample of the report appears in *Figure 10.16*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of each history in the Compressed ASCII history report.

Items included in the Compressed ASCII history report are similar to those included in the history report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order.

History File Download

You can also download the history report file from the relay. Use a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher type **FILE READ REPORTS HISTORY.TXT <Enter>**. Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, type **FILE READ REPORTS CHISTORY.TXT <Enter>**. In addition, you can use ACSELERATOR QuickSet to download history files.

SER (Sequential Events Recorder)

The SEL-487E SER (Sequential Events Recorder) gives you detailed information on relay states and relay element operation. The SER captures and time-tagged state changes of Relay Word bit elements and relay conditions. These conditions include power-up, relay enable and disable, group changes, settings changes, memory overflow, diagnostic restarts, and SER autoremoval/ reinsertion. The SEL-487E stores the latest 1000 SER entries to nonvolatile memory. *Figure 10.17* is a sample SEL-487E SER report.

To capture the data of fast-changing inputs, the relay samples the inputs at a higher rate than the other digital points. The resolutions are as follows:

- Inputs—0.5 milliseconds
- Other points—1/8 cycle

The SER report contains the following:

- Standard report header
  - Relay and terminal identification
  - Date and time of report
- SER number
- SER date and time
- Relay element or condition
- Element state

```
Relay 1                                          Date: 03/16/2001  Time: 13:09:29.341
Station A                                        Serial Number: 2008030645
FID=SEL-487E-R100-V0-Z001001-D20080407

4     04/21/2008  03:33:51.6472  Power-up             Group 1
3     04/21/2008  03:33:51.6472  Relay                Enabled
2     04/21/2008  03:37:53.1588  50SP1                Asserted
1     04/21/2008  03:37:56.0552  50SP1                Deasserted
```

SER Number — Relay Element

Figure 10.17 Sample SER Report

In the SER report, the oldest information has the highest number. The newest information is always number one. When using a terminal you can order the positions of the SER records in the SER report (see *Table 10.13*).

SRATE (Sample Rate)

Use the SRATE setting to select the effective sampling rate, i.e., the number of data points the relay records per second. You can set SRATE to 8 kHz, 4 kHz, 2 kHz, and 1 kHz.

Setting	Description	Range	Default	Category
SRATE	Sample Rate of Event Report	1, 2, 4, 8 kHz	2	Report

LER (Length of Event Report)

Use the LER setting to select the overall length (in seconds) of the event report data capture; the PRE setting determines the time reserved in the LER period when the relay records pretrigger (prefault) data.

Setting	Description	Range	Default	Category
LER	Length of Event Report	0.25–4.00	0.5	Report

PRE (Length of Pre-Fault)

Set the portion (in seconds) of the total event report you want to allocate to pre-fault values. Typically, you set the PRE time to 20 percent of the total LER period.

Setting	Description	Range	Default	Category
PRE	Length of Pre-Fault	0.05–3.95	0.1	Report

ERAQ[c] (Analog Quantities)

To supplement the fixed analog quantities in the event report, select here as many as 20 additional analog quantities for inclusion in the event report.

In particular, use six of these fixed analog quantities to report IRTHR*n* (*n* = A, B, C), the harmonic-compensated differential restraint current, and IRTFK*n*, the biased differential restraint current (see *Figure 4.6* for more detail). To include these differential restraint currents in the event report, use the **SET R** command and set the relay as follows:

```
Event Reporting Analog Quantities
(Maximum 20 Analog Quantities)

1: IRTHRA
2: IRTHRB
3: IRTHRC
4: IRTFKA
5: IRTFKB
6: IRTFKC
```

The relay correlates the free-form line number chronologically with the ERAQ[*c*] quantities. In this example, ERAQ01 = IRTHRA, ERAQ02 = IRTHRB, etc.

Setting	Description	Range	Default	Category
ERAQ[*c*][a]	Free form	See *Appendix H*	NA	Report

[a] c = 01–20.

ERDG[d] (Digital Elements)

Enter up to 800 Relay Word bit (or reporting name) from a maximum of 100 rows (see Appendix G) to be included in the digital part of the event report. Although there is a total of 100 rows available, the following rows are already allocated: rows 1–3, rows 10–11, rows 312–314, and row 111.

Setting	Description	Range	Default	Category
ERDG[*d*][a]	Free form	See *Appendix G*	NA	Report

[a] d = 1–800.

You can use the # to add spaces between the elements, but it takes up one column in the report.The default values are as follows:

1: TRPXFMR	25: SF32P	49: WR32Q	73: #	97: TMB6A	121: PLT05
2: TRIPS	26: SR32P	50: WF32G	74: OUT101	98: TMB7A	122: PLT06
3: TRIPT	27: SF32Q	51: WR32G	75: OUT102	99: TMB8A	123: PLT07
4: TRIPU	28: SR32Q	52: #	76: OUT103	100: #	124: PLT08
5: TRIPW	29: SF32G	53: XF32P	77: OUT104	101: ROKA	125: #
6: TRIPX	30: SR32G	54: XR32P	78: OUT105	102: RBADA	126: PCT01Q
7: #	31: #	55: XF32Q	79: OUT106	103: CBADA	127: PCT02Q
8: 87A	32: TF32P	56: XR32Q	80: OUT107	104: LBOKA	128: PCT03Q
9: 87B	33: TR32P	57: XF32G	81: OUT108	105: ANOKA	129: PCT04Q
10: 87C	34: TF32Q	58: XR32G	82: #	106: DOKA	130: PCT05Q
11: 87Q	35: TR32Q	59: #	83: RMB1A	107: #	131: PCT06Q
12: #	36: TF32G	60: FBFS	84: RMB2A	108: PSV01	132: PCT07Q
13: REFF1	37: TR32G	61: FBFT	85: RMB3A	109: PSV02	133: PCT08Q
14: REFF2	38: #	62: FBFU	86: RMB4A	110: PSV03	134: #
15: REFF3	39: UF32P	63: FBFW	87: RMB5A	111: PSV04	135: CCS
16: REFR1	40: UR32P	64: FBFX	88: RMB6A	112: PSV05	136: CCT
17: REFR2	41: UF32Q	65: #	89: RMB7A	113: PSV06	137: CCU
18: REFR3	42: UR32Q	66: IN101	90: RMB8A	114: PSV07	138: CCW
19: #	43: UF32G	67: IN102	91: #	115: PSV08	139: CCX
20: VPOLV	44: UR32G	68: IN103	92: TMB1A	116: #	140: OCS
21: VPOLZ	45: #	69: IN104	93: TMB2A	117: PLT01	141: OCT
22: LOPV	46: WF32P	70: IN105	94: TMB3A	118: PLT02	142: OCU
23: LOPZ	47: WR32P	71: IN106	95: TMB4A	119: PLT03	143: OCW
24: #	48: WF32Q	72: IN107	96: TMB5A	120: PLT04	144: OCX

Viewing the SER Report

The relay displays the SER records in ASCII and binary formats. Access the SER report from the communications ports and communications cards in Access Level 1 and higher. You can independently clear/reset already viewed SER data at each communications port (with the **SER CV** or **SER RV** command) so that users at other ports (SCADA, Engineering, for example) can retrieve complete SER reports. The **SER CV** or **SER RV** command will not clear any SER data that has been recorded, but not viewed, on a particular serial port. To clear all SER data on a serial port, use the **SER C** or **SER R** command.

To clear all SER data from all serial ports, use the **SER CA** or **SER RA** command, available only from Access Levels P, A, O, and 2. This procedure would normally be used after relay commissioning or testing. Use an ASCII terminal or ACSELERATOR QuickSet to examine SER records. You can use the **SER** command to view the SER report by date, date range, SER number, or SER number range. The relay labels each new SER record with a unique number.

Table 10.13 SER Commands[a]

Command	Description
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *k*	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.
SER *m n*	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.
SER *date1*[b]	Return the SER records on date *date1*.
SER *date1 date2*	Return the SER records from *date1* at the top of the list to *date2* at the bottom of the list.
SER C and **SER R**	Clear SER records on the present port.
SER CA and **SER RA**	Clear SER data for all ports.
SER CV and **SER RV**	Clear viewed SER records on the present port.
SER D	List chattering SER elements that the relay is removing from the SER records.

[a] The parameters m and n indicate SER numbers that the relay assigns at each SER trigger.
[b] Use the same date format as Global setting DATE_F.

You can retrieve SER records with ACSELERATOR QuickSet. The **HMI > Meter and Control** menu item gives you the SER report. See *Viewing the SER Report* for information and examples. The latest 200 SER events are viewable on the front-panel display through the front-panel EVENTS menu (see *Section 8: Front-Panel Operations*).

CSER

The relay outputs a Compressed ASCII SER report for SCADA and other automation applications. Issue the **CSE** command to view the Compressed ASCII SER report. A sample of the SER report appears in *Figure 10.18*; this is a comma-delimited ASCII file. The relay appends a four-digit hex checksum at the end of the lines in the Compressed ASCII report.

Items included in the Compressed ASCII SER report are similar to the SER report, although the relay reports the items in a special order. For the purpose of improving products and services, SEL sometimes changes the items and item order. See *SEL Compressed ASCII Commands on page 7.7* and *CSER on page 13.13* for more information on the Compressed ASCII command set.

```
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-487E-R100-V0-Z001001-D20080407","0e58"
"#","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","USEC","ELEMENT","STATE","116
8"
1,4,21,2008,3,37,56,55,200,"50SP1","Deasserted","0B3F"
2,4,21,2008,3,37,53,158,800,"50SP1","Asserted","0AAE"
3,4,21,2008,3,33,51,647,200,"Relay","Enabled","0ADA"
4,4,21,2008,3,33,51,647,200,"Power-up","Group 1","0BB0"
```

Figure 10.18 Sample Compressed ASCII SER Report

SER File Download

You can also download the SER data as a file from the relay. Use a terminal emulation program with file transfer capability. At an Access Level 1 prompt or higher type **FILE READ REPORTS SER.TXT <Enter>**. Start the terminal download routine to store the file on your computer. If you want the Compressed ASCII file, type **FILE READ REPORTS CSER.TXT <Enter>**.

Setting SER Point

You program the relay elements that trigger an SER record. You can select as many as 250 elements. These triggers, or points, can include control input and control output state changes, element pickups and dropouts, and so on. You can also change the names of the elements and enter descriptive names for the element clear and set states. Use the **SET R** command from a terminal, or use ACSELERATOR QuickSet Report branch of the Settings tree view to enter **SER Points**.

Use the text-edit line mode settings method to enter or delete SER elements. To set an SER element, enter the five items of this comma-delimited string (all but the first parameter are optional):

> Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Names (Reporting, Set State, and Clear State) can contain any printable ASCII character. The relay defaults to the element name when you do not provide a reporting name. The default names for the set and clear states are Asserted and Deasserted, respectively. By default, SER Points are not configured for HMI alarm display. The relay always creates an SER record for power-up, relay enable and relay disable, any group change and settings change, diagnostic restart, and memory overflow.

Automatic Deletion and Reinsertion

The SER also includes an automatic deletion and reinsertion function. The relay automatically deletes oscillating SER items from SER recording. This function prevents overfilling the SER buffer with “chattering” information. Set Report setting ESERDEL (Enable SER Delete) to Y to enable this function, and select values for the setting SRDLCNT (SER Delete Count) and the setting SRDLTIM (SER Delete Time) that mask the chattering SER element. The relay removes an item from all SER recordings once a point has changed state more than SRDLCNT times in an SRDLTIM period. Once deleted from SER recording, the relay ignores the item for a 10 • SRDLTIM period. At the end of this period, the relay checks the chatter criteria and, if the point does not exceed the criteria, the relay automatically reinserts the item into SER recording. To see a list of deleted SER points, use the **SER D** command.

Setting Descriptions

Use the **SET R** (Report) ASCII command to set the report settings.

ESERDEL (Enable SER Delete)

Set Report setting ESERDEL (Enable SER Delete) to Y to enable the automatic deletion and reinsertion of oscillating SER items from the SER recording.

Setting	Description	Range	Default	Category
ESERDEL	Automatic removal of Chattering SER points	Y, N	N	Report

SRDLCNT (SER Delete Count)

After setting ESERDEL = Y, select values for setting SRDLCNT (SER Delete Count) and setting SRDLTIM (SER Delete Time). The relay removes an item from all SER recordings once the item has changed state more than SRDLCNT times in an SRDLTIM period.

Setting	Description	Range	Default	Category
SRDLCNT	Number of counts before removal	2–20	5	Report

SRDLTIM (SER Delete Time)

After setting ESERDEL and SRDLCNT, select a time period for SRDLTIM (SER Delete Time) in seconds. The relay removes an item from all SER recordings once the item has changed state more than SRDLCNT times in an SRDLTIM period.

Setting	Description	Range	Default	Category
SRDLTIM	Time for auto-removal	0.1–30.0	1	Report

SER Points (Enter SER Items)

Use the comma-delimited, composite setting, shown below and defined in *Table 10.14* to enter SER points:

Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm

Table 10.14 SER Point Settings

Description	Range
Relay Word Bit	Any valid relay element or the alias of any valid relay element
Reporting Name	20-character maximum ASCII string
Set State Name (logical 1)	20-character maximum ASCII string
Clear State Name (logical 0)	20-character maximum ASCII string
HMI Alarm	Y, N

Names can contain any valid ASCII character. Enclose the name within double quotation marks. For example, assume you have wired an auxiliary contact from the transformer cooling bank to Input IN101. When the cooling bank runs, the auxiliary contact closes and asserts Input IN101, and when the cooling bank has stopped, the auxiliary contact opens, and de-asserts Input IN101. Below is the SER entry for cooling bank point, and summarized in *Table 10.15*.

1: IN101,“ Bank 1 Cooling Fans ”,“Running”,“Stopped”,“Y”

Table 10.15 SER Example Settings

Description	Default	Setting (Example)	Comment
Relay Word Bit	NA	IN101	No quotation marks
Reporting Name	NA	Bank 1 Cooling Fans	Enclose within double quotation marks
Set State Name	Asserted	Running	Enclose within double quotation marks
Clear State Name	Deasserted	Stopped	Enclose within double quotation marks
HMI Alarm	N	Y	Enables front-panel Alarm point

If you enter a Relay Word bit that does not match a valid relay element, the relay displays: `Unknown relay word reference`. If you enter a reporting name that is too long, the relay displays: `Reporting Name label too long`. The relay displays alarm points in a similar fashion as the SER. Up to 19 characters of the given reporting name are displayed, with a character reserved for the “*.” The asterisk denotes if the element is asserted. Initially, an alarm point must be asserted in order to be displayed; after the corresponding element deasserts, the asterisk is removed, but the reporting name is not. The relay displays alarm points in reverse chronological order, just as in the SER, with the most recently asserted alarm displayed on the top. Deasserted alarms may be removed from the display with user acknowledgement.

Section 11
Synchrophasors

Overview

The SEL-487E Relay provides Phasor Measurement Unit (PMU) capabilities when connected to a suitable IRIG-B time source. Synchrophasor is used as a general term that can refer to data or protocols.

This section covers:

See *Appendix D: High-Accuracy Timekeeping* for the requirements of the IRIG-B time source. Synchrophasors are still measured if the high-accuracy time source is not connected, however, the data is not time-synchronized to any external reference, as indicated by Relay Word bit TSOK = logical 0.

Introduction

The word synchrophasor is derived from two words: synchronized phasor. Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule in multiple locations. A high-accuracy clock, commonly a Global Positioning System (GPS) receiver such as the SEL-2407® Satellite-Synchronized Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as a number of SEL-487E relays, to synchronize the gathering of power system data. The accurate clock allows precise event report triggering and other off-line analysis functions.

The SEL-487E Global settings class contains the synchrophasor settings, including the choice of synchrophasor protocol and the synchrophasor data set the relay will transmit. The Port settings class selects which serial port(s) are reserved for synchrophasor protocol use. See *Settings for Synchrophasors*.

The SEL-487E High-Accuracy Timekeeping function generates status Relay Word bits and time-quality information that is important for synchrophasor measurement. Some protection SELOGIC variables, and programmable digital trigger information (C37.118 protocol only) is also added to the Relay Word bits for synchrophasors—see *Synchrophasor Relay Word Bits*.

When synchrophasor measurement is enabled, the SEL-487E creates the synchrophasor data set at a rate of either 50 or 60 times per second, depending on the nominal system frequency (Global setting NFREQ). This data set, including time-of-sample, is available in Analog Quantities in the SEL-487E. See *Synchrophasor Analog Quantities*. You can view synchrophasor data over a serial port set to PROTO := SEL, see *View Synchrophasors by Using the MET PM Command*.

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. Two synchrophasor protocols are available in the SEL-487E that allow for a centralized device to collect data efficiently from several phasor measurement units (PMUs). Some possible uses of a system-wide synchrophasor system include the following:

- Power-system state measurement
- Wide-area network protection and control schemes
- Small-signal analysis
- Power-system disturbance analysis

The SEL-3306 Synchrophasor Processor is a PC-based communications processor specifically designed to interface with PMUs. The SEL-3306 has two primary functions. The first is to collect and correlate synchrophasor data from multiple PMUs. The second is to then compact and transmit synchrophasor data either to a data historian for post-analysis or to visualization software for real-time viewing of a power system.

The SEL-3378 Synchrophasor Vector Processor (SVP) is a real-time synchrophasor programmable logic controller. Use the SVP to collect synchrophasor messages from relays and phasor measurement units (PMUs). The SVP time-aligns incoming messages, processes these messages with an internal logic engine, and sends control command to external devices to perform user-defined actions. Additionally, the SVP can send calculated or derived data to devices such as other SVPs, phasor data concentrators (PDCs), and monitoring systems.

In any installation, the SEL-487E can transmit synchrophasors using only one of the synchrophasor message formats, SEL Fast Message Synchrophasor, or C37.118, as selected by Global setting MFRMT. However, the chosen format is available on multiple serial ports when port setting(s) PROTO := PMU and PMUMODE := SERVER.

With either the SEL Fast Message or C37.118 synchrophasor format, the SEL-487E can receive control operation commands over the same channel used for synchrophasor data transmission. These commands are SEL Fast Operate messages, which are described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 7.10*.

Recording Files

After enabling the data recording function with the Global EPMDR settings, record synchrophasor data using the PMTRIG setting. When PMTRIG asserts, the relay records synchrophasor data in binary format (IEEE C37.118 data format compliant) for the duration specified with the PMLER setting.

The relay stores these files in the synchrophasor subdirectory in the relay. Use FILE READ or FTP with the SEL-2702 to retrieve the stored data files.

Real-Time Control

You can configure the SEL-487E to receive C37.118 protocol synchrophasor data. The SEL-487E receives the data over a serial connection and stores these data in Analog Quantities. Time-alignment is automatic. Use the local phasor data and as many as two remote sets of phasor data in SELOGIC equations.

Figure 11.1 shows an application example. In this example, Area 2 supplies power to Area 1 and Area 3. An important contingency is loss of both Link 1 and Link 2. In such a case, the generators in Area 2 accelerate. Alternate paths between Area 2 and Area 1 can also become stressed beyond their design limits. A simple solution is to measure the phase angle between Area 1 and Area 2. When the angle exceeds a predetermined limit, control the generation to avoid exceeding system limits.

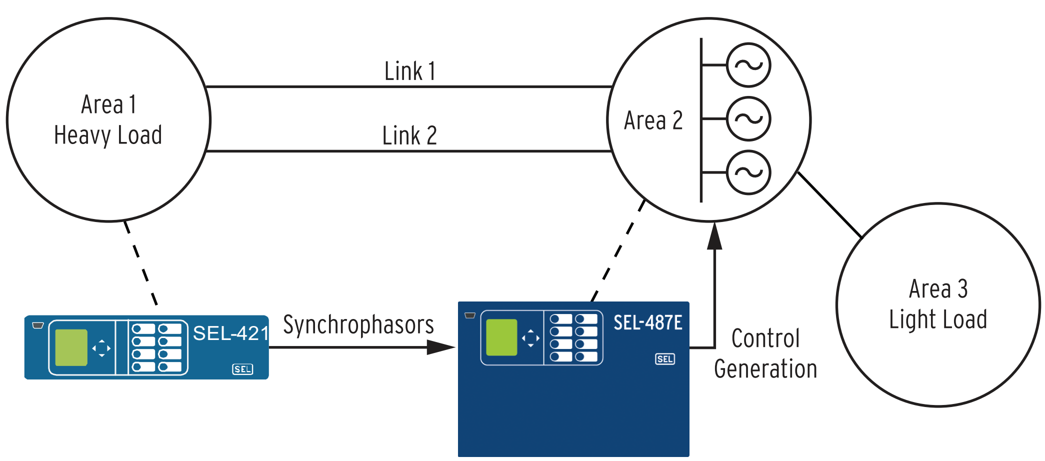

Figure 11.1 Real-Time Control Application

Figure 11.2 shows the SELOGIC for the relay controlling the generator (called the local relay in this example). Lines 1 and 2 store phasor data into PMV53 and PMV54 so they can be viewed through use of the **MET PMV** command.

Line 3 computes the angle difference between the local and remote relays. Lines 4 through 10 unwrap the phase angle when the difference exceeds ±180 degrees.

Line 11 calculates a qualification signal consisting of the local and remote quality indicators. RTCROKA is the local indicator. RTCAD16 is the remote quality indicator. *Figure 11.3* shows its construction at the remote relay.

Line 12 computes absolute value of the angle. Line 13 checks the angle against the reference value. In this case, the reference value is 6 degrees. Lines 14 and 15 build a timer that operates after two successive messages in excess of the threshold. On line 15, the value PSV05 tracks the last result of the angle difference check.

The final result, PSV04, asserts when the SEL-487E receives two successive synchrophasor messages with angle difference exceeding 6 degrees.

```
Protection 1
1: PMV53 := V1VPMAD
2: PMV54 := RTCAP02
3: PMV55 := V1VPMAD - RTCAP01
4: PSV01 := PMV55 >= 180.000000
5: PMV01 := -180.000000
6: PSV02 := PMV55 <= PMV01
7: PMV01 := PMV55 + 360.000000
8: PMV02 := PMV55 - 360.000000
9: PMV55 :=NOT PSV01*PMV55+PSV01*PMV02
10: PMV55 :=NOT PSV02*PMV55+PSV02*PMV01
11: PSV01 := RTCROKA AND RTCAD01
12: PMV56 := ABS(PMV55)
13: PSV03 :=(PMV56 > 10.000000) AND PSV01
14: PSV04 := PSV01 AND PSV03 AND PSV05
15: PSV05 := (NOT PSV01 AND PSV05 OR PSV01 AND PSV03)
```

Figure 11.2 Local Relay SELogic Settings

Figure 11.3 shows the SELogic settings for the remote relay. Set PSV64 to indicate that the sending data are correct. These data are sent with the synchrophasor data in the C37.118 data packet and are received by the local relay as RTCAD16. The RTCAD16 qualification on line 11 of the local relay (see *Figure 11.2*) contains this remote data quality indicator. A local relay quality indicator also qualifies line 11.

```
1: PSV64 := TSOK AND PMDOK
```

Figure 11.3 Remote Relay SELogic Settings

Set the remote relay global settings according to *Figure 11.4*. Set the number of digitals (NUMDSW) to one. In this case, the SEL-487E sends SELogic values PSV49 through PSV64 in the C37.118 data packet. This is how the remote TSOK AND PMDOK qualification maps to the local RTCAD16 Relay Word bit. Set the PMU application (PMAPP) to fast, because this is a protection application. Therefore, you must choose a filter for faster response. Also set the synchrophasor enable global setting to yes (EPMU = 'Y'). The MRTCDLY and RTCRATE settings are set but not used by the remote relay.

```
Synchronized Phasor Measurement Settings

MFRMT   := C37.118  MRATE   := 60       PMAPP   := F        PHCOMP  := Y
PMSTN   := "REMOTE RTC"
PMID    := 8
PHDATAV := V1       VCOMP   := 0.00     PHDATAI := NA       IWCOMP  := 0.00
IXCOMP  := 0.00     PHNR    := F        PHFMT   := P        FNR     := F
NUMANA  := 0        NUMDSW  := 1
TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
MRTCDLY := 500
RTCRATE := 2

Time and Date Management

IRIGC   := C37.118
```

Figure 11.4 Remote Relay Global Settings

Set the local relay global settings according to *Figure 11.5*. It is important for synchrophasors to be enabled (EPMU = 'Y'), the application to be fast (PMAPP = 'F'), the compensation settings to be set correctly (VCOMP, IWCOMP, and IXCOMP), and for IRIGC = C37.118.

Set MRTCDLY for the maximum expected communication channel delay in milliseconds. Any data arriving later than this time are rejected. The RTCDLYA Relay Word bit indicates this condition. Use the MRTCDLY to constrain the maximum longest operating time of the system. Set the RTCRATE to the rate of synchrophasor data being sent by remote relay. This is the MRATE setting on the remote relay.

The other Global settings are not relevant to this application.

```
Synchronized Phasor Measurement Settings

MFRMT   := C37.118  MRATE   := 2        PMAPP   := F        PHCOMP  := Y
PMSTN   := "LOCAL RTC"
PMID    := 4
PHVOLT  := “V”      PHDATAV := V1       PMFRQA  := S        VVCOMP  := 0.00
PHCURR  := “S”      PHDATAI := NA       ISCOMP  := 0.00     PHNR    := I
PHFMT   := R        FNR     := I        NUMANA  := 0        NUMDSW  := 1
TREA1   := NA
TREA2   := NA
TREA3   := NA
TREA4   := NA
PMTRIG  := NA
EPMDR   := N        RTCRATE := 60       MRTCDLY := 100

Time and Date Management

DATE_F  := MDY      IRIGC   := C37.118
```

Figure 11.5 Local Relay Global Settings

Set the Port settings for the port that sends the synchrophasor data on the remote relay, according to *Figure 11.6*.

```
Protocol Selection

PROTO   := PMU

Communications Settings

SPEED   := 57600    STOPBIT := 1        RTSCTS  := N

SEL Protocol Settings

FASTOP  := N

PMUMODE := SERVER
```

Figure 11.6 Remote Relay Port Settings

Set the port settings for the port that receives the synchrophasor data on the local relay, according to *Figure 11.7*. Notice that the RTCID setting must match the PMID setting of the remote relay.

```
Protocol Selection

PROTO   := PMU

Communications Settings

SPEED   := 57600    STOPBIT := 1        RTSCTS  := N

SEL Protocol Settings

FASTOP  := N

PMUMODE := CLIENTA
RTCID   := 8
```

Figure 11.7 Local Relay Port Settings

Several Relay Word bits are useful for monitoring system status. Add RTCCFGA and RTCDLYA to the SER.

The RTCCFGA Relay Word bit is asserted after the two relays have communicated configuration data successfully. RTCCFGA deassertion indicates that the system has changed, perhaps because of a setting change in one of the relays.

If the RTCCFGA Relay Word bit indicates a new configuration, you can issue the **RTC** command to ensure that the data being received have not changed. The **RTC** command displays a description of the synchrophasor data being received. Use this command to ensure that the remote value that you chose for the SELOGIC equation (for example, RTCAP01 in *Figure 11.2*) is the correct value to compare with the local synchrophasor value.

The RTCDLYA bit asserts when synchrophasor data have not been received within the window you set with the local MRTCDLY setting (100 ms in this example). If the RTCDLYA asserts, consider three options. First, the MRTCDLY setting can be increased. However, the MRTCDLY setting is your way of guaranteeing operation within a certain time. Increasing MRTCDLY allows for communication channels with longer transmission delay, but at the cost of increasing the maximum time of operation. A second option is to improve the communication channel so that it operates within the required MRTCDLY setting time. A final option is available if the assertion of MRTCDLY results from a temporary communication channel disruption. In this case, putting RTCDLYA in the SER provides warning.

The **COM RTC** command also provides information for monitoring system status. *Figure 11.8* shows a **COM RTC** command response. Use the maximum packet delay field to monitor the communication channel delay. This information can help you choose an appropriate value for the MRTCDLY setting.

```
Summary for RTC channel A
Port:              2
ID:                8
Present Status:    Receiving
Max Packet Delay:  50 msec
Message Rate:      60 msgs/sec

Summary for RTC channel B
Port:              1
ID:                9
Present Status:    Receiving
Max Packet Delay:  40 msec
Message Rate:      60 msgs/sec
```

Figure 11.8 Example COM RTC Command Response

Synchrophasor Measurement

NOTE: The synchophasor data stream is separate from the other protection and metering functions.

The phasor measurement unit in the SEL-487E measures eight three-phase signals on a constant-time basis. The three-phase signals can be any combination of voltage or current inputs available in the relay. The samples are synchronized to the high-accuracy IRIG time source, and occur at a fixed frequency of either 60 Hz or 50 Hz, depending on Global setting NFREQ. The relay then filters the measurement samples according to Global setting PMAPP := F or N—see *PMAPP*. The phase angle is measured relative to an absolute time reference, which is represented by a cosine function in *Figure 11.9*. The time-of-day is shown for the two time marks.

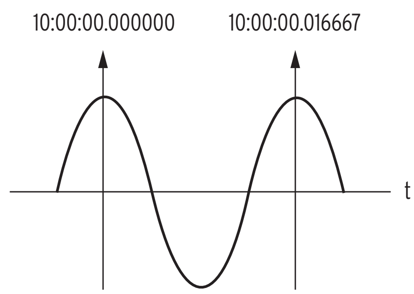

Figure 11.9 High-Accuracy Clock Controls Reference Signal (60 Hz System)

The instrumentation transformers (pts or cts) and the interconnecting cables may introduce a time shift in the measured signal. Global settings V*k*COMP (*k* = V, Z) and I*n*COMP (*n* = S, T, U, W, X), entered in degrees, are added to the measured phasor angles to create the corrected phasor angles, as shown in *Figure 11.10*, *Figure 11.11*, and *Equation 11.1*. The V*k*COMP and I*n*COMP settings may be positive or negative values.

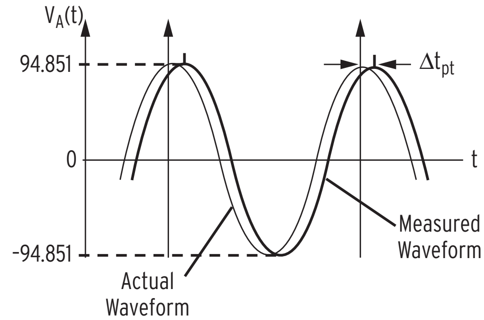

Figure 11.10 Waveform at Relay Terminals May Have a Phase Shift

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{\text{freq}_{\text{nominal}}}\right)} \bullet 360° = \Delta t_{pt} \bullet \text{freq}_{\text{nominal}} \bullet 360° \quad \textbf{Equation 11.1}$$

If the time shift on the pt measurement path Δt_{pt} = 0.784 ms and the nominal frequency, $\text{freq}_{\text{nominal}}$ = 60Hz, use *Equation 11.2* to obtain the correction angle:

$$0.784 \bullet 10^{-3}\text{s} \bullet 60\text{s}^{-1} \bullet 360° = 16.934° \quad \textbf{Equation 11.2}$$

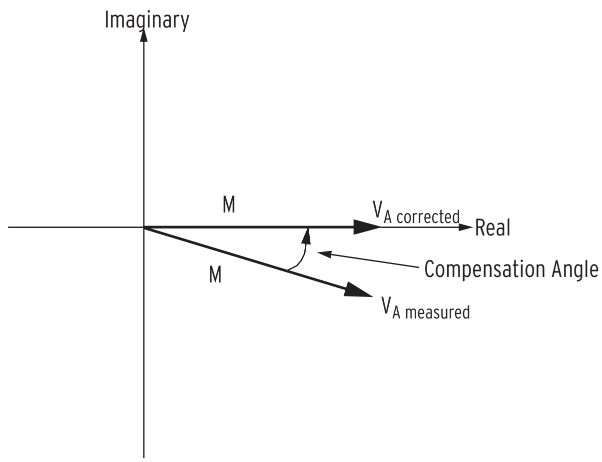

Figure 11.11 Correction of Measured Phase Angle

For a sinusoidal signal, the phasor magnitude is calculated as shown in *Equation 11.3*. The phasors are rms values scaled in primary units, as determined by Group settings PTRV or PTRZ (for the presently selected voltage source, V or Z, respectively), and CTR*n* (*n* = S, T, U, W, X, Y1).

$$\text{Magnitude M} = \frac{V_{pk}}{\sqrt{2}} \bullet \text{PTR}_{\text{setting}} \quad \textbf{Equation 11.3}$$

With PTRV = 2000, and the signal in *Figure 11.10* (with peak voltage V_{pk} = 94.851 V), use *Equation 11.4* to obtain the magnitude, VAVPMM:

$$\begin{aligned} \text{VAVPMM} &= \frac{94.851}{\sqrt{2}} \bullet 2000 \\ &= 134140 \text{ V} \\ &= 134.140 \text{ kV} \end{aligned}$$ **Equation 11.4**

Finally, the magnitude and angle pair for each synchrophasor is converted to a real and imaginary pair using *Equation 11.5* and *Equation 11.6*. For example, analog quantities VAVPMM and VAVPMA are converted to VAVPMI and VAVPMI. An example phasor with an angle measurement of 104.400° is shown in *Figure 11.12*.

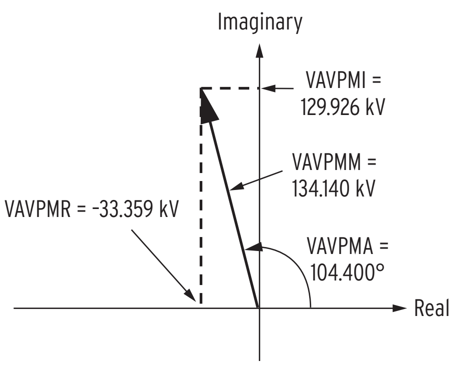

Figure 11.12 Example Calculation of Real and Imaginary Components of Synchrophasor

$$\text{Real part} = \text{M} \bullet \cos(\text{angle})$$ **Equation 11.5**

$$\text{Imaginary part} = \text{M} \bullet \sin(\text{angle})$$ **Equation 11.6**

Using the magnitude M from *Equation 11.4*, the real part is given in *Equation 11.7*.

$$\begin{aligned} \text{VAVPMR} &= 134.140 \text{ kV} \bullet \cos 104.400° \\ &= -33.359 \text{ kV} \end{aligned}$$ **Equation 11.7**

Similarly, the imaginary part is calculated in *Equation 11.8*

$$\begin{aligned} \text{VAVPMI} &= 134.140 \text{ kV} \bullet \sin 104.400° \\ &= 129.926 \text{ kV} \end{aligned}$$ **Equation 11.8**

Because the sampling reference is based on the GPS clock (IRIG-B signal) and not synchronized to the power system, an examination of successive synchrophasor data sets will almost always show some angular change between samples of the same signal. This is not a malfunction of the relay or the power system, but is merely a result of viewing data from one system with an instrument with an independent time base. In other words, a power system has a nominal frequency of either 50 or 60 Hz, but on closer examination, it is usually running a little faster or slower than the precise 50 or 60 Hz reference.

Accuracy

The listed SEL-487E phasor measurement accuracy is valid when frequency-based phasor compensation is enabled (Global setting PHCOMP := Y), and when the phasor measurement application setting is in the narrow bandwidth mode (Global setting PMAPP := N).

See IEEE C37.118 for an explanation of total vector error and for accuracy definitions and conditions.

NOTE: When the SEL-487E is in the fast response mode (Global setting PMAPP := F), the TVE is within specified limits only when the out of band interfering signals influence quantity is not included.

The SEL-487E synchrophasor measurement accuracy is:

TVE (total vector error) ≤1% for one or more of the following influence quantities:

- Signal Frequency Range: ±5 Hz of nominal (50 Hz or 60 Hz)
- Voltage Magnitude Range: 30 V – 150 V
- Current Magnitude Range: (0.1 – 2) • I_{nom}, (I_{nom} = 1 A or 5 A)
- Phase Angle Range: –179.99 to 180°
- Harmonic distortion ≤10% (any harmonic)
- Out of band interfering signals ≤ 10%

The out of band interfering signal frequency (f_i) must satisfy:

$| f_i – NFREQ | > MRATE/2$,

where NFREQ is nominal system frequency and MRATE is the message rate, as defined in IEEE C37.118.

Settings for Synchrophasors

The phasor measurement unit (PMU) settings are listed in *Table 11.1*. Make these settings when you want to use the C37.118 synchrophasor protocol, or if you want to use synchrophasor analog quantities.

All 24 channels are available for current and/or voltage collection from all five windings, both PTs, and the three neutral channels. From these 24 channels, the relay calculates up to 32 phasor values: three phase quantities and the positive-sequence value for the particular three phase quantities. Furthermore, at least one winding (group of three channels) must be a voltage winding (V or Z), and one other winding must be a current winding (S, T, U, W, X, Y). The remaining six windings can be any combination of voltage or current.

Because the Y-Winding consists of three single-phase channels, the following restrictions apply:

- The three Y-windings (IY1, IY2. and IY3) are not considered as individual windings, but considered as a single three-phase transformer winding.
- The nominal current (1 A or 5 A) of Winding IY1 applies to IY1, IY2, and IY3.
- The CT ratio of Winding IY1 applies to IY1, IY2, and IY3.
- IY1, IY2, and IY3 are all considered wye-connected.

The Global enable setting EPMU must be set to Y before the remaining SEL-487E synchrophasor settings are available. No synchrophasor data collection can take place when EPMU := N.

You must make the serial port settings in *Table 11.3* to transmit data with a synchrophasor protocol. It is possible to set EPMU := Y without using any serial ports for synchrophasor protocols. For example, the serial port **MET PM** ASCII command can still be used.

The global settings for the SEL Fast Message synchrophasor protocol are a subset of the *Table 11.1* settings, and are listed separately, see *SEL Fast Message Synchrophasor Protocol*.

Table 11.1 PMU Settings in the SEL-487E for C37.118 Protocol in Global Settings (Sheet 1 of 2)

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b]	C37.118
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, or 60)	2
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	STATION A
PMID	PMU Hardware ID (1–65534)	1
PHVOLT	Include Voltage Terminal[c]	V
PHDATAV	Phasor Data Set, Voltages (V1, PH, ALL, NA)	V1
PMFRQST	PMU Primary Frequency Source Terminal (V, Z)	V
PMFRQA	Frequency Application (F = Fast, S = Smooth)	S
V[*k*]COMP[d]	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHCURR[e]	Current Source[f]	S
PHDATAI	Phasor Data Set, Currents (I1, PH, ALL, NA)	NA
I[*n*]COMP[g]	Current Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHNR[h]	Phasor Numeric Representation (I = Integer, F = Floating point)	I
PHFMT[h]	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMANA	Number of Analog Values (0–32)	0
NUMDSW	Number of 16-bit Digital Status Words (0, 1, 2, 3, 4)	1
TREA1	Trigger Reason Bit 1 (SELOGIC Control Equation)	NA
TREA2	Trigger Reason Bit 2 (SELOGIC Control Equation)	NA
TREA3	Trigger Reason Bit 3 (SELOGIC Control Equation)	NA
TREA4	Trigger Reason Bit 4 (SELOGIC Control Equation)	NA
PMTRIG	Trigger (SELOGIC Control Equation)	NA
EPMDR	Enable PMU Data Recording (Y,N)	N
CONAM	Company Name (3 characters)	abc
PMLER	Length of PMU Triggered Data (2–60 sec)	30
PMPRE	Length of PMU Pre-Triggered Data (1–20 sec)	5

Table 11.1 PMU Settings in the SEL-487E for C37.118 Protocol in Global Settings (Sheet 2 of 2)

Setting	Description	Default
RTCRATE	Remote Messages per Second (1, 2, 5, 10, or 50 when NFREQ := 50) (1, 2, 4, 5, 10, 12, 15, 20, 30, or 60 when NFREQ := 60)	2
MRTCDLY	Maximum RTC Synchrophasor Packet Delay (20–10000 ms)	500

[a] Set EPMU := Y to access the remaining settings.
[b] C37.118 = IEEE C37.118 Standard; FM := SEL Fast Message—see Table 11.20.
[c] Any combination of V, Z.
[d] k = V, Z.
[e] Setting hidden when PHDATAI := NA.
[f] Any combination of S, T, U, W, X, Y.
[g] n = S, T, U, W, X, Y.
[h] Setting hidden when PHDATAV := NA and PHDATAI := NA.

Table 11.2 Time and Date Management

Label	Prompt	Default
IRIGC[a]	IRIG-B Control Bits Definition (None, C37.118)	None

[a] When MFRMT := C37.118, IRIGC is forced to C37.118.

Certain settings in *Table 11.1* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the PHCURR setting is hidden to limit the number of settings for your synchrophasor application.

The Port settings for PROTO := PMU, shown in *Table 11.3*, do not include the settings DATABIT and PARITY; these two settings are internally fixed as DATABIT := 8, PARITY := N (None).

Table 11.3 SEL-487E Serial Port Settings for Synchrophasors

Setting	Description	Default
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)[a, b]	SEL[c]
SPEED	Data Speed (300 to 57600)	9600
STOPBIT	Stop Bits (1, 2)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Enable Fast Operate Messages (Y, N)	N
PMUMODE[c]	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER
RTCID[d]	Remote PMU Hardware ID (1–65534)	1

[a] Some of the other PROTO setting choices may not be available.
[b] Setting choice PMU is not available on PORT 5.
[c] Set PROTO := PMU and PMUMODE := SERVER to enable (on this port) the synchrophasor protocol selected by Global setting MFRMT.
[d] Setting hidden when PMUMODE := SERVER.

PROTO := PMU Does Not Allow Commands on That Serial Port

The PROTO := PMU settings choice in *Table 11.3* can be made even when Global setting EPMU := N. However, in this situation, the serial port will not respond to any commands or requests. Either enable synchrophasors by making the *Table 11.1* settings, or change the port PROTO setting to SEL.

If you use a computer terminal session or ACSELERATOR QuickSet® SEL-5030 Software connected to a serial port, and then set that same serial port PROTO setting to PMU, you will lose the ability to communicate with the relay through ASCII commands or virtual file interface commands. If this happens, either connect via another serial port (that has PROTO := SEL) or use the front-panel HMI SET/SHOW screen to change the disabled port PROTO setting back to SEL.

Table 11.4 SEL-487E Ethernet Port Settings for Synchrophasors

Setting	Description	Default
EPMIP	Enable PMU Processing (Y,N)	N
PMOTS1	PMU Output 1 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMOIPA1	PMU Output 1 Client IP (Remote) Address (www.xxx.yyy.zzz)	OFF
PMOTCP1	PMU Output 1TCP/IP (Local) Port Number (1–65534)	4712
PMOUDP1	PMU Output 1 UDP/IP Data (Remote) Port Number (1–65534)	4713
PMOTS2	PMU Output 2 Transport Scheme (OFF, TCP, UDP_S, UDP_T, UDP_U)	OFF
PMOIPA2	PMU Output 2 Client IP (Remote) Address (www.xxx.yyy.zzz)	OFF
PMOTCP2	PMU Output 2 TCP/IP (Local) Port Number (1–65534)	4722
PMOUDP2	PMU Output 2 UDP/IP Data (Remote) Port Number (1–65534)	4713

Descriptions of Synchrophasor Settings

Definitions for some of the settings in *Table 11.1* and *Table 11.3* are as follows:

MFRMT

Selects the message format for synchrophasor data streaming on serial ports.

SEL recommends the use of MFRMT := C37.118 for any new PMU applications because of increased setting flexibility and the expected availability of software for synchrophasor processors. The SEL-487E still includes the MFRMT := FM setting choice to maintain compatibility in any systems presently using SEL Fast Message synchrophasors.

MRATE

Selects the message rate in messages per second for synchrophasor data streaming on serial ports.

Choose the MRATE setting that suits the needs of your PMU application. This setting is one of ten settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size. See *Communications Bandwidth on page 11.27* for detailed information.

PMAPP

Selects the type of digital filters used in the synchrophasor algorithm:

- The Narrow Bandwidth setting (N) represents filters with a cutoff frequency approximately ¼ of MRATE. The response in the frequency domain is narrower, and response in the time domain is slower. This method results in synchrophasor data that are free of aliasing signals and well suited for post-disturbance analysis.
- The Fast Response setting (F) represents filters with a higher cutoff frequency. The response in the frequency domain is wider and the response in the time domain is faster. This method results in synchrophasor data that can be used in synchrophasor applications requiring more speed in tracing system parameters.

PHCOMP

Enables or disables frequency-based compensation for synchrophasors.

For most applications, set PHCOMP := Y to activate the algorithm that compensates for the magnitude and angle errors of synchrophasors for frequencies that are off nominal. Use PHCOMP := N if you are concentrating the SEL-487E synchrophasor data with other PMU data that do not employ frequency compensation.

PMSTN and PMID

Defines the name and number of the PMU.

NOTE: The PMSTN setting is not the same as the SEL-487E Global setting SID (Station Identifier), even though they share the same factory default value.

The PMSTN setting is an ASCII string with as many as 16 characters. The PMID setting is a numeric value. Use your utility or synchrophasor data concentrator naming convention to determine these settings.

PHVOLT, PHDATAV, and V[k]COMP

PHDATAV and PHVOLT select which voltage synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. These are two of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth* for detailed information.

- PHDATAV := V1 will transmit only positive-sequence voltage, V_1
- PHDATAV = PH will transmit phase voltages only (V_A, V_B, V_C)
- PHDATAV := ALL will transmit V_1, V_A, V_B, and V_C
- PHDATAV := NA will not transmit any voltages

PHVOLT selects the voltage sources for the synchrophasor data selected by PHDATAV.

- PHVOLT := V uses the voltage measured on the Va, Vb, Vc inputs
- PHVOLT := Z uses the voltage measured on the Za, Zb, Zc inputs
- PHVOLT := V, Z uses the voltage measured on the V and Z three-phase voltage inputs to the relay

Table 11.5 describes the order of synchrophasors inside the data packet.

The V[*k*]COMP (*k* = any combination of V, Z voltage terminals) setting allows correction for any steady-state voltage phase errors (from the potential transformers or wiring characteristics). See *Synchrophasor Measurement* for details on this setting.

PHCURR, PHDATAI, and I[n]COMP

PHDATAI and PHCURR select which current synchrophasors to include in the data packet. Consider the burden on your synchrophasor processor and offline storage requirements when deciding how much data to transmit. These settings are two of the eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth* for detailed information.

- PHDATAI := I1 will transmit only positive-sequence current, I_1
- PHDATAI := PH transmits phase currents (I_A, I_B, I_C)
- PHDATAI := ALL will transmit I_1, I_A, I_B, and I_C
- PHDATAI := NA will not transmit any currents

PHCURR selects the source current(s) for the synchrophasor data selected by PHDATAI. Use the PHCURR setting to select any combination of current Terminals S, T, U, W, X, and Y. For example:

- PHCURR := S uses the currents measured on the S terminal current inputs (IAS, IBS, ICS)
- PHCURR := S, T, U uses the currents measured on the S, T, U terminal current inputs (IAS, IBS, ICS, IAT, IBT, ICT, IAU, IBU, ICU)

Table 11.5 describes the order of synchrophasors inside the data packet.

The I[*n*]COMP (*n*= any combination of S, T, U, W, X, Y current terminals) settings allow correction for any steady-state phase errors (from the current transformers or wiring characteristics). See *Synchrophasor Measurement* for details on these settings.

Table 11.5 Synchrophasor Order in Data Stream (Voltages and Currents)

Synchrophasors[a] (Analog Quantity Names)				Included When Global Settings are as follows:
Polar[b]		Rectangular[c]		
Magnitude	Angle	Real	Imaginary	
V1*m*PMM[d]	V1*m*PMA	V1*m*PMR	V1*m*PMI	PHDATAV := V1 or ALL
VA*m*PMM	VA*m*PMA	VA*m*PMR	VA*m*PMI	PHDATAV := PH or ALL
VB*m*PMM	VB*m*PMA	VB*m*PMR	VB*m*PMI	
VC*m*PMM	VC*m*PMA	VC*m*PMR	VC*m*PMI	
I1*n*PMM[e]	I1*n*PMA	I1*n*PMR	I1*n*PMI	PHDATAI := I1 or ALL
IA*n*PMM	IA*n*PMA	IA*n*PMR	IA*n*PMI	PHDATAI := PH or ALL
IB*n*PMM	IB*n*PMA	IB*n*PMR	IB*n*PMI	
IC*n*PMM	IC*n*PMA	IC*n*PMR	IC*n*PMI	

[a] Synchrophasors are included in the order shown (i.e., voltages, if selected, will always precede currents).
[b] Polar coordinate values are sent when PHFMT := P.
[c] Rectangular (real and imaginary) values are sent when PHFMT := R.
[d] Where:
m = V if PHVOLT includes V
m= Z if PHVOLT includes Z
[e] Where:
n = S if PHCURR includes S
n = T if PHCURR includes T
n = U if PHCURR includes U
n = W if PHCURR includes W
n = X if PHCURR includes X
n = Y if PHCURR includes Y

PMFRQST

Selects the voltage terminal (V or Z) that will be the primary source of the system frequency for the PMU calculations. For example, if PMFRQST = V, then the V PT terminal is primary source, and the Z PT becomes the secondary PT. You do not have to set the Z PT as secondary source; by setting V as primary source, Z becomes the secondary frequency source. If the primary frequency source falls away, then the relay automatically switches to the secondary frequency source and continues with the calculations. When the primary frequency source is restored, the relay automatically switches back to the primary source.

PMFRQA

Selects the PMU frequency application. A setting of S sets a smooth frequency application. A setting of F selects a fast frequency application.

The frequency application is used in the calculation of the rate of change of frequency for a given analog signal. A smooth frequency application setting (PMFRQA = S) uses 9 cycles of data for the rate of change calculation. A fast frequency application setting (PMFRQS = F) uses 3 cycles of data for the rate of change calculation.

The Fast frequency application will detect rapid changes in frequency faster, but will also contain more low level oscillations. The Slow frequency application will provide a rate of change profile that is smoother, but slower to respond to rapid frequency fluctuations.

PHNR

Selects the numeric representation of voltage and current phasor data in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth* for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHNR := I sends each voltage and/or current synchrophasor as 2 two-byte integer values. In this representation, synchrophasor current measurements have an upper limit of $7 \cdot I_{nom}$, where $I_{nom} = 1$ A or 5 A, depending on the current input rating—see *Secondary Circuits on page 2.4*.

Setting PHNR := F sends each voltage and/or current synchrophasor as 2 four-byte floating-point values.

The PHFMT setting determines the format of the data.

PHFMT

Selects the phasor representation of voltage and current phasor data in the synchrophasor data stream.

The choices for this setting depend on synchrophasor processor requirements.

Setting PHFMT := R (rectangular) sends each voltage and/or current synchrophasor as a pair of signed real and imaginary values.

Setting PHFMT := P (polar) sends each voltage and/or current synchrophasor as a magnitude and angle pair. The angle is in radians when PHNR := F, and in radians • 10^4 when PHNR := I. The range is as follows:

$$-\pi < \text{angle} \le \pi.$$

In both the rectangular and polar representations, the values are scaled in rms (root mean square) units. For example, a synchrophasor with a magnitude of 1.0 at an angle of –30 degrees will have a real component of 0.866, and an imaginary component of –0.500. See *Synchrophasor Measurement* for a sample conversion between polar and rectangular coordinates.

FNR

Selects the numeric representation of the two frequency values in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth* for detailed information.

The choices for this setting depend on synchrophasor processor requirements.

Setting FNR := I sends the frequency data as a difference from nominal frequency, NFREQ, with the following formula:

$$(FREQ_{measured} - NFREQ) \cdot 1000,$$

represented as a signed, two-byte value.

Setting FNR := I also sends the rate-of-change of frequency data with scaling.

$$DFDT_{measured} \cdot 100,$$

represented as a signed, two-byte value.

Setting FNR := F sends the measured frequency data and rate-of-change-of-frequency as two four-byte, floating point values.

NUMANA

Selects the number of user-definable analog values to be included in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth* for detailed information.

The choices for this setting depend on the synchrophasor system design.

Setting NUMANA := 0 sends no user-definable analog values.

Setting NUMANA := 1–16 sends the user-definable analog values, as listed in *Table 11.6*.

The format of the user-defined analog data is always floating point, and each value occupies four bytes.

Table 11.6 User-Defined Analog Values Selected by the NUMANA Setting

NUMANA Setting	Analog Quantities Sent	Total Number of Bytes Used for Analog Values
0	None	0
1	PMV64	4
2	Above, plus PMV63	8
3	Above, plus PMV62	12
4	Above, plus PMV61	16
5	Above, plus PMV60	20
6	Above, plus PMV59	24
7	Above, plus PMV58	28
8	Above, plus PMV57	32
9	Above, plus PMV56	36
10	Above, plus PMV55	40
11	Above, plus PMV54	44
12	Above, plus PMV53	48
13	Above, plus PMV52	52
14	Above, plus PMV51	56
15	Above, plus PMV50	60
16	Above, plus PMV49	64

NUMDSW

Selects the number of user-definable digital status words to be included in the synchrophasor data stream.

This setting is one of eight settings that determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Communications Bandwidth* for detailed information.

The choices for this setting depend on the synchrophasor system design. The inclusion of binary data can help indicate breaker status or other operational data to the synchrophasor processor. See *PMU Setting Example* for a suggested use of the digital status word fields.

Setting NUMDSW := 0 sends no user-definable binary status words.

Setting NUMDSW := 1, 2, 3, or 4 sends the user-definable binary status words, as listed in *Table 11.7*.

Table 11.7 User-Defined Digital Status Words Selected by the NUMDSW Setting

NUMDSW Setting	Digital Status Words Sent	Total Number of Bytes Used for Digital Values
0	None	0
1	[PSV64, PSV63 … PSV49]	2
2	[PSV64, PSV63 … PSV49] [PSV48, PSV47 … PSV33]	4
3	[PSV64,PSV63 … PSV49] [PSV48,PSV47 … PSV33] [PSV32,PSV31 … PSV17]	6
4	[PSV64,PSV63 … PSV49] [PSV48,PSV47 … PSV33] [PSV32,PSV31 … PSV17] [PSV16,PSV15 … PSV01]	8

TREA1, TREA2, TREA3, TREA4, and PMTRIG

NOTE: The PM Trigger function is not associated with the SEL-487E Event Report Trigger ER, a SELOGIC control equation in the Group settings class.

NOTE: Select PMTRIG trigger conditions to assert PMTRIG only once during a four-hour period.

Defines the programmable trigger bits as allowed by IEEE C37.118.

Each of the four Trigger Reason settings, TREA1–TREA4, and the PMU Trigger setting, PMTRIG, are SELOGIC control equations in the Global settings class. The SEL-487E evaluates these equations and places the results in Relay Word bits with the same names: TREA1–TREA4, and PMTRIG.

The trigger reason equations represent the Trigger Reason bits in the STAT field of the data packet. After the trigger reason bits are set to convey a message, the PMTRIG Equation should be asserted for a reasonable amount of time, to allow the synchrophasor processor to read the TREA1–TREA4 fields.

The IEEE C37.118 standard defines the first eight of 16 binary combinations of these trigger reason bits (bits 0–3).

The remaining eight binary combinations are available for user definition.

Table 11.8 PM Trigger Reason Bits—IEEE C37.118 Assignments (Sheet 1 of 2)

TREA4	TREA3	TREA2	TREA1		Meaning[a]
(bit 3)	(bit 2)	(bit 1)	(bit 0)	Hexadecimal	
0	0	0	0	0x00	Manual
0	0	0	1	0x01	Magnitude Low
0	0	1	0	0x02	Magnitude High
0	0	1	1	0x03	Phase Angle Diff.
0	1	0	0	0x04	Frequency High/Low
0	1	0	1	0x05	df/dt High

Table 11.8 PM Trigger Reason Bits—IEEE C37.118 Assignments (Sheet 2 of 2)

TREA4	TREA3	TREA2	TREA1		Meaning[a]
(bit 3)	(bit 2)	(bit 1)	(bit 0)	Hexadecimal	
0	1	1	0	0x06	Reserved
0	1	1	1	0x07	Digital
1	0	0	0	0x08	User
1	0	0	1	0x09	User
1	0	1	0	0x0A	User
1	0	1	1	0x0B	User
1	1	0	0	0x0C	User
1	1	0	1	0x0D	User
1	1	1	0	0x0E	User
1	1	1	1	0x0F	User

[a] When PMTRIG is asserted. The terminology comes from IEEE C37.118.

The SEL-487E does not automatically set the TREA1–TREA4 or PMTRIG Relay Word bits—these bits must be programmed.

These bits may be used to send various messages at a low bandwidth via the synchrophasor message stream. Digital Status Words may also be used to send binary information directly, without the need to manage the coding of the trigger reason messages in SELOGIC.

Use these Trigger Reason bits if your synchrophasor system design requires these bits. The SEL-487E synchrophasor processing and protocol transmission are not affected by the status of these bits.

EPMDR

Use the EPMDR setting to enable phasor measurement unit (PMU) data recording. When EPMDR = Y, phasor measurement data recording will begin on the rising edge of PMTRIG. Any subsequent PMTRIG assertions during the allotted recording period (PMLER) will not result in another PMU data recording being started. The relay will store synchrophasor measurement data as a C37.118 binary format file that can be retrieved from the relay using File Transfer Protocol. Synchrophasor Data is recorded into a file with extension *.PMU.

CONAM

The CONAM setting provides a means for inserting a text field into the captured phasor file name. The CONAM setting is three characters long. The settings allows all printable characters except “ / \ < > * | : ; [ ] $ % { }. The name of the *.PMU file will be as follows:

yymmdd,hhmmss,0,aaa,bbbb,ccc.PMU

where *ccc* is the CONAM setting.

PMLER

PMLER sets the total length of the phasor measurement recording, in seconds. The PMLER time includes the PMPRE time. For example, if PMLER is set for 30 seconds of PMU recorded data, and PMPRE is set for 10 seconds of pre-trigger data, the final recording will contain 10 seconds of pre-trigger data and 20 seconds of triggered data for a total report time of 30 seconds.

PMPRE

The PMPRE setting sets the length of the pre-trigger data within the phasor measurement recording. The PMPRE data begins at the PMTRIG point of the recording, and extends back in time (previous time to the trigger event) for the designated amount of time.

MRTCDLY

Selects the maximum acceptable delay for received synchrophasor messages.

NOTE: The maximum channel delay is available in the **COM RTC** command.

When the SEL-487E is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), it only accepts incoming messages that are not older than allowed by this setting. When determining an appropriate value for this setting, consider the channel delay, the transfer time at the selected baud rate, plus add some margin for internal delays in both the remote and local relay.

RTCRATE

Rate at which to expect messages from the remote synchrophasor device.

When the SEL-487E is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), the relay will only accept incoming messages at this rate. Make sure the remote synchrophasor source(s) is configured to send messages at this same rate.

PMUMODE

Selects whether the port is operating as a synchrophasor server (source of data) or a client (consumer of data).

When the port is intended to be a source of synchrophasor data, set this setting to SERVER. The Global setting MFRMT determines the format of the transmitted data.

When using the port to receive synchrophasor data from another device, set this setting to either CLIENTA or CLIENTB. Only two ports may be configured as client ports and they must be uniquely configured for channel A or channel B. When a port is configured to receive synchrophasor data, the port will only receive data using the C37.118 format, regardless of the MFRMT setting.

RTCID

Expected synchrophasor ID from remote relay.

When the SEL-487E is operating as a synchrophasor client (PMUMODE set to CLIENTA or CLIENTB), it will only accept incoming messages that contain this ID. Make sure this ID matches the ID configured in the remote relay.

Synchrophasor Relay Word Bits

Table 11.9 and *Table 11.10* list the SEL-487E Relay Word bits that are related to synchrophasor measurement.

The Synchrophasor Trigger Relay Word bits in *Table 11.9* follow the state of the SELOGIC control equations of the same name, listed at the bottom of *Table 11.1*. These Relay Word bits are included in the IEEE C37.118 synchrophasor data frame STAT field. See *Table 11.7* for standard definitions for these settings.

Table 11.9 Synchrophasor Trigger Relay Word Bits

Name	Description
PMTRIG	Trigger (SELOGIC Control Equation).
TREA4	Trigger Reason Bit 4 (SELOGIC Control Equation)
TREA3	Trigger Reason Bit 3 (SELOGIC Control Equation)
TREA2	Trigger Reason Bit 2 (SELOGIC Control Equation)
TREA1	Trigger Reason Bit 1 (SELOGIC Control Equation)

The Time Synchronization Relay Word bits in *Table 11.10* indicate the present status of the high-accuracy timekeeping function of the SEL-487E.

Table 11.10 Time Synchronization Relay Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
TSOK	Time Synchronization OK. Asserts while time is based on high-accuracy IRIG-B time source (HIRIG mode) of sufficient accuracy for synchrophasor measurement.
PMDOK	Phasor Measurement Data OK. Asserts when the SEL-487E is enabled and synchrophasors are enabled (Global setting EPMU := Y).

When using the relay as a synchrophasor client, the Relay Word bits in *Table 11.11* indicate the state of the synchronization.

Table 11.11 Synchrophasor Client Status Bits (Sheet 1 of 2)

Name	Description
RTCENA	Asserts for one processing interval when a valid message is received on channel A
RTCENB	Asserts for one processing interval when a valid message is received on channel B
RTCROKA	Asserts for one processing interval when data is aligned for channel A. Use this bit to condition usage of the channel A data.
RTCROKB	Asserts for one processing interval when data is aligned for channel B. Use this bit to condition usage of the channel B data.
RTCROK	Asserts for one processing interval when data for all enabled channels are aligned. Use this bit to condition general usage of the aligned synchrophasor data.
RTCDLYA	This bit is asserted when the last received valid message on channel A is older than MRTCDLY.
RTCDLYB	This bit is asserted when the last received valid message on channel B is older than MRTCDLY.

Table 11.11 Synchrophasor Client Status Bits (Sheet 2 of 2)

Name	Description
RTCSEQA	This bit is asserted when the processed received message on channel A is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of channel A data in applications where sequential data are required.
RTCSEQB	This bit is asserted when the processed received message on channel B is the expected next-in-sequence. It is deasserted if it is not. The deassertion implies that one or more packets of information were lost. Use this bit to condition usage of channel B data in applications where sequential data are required.
RTCCFGA	Indicates channel A is successfully configured.
RTCCFGB	Indicates channel B is successfully configured.

When received, synchrophasor messages contain digital data. This data is stored in the Remote Synchrophasor Relay Word bits in *Table 11.12*.

Table 11.12 Remote Synchrophasor Data Bits

Name	Description
RTCAD01–RTCAD16	First sixteen digitals received in synchrophasor message on channel A. Only valid when RTCROKA is asserted.
RTCBD01–RTCBD16	First sixteen digitals received in synchrophasor message on channel B. Only valid when RTCROKB is asserted.

Synchrophasor Analog Quantities

The synchrophasor measurements in *Table 11.13* are available whenever Global setting EPMU := Y. When EPMU := N, these analog quantities are set to 0.0000.

It is important to note that the synchrophasors are only valid when the relay is in HIRIG timekeeping mode, which can be verified by monitoring the TSOK Relay Word bit. When TSOK = logical 1, the SEL-487E timekeeping is synchronized to the high-accuracy IRIG-B signal, and the synchrophasor data is precisely time-stamped.

Table 11.13 Synchrophasor Analog Quantities (Sheet 1 of 2)

Name	Description	Units
Frequency		
FREQPM	Measured system frequency[a]	Hz
DFDTPM	Rate-of-change of frequency, df/dt[a]	Hz/s
Synchrophasor Measurements		
V*km*PMM, V*km*PMA, V*km*PMR, V*km*PMI[b,c]	Phase *k* synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary
V1*m*PMM, V1*m*PMA, V1*m*PMR, V1*m*PMI	Positive-sequence synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary

Table 11.13 Synchrophasor Analog Quantities (Sheet 2 of 2)

Name	Description	Units
I*kn*PMM, I*kn*PMA, I*kn*PMR, I*kn*PMI[b,d]	Phase *k* synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
I1*n*PMM, I1*n*PMA, I1*n*PMR, I1*n*PMI	Positive-sequence synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
SODPM	Second of the day of the PM data	s
FOSPM	Fraction of the second of the PM data	s

[a] Measured value if the voltages are valid and EMPU = Y, otherwise FREQ_PM = nominal frequency setting NFREQ, and DFDT is zero.
[b] k = A, B, or C.
[c] m = V or Z.
[d] n = S, T, U, W, X, Y.

When using the SEL-487E for synchrophasor acquisition, the delayed and aligned analog quantities listed in *Table 11.14* are available. Be aware that these quantities are only valid when RTCROK is asserted and only for the enabled channels. The specific channel quantities are also valid whenever their respective RTCROK*c* Relay Word bit is set.

Table 11.14 Synchrophasor Aligned Analog Quantities (Sheet 1 of 2)

Name	Description	Units
RTCAP01–RTCAP32	Remote phasor pairs for channel A. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCBP01–RTCBP32	Remote phasor pairs for channel B. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCAA01–RTCAA08	Remote analogs for channel A. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCBA01–RTCBA08	Remote analogs for channel B. Only those channels provided by the remote are valid to use. Use the **RTC** command to confirm interpretation of these quantities.	
RTCFA	Remote frequency for channel A	Hz
RTCFB	Remote frequency for channel B	Hz
RTCDFA	Remote frequency rate-of-change for channel A	Hz/s
RTCDFB	Remote frequency rate-of-change for channel B	Hz/s
V*km*PMM, V*km*PMA, V*km*PMR, V*km*PMI[a,b]	Aligned phase *k* synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary
V1*m*PMM, V1*m*PMA, V1*m*PMR, V1*m*PMI[b]	Aligned positive-sequence synchrophasor voltage (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *m*	kV Primary, degrees, kV Primary, kV Primary

Table 11.14 Synchrophasor Aligned Analog Quantities (Sheet 2 of 2)

Name	Description	Units
I*kn*PMMD, I*kn*PMAD, I*kn*PMRD, I*kn*PMID[a,c]	Aligned phase *k* synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
I1*n*PMMD, I1*n*PMAD, I1*n*PMRD, I1*n*PMID[c]	Aligned positive-sequence synchrophasor current (M-magnitude, A-Angle, R-Real, I-Imaginary) Terminal *n*	A Primary, degrees, A Primary, A Primary
SODPMD	Second-of-day for all aligned data	Seconds
FOSPMD	Fraction-of-second for all aligned data	Seconds
FREQPMD	Aligned local system frequency	Hz
DFDTD	Aligned local rate-of-change of frequency	Hz/s

[a] k = A, B, or C.
[b] m = V or Z.
[c] n = S, T, U, W, X, Y.

View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-487E synchrophasor measurements. See *METER on page 13.26* for general information on the **MET** command.

There are multiple ways to use the **MET PM** command:

- As a test tool, to verify connections, phase rotation, and scaling
- As an analytical tool, to capture synchrophasor data at an exact time, in order to compare it with similar data captured in other phasor measurement unit(s) at the same time
- As a method of periodically gathering synchrophasor data through a communications processor

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings MFRMT, PHDATAV, PHDATAI, and PHCURR. The **MET PM** command can function even when no serial ports are sending synchrophasor data—it is unaffected by serial port setting PROTO.

The **MET PM** command will only operate when the SEL-487E is in the HIRIG timekeeping mode, as indicated by Relay Word bit TSOK = logical 1.

Figure 11.13 shows a sample **MET PM** command response. The synchrophasor data is also available via the **HMI > Meter & Control** menu in ACSELERATOR QuickSet, and has a similar format to *Figure 11.13*.

The **MET PM *time*** command can be used to direct the SEL-487E to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure 11.13* occurring just after 14:14:12, with the time stamp 14:14:12.000000.

This method of data capture will always report from the exact second, even if the time parameter is entered with fractional seconds. For example, entering **MET PM 14:14:12.200** will result in the same data capture as **MET PM 14:14:12**, because the relay ignores the fractional seconds.

See *MET PM on page 13.29* for complete command options, and error messages.

```
=>>MET PM <Enter>
Relay 1                                    Date: 04/20/2008  Time: 22:02:12.000
Station A                                  Serial Number: 2008030645

Time Quality   Maximum time synchronization error:  >999.999 (ms)  TSOK = 0
Synchrophasors
                     VV Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)        127.266   126.972   127.148           127.128
ANG (DEG)        73.542   -46.400  -166.103            73.677

                     VZ Phase Voltages            Pos. Sequence Voltage
                 VA        VB        VC                V1
MAG (kV)         76.383    76.103    76.277            76.254
ANG (DEG)        73.623   -46.319  -166.175            73.707

                     IS Phase Currents         IS Pos. Sequence Current
                 IA        IB        IC                 I1S
MAG (A)         221.707   221.851   221.661           221.740
ANG (DEG)        57.667   -62.223   177.875            57.767

                     IT Phase Currents         IT Pos. Sequence Current
                 IA        IB        IC                 I1T
MAG (A)         440.487   441.507   440.698           440.897
ANG (DEG)      -122.055   118.057    -1.933          -121.983

                     IU Phase Currents         IU Pos. Sequence Current
                 IA        IB        IC                 I1U
 I1U
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IW Phase Currents         IW Pos. Sequence Current
                 IA        IB        IC                 I1W
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IX Phase Currents         IX Pos. Sequence Current
                 IA        IB        IC                 I1X
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

                     IY Phase Currents         IY Pos. Sequence Current
                 IA        IB        IC                 I1Y
MAG (A)           0.000     0.000     0.000             0.000
ANG (DEG)         0.000     0.000     0.000             0.000

FREQ (Hz) 59.990          Frequency Tracking = Y
Rate-of-change of FREQ (Hz/s)    0.00

Digitals
PSV08  PSV07  PSV06  PSV05  PSV04  PSV03  PSV02  PSV01
  0      0      0      0      0      0      0      0
PSV16  PSV15  PSV14  PSV13  PSV12  PSV11  PSV10  PSV09
  0      0      0      0      0      0      0      0
PSV24  PSV23  PSV22  PSV21  PSV20  PSV19  PSV18  PSV17
  0      0      0      0      0      0      0      0
PSV32  PSV31  PSV30  PSV29  PSV28  PSV27  PSV26  PSV25
  0      0      0      0      0      0      0      0
PSV40  PSV39  PSV38  PSV37  PSV36  PSV35  PSV34  PSV33
  0      0      0      0      0      0      0      0
PSV48  PSV47  PSV46  PSV45  PSV44  PSV43  PSV42  PSV41
  0      0      0      0      0      0      0      0
PSV56  PSV55  PSV54  PSV53  PSV52  PSV51  PSV50  PSV49
  0      0      0      0      0      0      0      0
PSV64  PSV63  PSV62  PSV61  PSV60  PSV59  PSV58  PSV57
  0      0      0      0      0      0      0      0

Analogs
PMV49      0.000  PMV50      0.000  PMV51      0.000  PMV52      0.000
PMV53      0.000  PMV54      0.000  PMV55      0.000  PMV56      0.000
PMV57      0.000  PMV58      0.000  PMV59      0.000  PMV60      0.000
PMV61      0.000  PMV62      0.000  PMV63      0.000  PMV64      0.000
=>>
```

Figure 11.13 Sample MET PM Command Response

C37.118 Synchrophasor Protocol

The SEL-487E complies with IEEE C37.118, Standard for Synchrophasors for Power Systems, when Global setting MFRMT := C37.118.

The protocol is available on serial ports 1, 2, 3, and F by setting the corresponding Port setting PROTO := PMU.

The protocol is available on the Ethernet port when EPMIP := Y.

This subsection does not cover the details of the protocol, but highlights some of the important features and options that are available.

Settings Affect Message Contents

The SEL-487E allows several options for transmitting synchrophasor data. These are controlled by Global settings described in *Settings for Synchrophasors*. You can select how often to transmit the synchrophasor messages (MRATE), which synchrophasors to transmit (PHDATAV, PHDATAI, and PHCURR), which numeric representation to use (PHNR), and which coordinate system to use (PHFMT).

The SEL-487E automatically includes the frequency and rate-of-change-of-frequency in the synchrophasor messages. Global setting FNR selects the numeric format to use for these two quantities.

The relay can include up to sixteen user-programmable analog values in the synchrophasor message, as controlled by Global setting NUMANA, and 0, 16, 32, 48, or 64 digital status values, as controlled by Global setting NUMDSW.

The SEL-487E always includes the results of four synchrophasor trigger reason SELOGIC equations TREA1, TREA2, TREA3, and TREA4, and the trigger SELOGIC control equation result PMTRIG, in the synchrophasor message.

Communications Bandwidth

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message rate of once per second places little burden on the communications channel. As more synchrophasors, analog values, or digital status words are added, or if the message rate is increased, some communications channel restrictions come into play.

If the SPEED setting on any serial port set with PROTO := PMU is insufficient for the PMU Global settings, the SEL-487E or SEL-5030 software will display an error message and fail to save settings until the error is corrected.

The C37.118 synchrophasor message format always includes 16 bytes for the message header and terminal ID, time information, and status bits. The selection of synchrophasor data, numeric format, programmable analog, and programmable digital data will add to the byte requirements. *Table 11.15* can be used to calculate the number of bytes in a synchrophasor message.

Table 11.15 Size of a C37.118 Synchrophasor Message

Item	Possible number of quantities	Bytes per quantity	Minimum number of bytes	Maximum number of bytes
Fixed			18	18
Synchrophasors	0, 1, 2…32	4 {PHNR := I} 8 {PHNR := F}	0	256
Frequency	2 (fixed)	2 {FNR := I} 4 {FNR := F}	4	8
Analog Values	0 – 16	4	0	64
Digital Status Words	0 – 4	2	0	8
Total (Minimum and Maximum)			22	354

Table 11.16 lists the baud settings available on any SEL-487E serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 20 bytes.

Table 11.16 Serial Port Bandwidth for Synchrophasors (in Bytes)

Global setting MRATE	Port setting SPEED								
	300	600	1200	2400	4800	9600	19200	38400	57600
1	21	42	85	170	340	680	1360	2720	4080
2		21	42	85	170	340	680	1360	2040
4 (60 Hz only)			21	42	85	170	340	680	1020
5				34	68	136	272	544	816
10					34	68	136	272	408
12 (60 Hz only)					28	56	113	226	340
15 (60 Hz only)					21	45	90	181	272
20 (60 Hz only)						34	68	136	204
25 (50 Hz only)						27	54	108	163
30 (60 Hz only)						22	45	90	136
50 (50 Hz only)							27	54	81
60 (60 Hz only)							22	45	68

Referring to Table 11.15 and Table 11.16, it is clear that the lower SPEED settings are very restrictive.

The smallest practical synchrophasor message would be comprised of one synchrophasor and one digital status word, and this message would consume between 26 and 34 bytes, depending on the numeric format settings. This type of message could be sent at any message rate (MRATE) when SPEED := 38400 or 57600, up to MRATE := 50 or 30 when SPEED := 19200, and up to MRATE := 25 or 20 when SPEED := 9600.

Another example application has messages comprised of eight synchrophasors, one digital status word, and two analog values. This type of message would consume between 62 and 98 bytes, depending on the numeric format settings. The 62-byte version, using integer numeric representation, could be sent at any message rate (MRATE) when SPEED := 57600. The

98-byte version, using floating-point numeric representation, could be sent at up to MRATE := 30 when SPEED := 57600, up to MRATE := 25 when SPEED := 38400, and up to MRATE := 12 when SPEED := 19200.

Protocol Operation

The SEL-487E will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-487E, with IEEE C37.118 commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor can automatically build a database structure.

Transmit Mode Control

The SEL-487E will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission when the appropriate command is received from the synchrophasor processor. The SEL-487E can also indicate when a configuration change occurs, so the synchrophasor processor can request a new configuration block and keep its database up-to-date.

The SEL-487E will only respond to configuration block request messages when it is in the non-transmitting mode.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the slowest SPEED setting on a PROTO := PMU port will affect the maximum Global MRATE setting that can be used.

PMU Setting Example

A power utility is upgrading the transformer protection to use the SEL-487E Relay as main protection. The system operator also wants the utility to install phasor measurement units (PMUs) in each substation to collect data for a new remedial action scheme, and to eventually replace their present state-estimation system.

The PMU data collection requirements call for the following data, collected at 10 messages per second:

- Frequency
- Positive-sequence voltage from the low voltage bus in the substation
- Three-phase and positive-sequence current for each transformer winding
- Indication when the transformer breaker is open
- Indication when the voltage or frequency information is unusable
- Ambient temperature (one reading per station)

- Station battery voltage
- No relay control from the PMU communications port, for the initial stage of the project

The utility is able to meet the system operator requirements with the SEL-487E, an SEL-2600A RTD Module, an SEL-2407® Satellite Synchronized Clock, and an SEL-3306 Synchrophasor Processor in each substation.

This example will cover the PMU settings in one of the SEL-487E relays.

Some system details:

- The nominal frequency is 60 Hz.
- The transformer is interrupted by a high side, three-phase breaker.
- The station ambient temperature is collected by an SEL-2600A, channel RTD01.
- The line pts and wiring have a phase error of 4.20 degrees (lagging) at 60 Hz.
- The primary (high-side) transformer cts and wiring have a phase error of 3.50 degrees (lagging) at 60 Hz.
- The secondary transformer (low-side) cts and wiring have a phase error of 5.50 degrees (lagging) at 60 Hz.
- The synchrophasor data will be using Port 3, and the maximum baud allowed is 19200.
- The system designer specified floating point numeric representation for the synchrophasor data, and rectangular coordinates.
- The system designer specified integer numeric representation for the frequency data.
- The system designer specified fast synchrophasor response, because the data is being used for system monitoring.

The protection settings and RTD serial port settings will not be shown.

Determining Settings

The protection engineer performs a bandwidth check, using *Table 11.15*, and determines the required message size. The system requirements, in order of appearance in *Table 11.15*, are:

- 5 Synchrophasors, in floating point representation
- Integer representation for the frequency data
- 2 analog values
- 3 digital status bits, which require one status word

The message size is 16 + 5 • 8 + 2 • 2 + 2 • 4 + 1 • 2 = 70 bytes. Using *Table 11.16*, the engineer verifies that the port baud of 19200 is adequate for the message, at 10 messages per second.

Protection Math Variables PMV64 and PMV63 will be used to transmit the RTD01 ambient temperature data and the station battery voltage DC1, respectively.

The Protection SELOGIC Variables PSV64, PSV63, and PSV62 will be used to transmit the breaker status, loss-of-potential alarm, and frequency measurement status, respectively.

The Port 3 FASTOP setting will be set to N, to disable any control attempts from the PMU port.

Make the Global settings as shown in *Table 11.17*.

Table 11.17 Example Synchrophasor Global Settings

Setting	Description	Value
NFREQ	Nominal System Frequency (50, 60 Hz)	60
EPMU	Enable Synchronized Phasor Measurement (Y, N)	Y
MFRMT	Message Format (C37.118, FM)	C37.118
MRATE	Messages per Second (1, 2, 4, 5, 10, 12, 15, 20, 30, 60)	10
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	F
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMSTN	Station Name (16 characters)	SAMPLE1
PMID	PMU Hardware ID (1–65534)	14
PHVOLT	Voltage Source (combination of V,Z)	V
PHDATAV	Phasor Data Set, Voltages (V1, PH, ALL, NA)	V1
VVCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	4.20
PHCURR	Current Source (Combination of S, T, U, W, X, Y)	S, T
PHDATAI	Phasor Data Set, Currents (I1, PH, ALL, NA)	ALL
PMFRQA	Phasor Measurement Frequency Application	S
ISCOMP	IS Angle Compensation Factor (–179.99 to 180 degrees)	3.50
ITCOMP	IT Angle Compensation Factor (–179.99 to 180 degrees)	5.50
PHNR	Phasor Numeric Representation (I = Integer, F = Floating point)	F
PHFMT	Phasor Format (R = Rectangular coordinates, P = Polar coordinates)	R
FNR	Frequency Numeric Representation (I = Integer, F = Float)	I
NUMANA	Number of Analog Values (0–16)	2
NUMDSW	Number of 16-bit Digital Status Words (0, 1, 2, 3, 4)	1

The two analog quantities and three Relay Word bits required in this example must be placed in certain protection math variables and protection SELOGIC variables. Make the Protection Free-Form logic settings in *Table 11.18* in all six settings groups.

Table 11.18 Example Synchrophasor Protection Free-Form Logic Settings

Setting	Value
PSV64	52CLS # Transformer breaker status
PSV63	LOP # Loss-of-Potential
PMV62	RTD01 # Ambient Temperature
PMV61	DC1 # Station Battery Voltage

Make the *Table 11.19* settings for serial port 3, using the **SET P 3** command.

Table 11.19 Example Synchrophasor Port Settings

Setting	Description	Value
PROTO	Protocol (SEL, DNP, MBA, MBB, RTD, PMU)	PMU
SPEED	Data Speed (300 to 57600)	19200
STOPBIT	Stop Bits (1, 2 bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N
FASTOP	Enable Fast Operate Messages (Y, N)	N
PMUMODE	PMU Mode (CLIENTA, CLIENTB, SERVER)	SERVER

The sample **MET PM** capture in *Figure 11.13* shows data that could be measured by this system, including the digital and analog data near the bottom of the figure, that represent the protection free-form logic from *Table 11.18*.

SEL Fast Message Synchrophasor Protocol

SEL Fast Message Unsolicited Write (synchrophasor) messages are general Fast Messages (A546h) that transport measured synchrophasor information. The SEL-487E can send unsolicited write messages as fast as every 50 ms on a 60 Hz system, and 100 ms on a 50 Hz system. Use Global settings PHDATAV, PHDATAI, PHVOLT, and PHCURR to select the voltage and current data to include in the Fast Message. *Table 11.22* and *Table 11.23* list analog quantities included in the Fast Message for various Global settings (frequency is included in all messages). Not all messages are supported at all data speeds. If the selected data rate is not sufficient for the given message length, the relay responds with an error message.

Table 11.20 lists the Synchrophasor Fast Message Write function codes and the actions the relay takes in response to each command.

Table 11.20 Fast Message Command Function Codes for Synchrophasor Fast Write

Function Code (Hex)	Function	Relay Action
00h	Fast message definition block request	Relay transmits Fast Message definition request acknowledge (Function Code 80)
01h	Enable unsolicited transfer	Relay transmits Fast Message command acknowledged message (Function Code 81). Relay transmits Synchrophasor Measured Quantities (function to enable: Unsolicited Write broadcast, Function Code 20)
02h	Disable unsolicited transfer	Relay sends Fast Message command acknowledge message (Function Code 82) and discontinues transferring unsolicited synchrophasor messages (function to disable: Unsolicited Write broadcast, Function Code 20)
05h	Ping: determine if channel is operable	Relay aborts unsolicited message in progress and transmits ping acknowledge message (Function Code 85)

See SEL Application Guide *AG2002-08, Using SEL-421 Relay Synchrophasors in Basic Applications* for more information on the SEL Fast Message Synchrophasor protocol.

SEL-487E Fast Message Synchrophasor Settings

The settings for SEL Fast Message synchrophasors are listed in *Table 11.21*. Many of these settings are identical to the settings for the C37.118 format. See *Settings for Synchrophasors*.

Table 11.21 PMU Settings in the SEL-487E for SEL Fast Message Protocol, in Global Settings

Setting	Description	Default
EPMU	Enable Synchronized Phasor Measurement (Y, N)	N[a]
MFRMT	Message Format (C37.118, FM)[b]	C37.118
PMAPP	PMU Application (F = Fast Response, N = Narrow Bandwidth)	N
PHCOMP	Frequency-Based Phasor Compensation (Y, N)	Y
PMID	PMU Hardware ID (0x00000000–0xFFFFFFFF)	0x00000001
PHVOLT	Include Voltage Terminal (range)	V
PHDATAV	Phasor Data Set, Voltages (V1, ALL)	V1
V[*k*]COMP[c]	V[*k*] Voltage Angle Compensation Factor (–179.99 to +180 degrees)	0.00
PHCURR[d]	Current Source (S, T, U, W, X, Y)	S
PHDATAI[e]	Phasor Data Set, Currents (ALL, NA)	NA
I[*n*]COMP[f]	I[*n*] Angle Compensation Factor (–179.99 to +180 degrees)	0.00

[a] Set EPMU := Y to access the remaining settings.
[b] C37.118 = IEEE C37.118 Standard—see Table 11.1; FM := SEL Fast Message. Set MFRMT := FM to enter the Fast Message settings.
[c] K = V, Z.
[d] Setting hidden when PHDATAI := NA.
[e] When PHDATAV := V1, this setting is forced to NA and cannot be changed.
[f] n = S, T, U, W, X, Y.

Certain settings in *Table 11.21* are hidden, depending on the status of other settings. For example, if PHDATAI := NA, the PHCURR setting is hidden to limit the number of settings for your synchrophasor application.

Descriptions of Fast Message Synchrophasor Settings

The SEL Fast Message synchrophasor settings are a subset of the C37.118 settings. See *Descriptions of Synchrophasor Settings* for details on settings PMAPP, PHCOMP, V[*k*]COMP where *k* = any combination of V, Z, and I[*n*]COMP where *n* = any combination of S, T, U, W, X, Y. For the remaining settings, the differences are explained in the following pages.

PMID

Defines the number of the PMU.

The PMID setting is a 32-bit numeric value. Use your utility or synchrophasor data concentrator labeling convention to determine this setting.

PHVOLT, PHDATAV, PHCURR, and PHDATAI

These settings define the synchrophasors to be included in the data stream.

There are fewer combinations of synchrophasor data available in the SEL Fast Message synchrophasor format. For example, it is not possible to send only current synchrophasors. You must also send voltages.

See *Table 11.22* for a list of synchrophasors that can be sent in SEL Fast Message format, and the order.

Table 11.22 SEL Fast Message Voltage and Current Selections Based on PHDATAV and PHDATAI

Global Settings	Number of Synchrophasor Magnitude and Angle Pairs Transmitted	Synchrophasor Magnitude and Angle Pairs to Transmit, and the Transmit Order[a]
PHDATAV := V1 PHDATAI := NA	1	V_1
PHDATAV := ALL PHDATAI := NA	4	V_A, V_B, V_C, V_1
PHDATAV := ALL PHDATAI := ALL	8	V_A, V_B, V_C, V_1, I_A, I_B, I_C, I_1

[a] The voltages and currents are defined in Table 11.23.

Table 11.23 SEL Fast Message Voltage and Current Synchrophasor Sources

Synchrophasor Labels From Table 11.22	Synchrophasor Magnitude and Angle Pair Definition (Analog Quantities)	
	Magnitude	**Angle**
V_A	VA*m*PMM[a]	VA*m*PMA[a]
V_B	VB*m*PMM[a]	VB*m*PMA[a]
V_C	VC*m*PMM[a]	VC*m*PMA[a]
V_1	V1*m*PMM[a]	V1*m*PMA[a]
I_A	IA*n*PMM[b]	IA*n*PMA[b]
I_B	IB*n*PMM[b]	IB*n*PMA[b]
I_C	IC*n*PMM[b]	IC*n*PMA[b]
I_1	I1*n*PMM[b]	I1*n*PMA[b]

[a] Where:
m = V if PHVOLT: = V
m = Z if PHVOLT: = Z

[b] Where:
n = S if PHCURR: = S
n = T if PHCURR: = T
n = U if PHCURR: = U
n = W if PHCURR: = W
n = X if PHCURR: = X
n = Y if PHCURR: = Y

Other Settings Not Present

The SEL Fast Message format does not require the following settings: PHNR, PHFMT, FNR, NUMANA, NUMDSW, TREA1–TREA4, PMTRIG, EPMDR,CONAM,PMLER, and PMPRE.

The SEL Fast Message synchrophasor protocol always includes the frequency information in floating-point representation, and fourteen user-programmable SELOGIC variables PSV49 through PSV64. There are no user-programmable analog quantities in the SEL Fast Message synchrophasor protocol.

Communications Bandwidth

A phasor measurement unit (PMU) that is configured to transmit a single synchrophasor (positive-sequence voltage, for example) at a message period of one second places little burden on the communications channel. As more synchrophasors are added, or if the message rate is increased, some communications channel restrictions come into play.

In the SEL Fast Message synchrophasor protocol, the master device determines the message period (the time among successive synchrophasor message time-stamps) in the enable request. If the SEL-487E can support the requested message period on that serial port, the relay acknowledges the request (if an acknowledge was requested) and commences synchrophasor data transmission. If the SEL-487E cannot support the requested message period, the relay responds with a response code indicating bad data (if an acknowledge was requested).

The SPEED setting on any serial port set with PROTO := PMU should be set as high as possible, to allow for the largest number of possible message period requests to be successful.

The SEL-487E Fast Message synchrophasor format always includes 32 bytes for the message header and terminal ID, time information, frequency, and status bits. The selection of synchrophasor data will add to the byte requirements. *Table 11.24* can be used to calculate the number of bytes in a synchrophasor message.

Table 11.24 Size of an SEL Fast Message Synchrophasor Message

Item	Possible Number of Quantities	Bytes per Quantity	Minimum Number of Bytes	Median Number of Bytes	Maximum Number of Bytes
Fixed			32	32	32
Synchrophasors	1, 4, or 8	8	8	32	64
Total (Minimum, Median, and Maximum)			40	64	96

Table 11.25 lists the baud settings available on any SEL-487E serial port (setting SPEED), and the maximum message size that can fit within the port bandwidth. Blank entries indicate bandwidths of less than 40 bytes.

Table 11.25 Serial Port Bandwidth for Synchrophasors (in Bytes)

Requested Message Period (ms)	Equivalent Message Rate (messages per second)	Port Setting SPEED								
		300	600	1200	2400	4800	9600	19200	38400	57600
1000	1		41	83	166	333	666	1332	2665	3998
500	2			41	83	166	333	666	1332	1999
250 (60 Hz only)	4				41	83	166	333	666	999
200	5					66	133	266	533	799
100	10						66	133	266	399
50 (60 Hz only)	20							66	133	199

Referring to *Table 11.24* and *Table 11.25*, it is clear that the lower SPEED settings are very restrictive.

Some observations from *Table 11.25*:

- ➤ A serial port set with SPEED := 38400 or 57600 can handle any size message at any data rate.
- ➤ A serial port set with SPEED := 19200 can handle a single-synchrophasor or four-synchrophasor message at any data rate, and any size message up to 10 messages per second.
- ➤ A serial port set with SPEED := 9600 can handle a single-synchrophasor message at any data rate, a four-synchrophasor message at up to 10 messages per second, and any size message at up to 5 messages per second.
- ➤ A serial port set with SPEED := 300 cannot be used for Fast Message synchrophasors.

Protocol Operation

The SEL-487E will only transmit synchrophasor messages over serial ports that have setting PROTO := PMU. The connected device will typically be a synchrophasor processor, such as the SEL-3306. The synchrophasor processor controls the PMU functions of the SEL-487E, with SEL Fast Message commands, including commands to start and stop synchrophasor data transmission, and commands to request a configuration block from the relay, so the synchrophasor processor determine the correct configuration for storing the synchrophasor data.

Transmit Mode Control

The SEL-487E will not begin transmitting synchrophasors until an enable message is received from the synchrophasor processor. The relay will stop synchrophasor transmission on a particular serial port when the disable command is received from the synchrophasor processor, or when the relay settings for that port are changed. The SEL-487E will stop synchrophasor transmission on all serial ports when any Global or Group settings change is made.

The SEL-487E will respond to configuration block request messages regardless of the present transmit status, waiting only as long as it takes for any partially-sent messages to be completely transmitted.

The SEL-487E will respond to a Ping request immediately upon receipt, terminating any partially sent messages.

Independent Ports

Each serial port with the PROTO := PMU setting is independently configured and enabled for synchrophasor and Fast Operate commands. For example, if there are two serial ports set to PROTO := PMU, the status of one port has no effect on the other port. One port might be commanded to start transmitting synchrophasor messages, while the other port is idle, responding to a configuration block or Fast Operate request, or transmitting synchrophasors. The ports are not required to have the same SPEED setting, although the SPEED setting on each PROTO := PMU port will affect the minimum synchrophasor message data period that can be used on that port.

Synchrophasor Protocols and SEL Fast Operate Commands

The SEL-487E can be configured to process SEL Fast Operate commands received on serial ports that have Port setting PROTO := PMU, when the Port setting FASTOP := Y.

This functionality can allow a host device to initiate control actions in the PMU without the need for a separate communications interface.

If port setting FASTOP:= Y on a serial port set to PROTO := PMU, the SEL-487E will provide Fast Operate support. The host device can request a Fast Operate Configuration Block when the relay is in the nontransmitting mode, and the relay will respond with the message, which includes codes that define the circuit breaker and remote bit control points that are available via Fast Operate commands.

The SEL-487E will process Fast Operate requests regardless of whether synchrophasors are being transmitted, as long as serial port setting FASTOP := Y. When FASTOP := N, the relay will ignore Fast Operate commands. Use the FASTOP := N option to lockout any control actions from that serial port if required by your company operating practices.

The SEL-487E does not acknowledge received Fast Operate commands, however, it is easy to program one or more Relay Word bits in the digital status word to observe the controlled function. For example, a Fast Operate Circuit Breaker S close command could be confirmed by monitoring the S terminal breaker status bit 52CLS by assigning SELOGIC free-form protection logic setting PMV64 := 52CLS.

SEL Fast Operate commands are discussed in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 7.10*. Note that only the Fast Operate function is available on ports set to PROTO := PMU. The protocols SEL Fast Meter and SEL Fast SER are unavailable on PROTO := PMU ports.

Section 12

SELOGIC Control Equations

Overview

This section describes use of SELOGIC® control equation programming to customize relay operation and automate substations. This section covers the following topics:

SELOGIC Control Equation History

SEL introduced SELOGIC control equations in the SEL-300 series relays to provide relay operation customization. SELOGIC control equations in the SEL-487E Relay provide both protection application flexibility and a platform for substation automation.

SELOGIC control equation programming in the SEL-487E includes several features and capabilities not included in SEL-300 series relays. The new features with a brief description are listed in *Table 12.1*.

Table 12.1 Advanced SEL-487E SELOGIC Control Equation Features (Sheet 1 of 2)

Feature	Description
Protection/automation separation	Segregation of protection and automation work and settings
Free-form logic	Custom logic operation and execution order
Comments	Documentation of SELOGIC control equations within the equation

Table 12.1 Advanced SEL-487E SELOGIC Control Equation Features (Sheet 2 of 2)

Feature	Description
Math operations	Calculations for automation or extended protection functions
Sequencing timers	Additional timers designed for sequencing automated operations
Counters	Increased sophistication in custom protection and automation programming
Aliases	Custom programming is more readable when you rename as many as 200 analog or digital quantities

Use SELOGIC control equations in the SEL-487E to customize protection operation, create custom protection elements, and automate substation operation. The SEL-487E introduces several advanced programming features, operators, and methods. *Table 12.2* is a summary that compares SELOGIC control equation programming in SEL-351 series relays and SEL-311 series relays with the SEL-487E.

Table 12.2 SEL-487E SELOGIC Control Equation Programming Summary

Element	SEL-351 Series/ SEL-311 Series	SEL-487E	
		Protection Free Form	Automation Free Form
SELOGIC control equation variables	16	64	256
SELOGIC math variables	0	64	256
Conditioning timers[a]	16	32	0
Sequencing timers	0	32	32
Counters	0	32	32
Latch bits	16	32	32

[a] Similar to SEL-300 series relay SELOGIC control equation programming.

Separation of Protection and Automation Areas

The SEL-487E acts as a protective relay and as a smart node in distributed substation automation. The relay collects data, coordinates inputs from many interfaces, and automatically controls substation equipment. The relay performs protection and automation functions but keeps programming of these functions separate. For example, someone modifying or testing a capacitor bank control system or station restoration system created in automation programming should not be able to corrupt programming for protection tasks. Similarly, extended protection algorithms must operate at protection speeds unaffected by the volume of automation programming.

The SEL-487E contains several separate programming areas discussed in *SELOGIC Control Equation Setting Structure on page 12.6*. Separate access levels and passwords control access to each programming area and help eliminate accidental programming changes. For example, use Access Level P to modify protection configuration and protection free-form SELOGIC control equation programming and Access Level A to access automation programming.

NOTE: If you want unlimited access to both automation and protection configuration and programming, log in to Access Level 2.

Protection and automation areas must interact and exchange information. Protection and automation interact and exchange information through separate storage areas (variables) for results of automation and protection programming. The relay combines the results in the output settings that drive relay outputs to control substation equipment. Separation of protection and automation storage areas is illustrated in *Figure 12.1*.

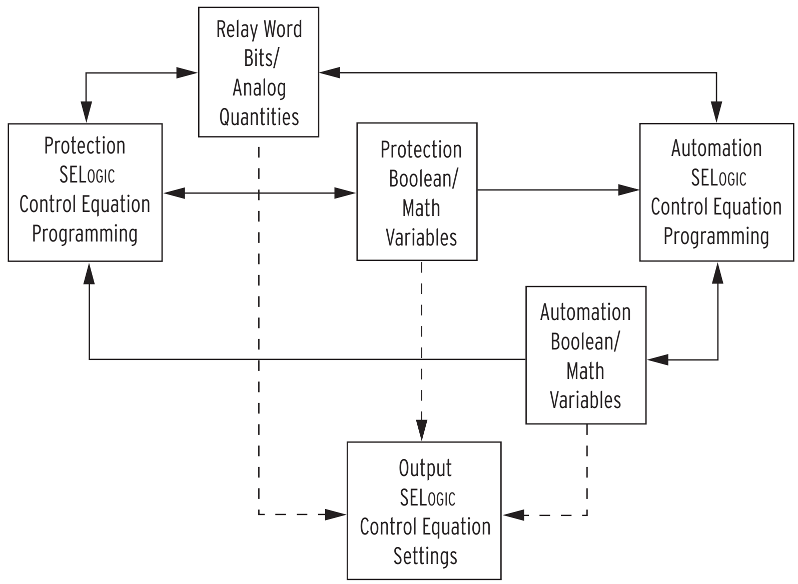

Figure 12.1 Protection and Automation Separation

Figure 12.1 illustrates how the SEL-487E keeps protection and automation programming separate while still exchanging information. The arrows indicate data flow between components. The Relay Word Bits and Analog Quantities are visible to protection, automation, and output programming. Protection programming uses the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables as inputs, but only writes and stores information to the Protection Variables. Similarly, automation programming uses data from all parts of the relay, but only stores data in the Automation Variables.

The Output SELOGIC control equation settings use the Relay Word Bits, Analog Quantities, Protection Variables, and Automation Variables to control outputs and other information leaving the relay. Use the output settings to create a custom combination of the results of protection and automation operations. For example, an OR operation will activate an output when protection or automation programming results necessitate activating the output. You can use more complicated logic to supervise control of the output with other external and internal information. For example, use a command from the SCADA master to supervise automated control of a motor-operated disconnect in the substation.

SELOGIC Control Equation Programming

There are two major areas where the SEL-487E uses SELOGIC control equations. First, fixed SELOGIC control equations define the operation of fixed protection elements or outputs. As with SEL-300 series relay programming, protection programming and outputs use fixed SELOGIC control equations. Second, you can use free-form SELOGIC control equations for free-form programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

Fixed SELOGIC Control Equations

Fixed result SELOGIC control equations are equations in which the left side (result storage location), or LVALUE, is fixed. Programming in SEL-300 series relays consists of all fixed SELOGIC control equations. Fixed equations include protection and output settings that you set with SELOGIC control equations.

SEL-487E fixed SELOGIC control equations are Boolean equations. Fixed result control equations can be as simple as a single element reference (for example PSV01) or can include a complex equation. An example of fixed programming is shown in *Example 12.1*.

EXAMPLE 12.1 Fixed SELOGIC Control Equations

The following equations are examples of fixed SELOGIC control equations for relay Output OUT101. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

OUT101 := **1** # Turn on OUT101

OUT101 := **NA** # Do not evaluate an equation for OUT101

OUT101 := **OUT102 AND RB02** # Turn on OUT101 if OUT102 and RB02 are on

Fixed SELOGIC control equations include expressions that evaluate to a Boolean value, True or False, represented by a logical 1 or logical 0.

OUT101 := **PSV04** # Turn on OUT101 if protection PSV04 is on

More complex programming in the free-form area controls OUT101. The result of the free-form programming is available as an element in a fixed equation.

OUT101 := **AMV003 > 5** # Turn on OUT101 if AMV003 is greater than 5

While you cannot perform mathematical operations in fixed programming, you can perform comparisons on the results of mathematical operations performed elsewhere.

Free-Form SELOGIC Control Equations

Free-form SELOGIC control equations provide advanced relay customization and automation programming. There are free-form SELOGIC control equation programming areas used for protection and automation. You can use free-form SELOGIC control equation programming to enter program steps sequentially so that the relay will perform steps in the order that you specify. You can refer to storage locations multiple times and build up intermediate results in successive equations. You can also enter entire line comments to help document programming. Mathematical operations are available only in free-form SELOGIC control equation programming areas. An example of free-form SELOGIC control equation programming is shown in *Example 12.2*.

EXAMPLE 12.2 Free-Form SELOGIC Control Equations

The following equations are examples of free-form SELOGIC control equations. The text after the # character is a comment included in the equation and stored in the relay for future reference and documentation.

Free-form equation example programming

#

Is 80% of A-phase fundamental voltage greater than 12kV

PMV01 := **IASFM * 0.8** # 80% of A-phase, Winding S, fundamental current

PSV04 := **PMV01 >= 12000** # True if A-phase fundamental voltage is greater than or equal to 12000

Use comments to group settings in the free-form SELOGIC control equations by task and to document individual equations. In this example, an intermediate calculation generates the value we want to test to determine if PSV04 will be turned on.

Assignment Statements

Both fixed and free-form SELOGIC control equations are a basic type of computer programming statement called an assignment statement. Assignment statements have a basic structure similar to that shown below:

LVALUE := Expression

Starting at the left, the LVALUE is the location where the result of an evaluation of the expression on the right will be stored. The := symbol marks the statement as an assignment statement and provides a delimiter or separator between the LVALUE and the expression. Type the := symbol as a colon and equal sign. The assignment symbol is different than a single equal sign (=) to avoid confusion with a logical comparison between two values. The type of LVALUE must match the result of evaluating the expression on the right.

There are two basic types of assignment statements that form SELOGIC control equations. In the first type, Boolean SELOGIC control equations, the SEL-487E evaluates the expression on the right to a result that is a logical 1 or a logical 0. The LVALUE must be some type of Boolean storage location or setting that requires a Boolean value. For example, the setting for the Protection Conditioning Timer 7 Input, PCT07IN, requires a value of 0 or 1, which you set with a Boolean SELOGIC control equation.

The second type is a math SELOGIC control equation. Use the math SELOGIC control equation to perform numerical calculations on data in the relay. For example, in protection free-form programming, enter AMV034 := 5 * IASFM to store the product of 5 and Winding S, A-phase current in automation math variable 34. *Example 12.3* lists several examples of Boolean and math SELOGIC control equations.

EXAMPLE 12.3 Boolean and Math SELOGIC Control Equations

The equations below are examples of Boolean SELOGIC control equations.

```
# Example Boolean SELOGIC control equations
PSV01 := IN101 # Store the value of IN101 in PSV01
PSV02 := IN101 AND RB03 # Store result of logical AND in PSV02
PST01IN := IN104 # Use IN104 as the input value for PST01
PSV03 := PMV33 >= 7 # Set PSV03 when PMV33 greater than or equal to 7
```

The lines below are examples of math SELOGIC control equations.

```
# Example math SELOGIC control equations
PMV01 := 5 # Store the constant 5 in PMV01
PMV02 := 0.5 * IASFM # Store the product of A-phase, Winding S, current,
and 0.5 in PMV02
```

Comments

The SEL-487E provides the following two type of comments:

- in-line comments: (*comment*)
- end-of-line comments: #xxx

Example of in-line comment:

```
1: PCT01IN := (*this is an in-line comment*)pct01in(**) := (*this is an in-line
comment *)
```

Example of end-of-line comment:

```
1: PCT01IN := 10 # this is an end-of-line comment
```

Include comment statements in SELOGIC control equations to help document SELOGIC control equation programming. You can start a comment anywhere in a SELOGIC control equation with the # character. The comment then continues to the end of the line. If you begin a SELOGIC control equation with a comment character, then the entire line is a comment.

NOTE: During troubleshooting or testing, reenter a line and insert the comment character to disable it. Enter the line without the comment character to enable the line later when you want it to be executed.

Comments are a powerful documentation tool for helping both you and others understand the intent of programming and configuration in the SEL-487E. You can use comments liberally; comments do not reduce SELOGIC control equation execution capacity.

SELOGIC Control Equation Setting Structure

The SEL-487E uses SELOGIC control equations in three major areas. First, you can customize protection operations with SELOGIC control equation settings and free-form programming. Second, there is a free-form programming area for more sophisticated automation SELOGIC control equation programming. Third, there is a fixed area for relay output programming. The SELOGIC control equation programming areas are shown in *Figure 12.2*. There are also a small number of fixed SELOGIC control equations in other settings areas including front-panel settings that allow you to customize relay features not directly related to protection or automation.

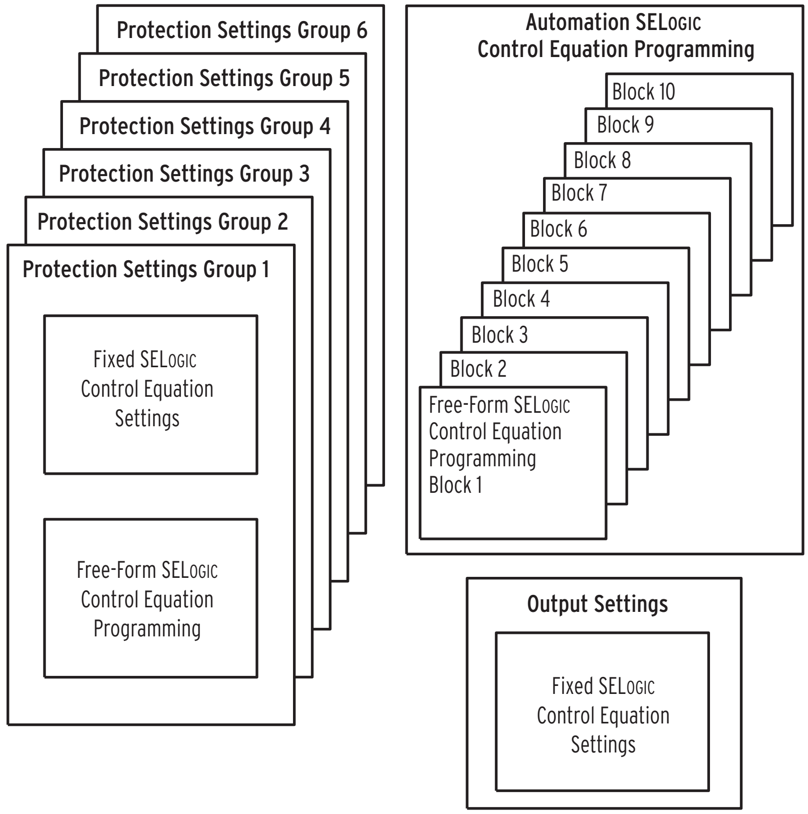

Figure 12.2 SELOGIC Control Equation Programming Areas

Protection

Protection SELOGIC control equation programming includes a fixed area and a free-form area. You can configure many protection settings within the relay (for example TR) with fixed SELOGIC control equation programming. Use these settings to control protection operation and customize relay operation. The programming and operation of fixed SELOGIC control equations in this area is very similar to programming in SEL-300 series relays.

There is a free-form SELOGIC control equation programming area associated with protection. Because this area operates at the protection processing interval along with protection algorithms and outputs, use this area to extend and customize protection operation. Protection free-form SELOGIC control equation programming includes a complete set of timers, counters, and variables.

For all protection settings, including protection SELOGIC control equation programming, there are six groups of settings that you activate with the protection settings group selection. Only one group is active at a time. When you switch groups, for example, you can activate completely different programming that corresponds to the conditions indicated by the active group. See *Multiple Setting Groups on page 12.8* for more information.

If you want the programming to operate identically in all groups, develop the settings in one group and copy these to all groups. You can copy settings using the **COPY** command documented in *Section 13: ASCII Command Reference*. You can also perform cut-and-paste operations in the ACSELERATOR QuickSet® SEL-5030 Software.

NOTE: Perform operations that are not time critical in automation SELOGIC control equation programming. You can use this automation to reduce the demand and complexity of protection SELOGIC control equation programming.

All of the SELOGIC control equation programming in the protection area executes at the same deterministic interval as the protection algorithms. Because of this type of programming execution, you can use protection free-form and fixed programming to extend and customize protection operation.

Automation

Automation SELOGIC control equation programming is a large free-form programming area that consists of 10 blocks. The relay executes each block sequentially from the first block to the last. You do not need to fill a block completely or enter any equations in a block before starting to write SELOGIC control equations in the following blocks.

The SEL-487E dedicates a minimum processing time when executing automation SELOGIC control equations. If the processing load is light, the relay uses more processing time for executing programming. This means that the overall execution time fluctuates. You can display the average and peak execution time with the **STATUS S ASCII** command. Use the **STATUS SC** command to reset the peak execution time.

NOTE: Organize automation SELOGIC control equation programming into blocks based on function. It is easier to edit and troubleshoot small partially filled blocks that contain related programming.

Use automation SELOGIC control equation programming to automate tasks that do not require time-critical, deterministic execution. For example, if you are coordinating control inputs from a substation HMI and SCADA master, use automation free-form SELOGIC control equations and set the output contact setting to the automation SELOGIC control equation variable that contains the result.

Perform time-critical tasks with protection free-form SELOGIC control equations. For example, if you require a SELOGIC control equation for TR (trip) that contains more than 15 elements, you must perform that calculation in several steps. Because detection of a TR condition is a time-critical activity, perform the calculation with protection free-form SELOGIC control equations and set TR to the protection SELOGIC control equation variable that contains the result.

Outputs

To provide protection and automation area separation, the output settings are in a fixed SELOGIC control equation area separate from protection and automation programming. You can take advantage of this separation to combine protection and automation in a manner that best fits your application. Outputs include the relay control outputs, outgoing MIRRORED BITS® points, and communications card control points. The relay executes output logic and processes outputs at the protection processing interval.

Multiple Setting Groups

The SEL-487E has six (6) independent setting groups, as shown in the left-hand side of *Figure 12.2*. Each setting group has complete relay settings (distance, directional, overcurrent, reclosing, etc.—see *SHO on page 13.43*) and protection SELOGIC settings (see *SHO L on page 13.44*). The active setting group can be:

- Shown or selected with the SEL ASCII serial port **GROUP** command—see *GROUP on page 13.21*.
- Shown or selected with the `MAIN` menu `Set/Show` menu item and the `Active Group` submenu item.

- ➤ Selected with SELogic control equation settings SS1 through SS6. Settings SS1 through SS6 have priority over all other selection methods. Use remote bits in these equations to select setting groups with Fast Operate commands as described in *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 7.10*.
- ➤ Shown with DNP3 Objects 20 and 22 and selected with Objects 40 and 41.

Setting Groups: Application Ideas

Setting groups can be used for such applications as:

- ➤ Environmental conditions such as winter storms, periods of high summer heat, etc.
- ➤ Hot-line tag that disables closing and sensitizes protection
- ➤ Commissioning and operation

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1 through SG6 indicate the active setting group, as shown in *Table 12.3*.

Table 12.3 Definitions for Active Setting Group Indication Relay Word Bits SG1 Through SG6

Relay Word Bit	Definition
CHSG	Indication that a group switch timer is operating, or a group switch change is underway.
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group
SG5	Indication that setting Group 5 is the active setting group
SG6	Indication that setting Group 6 is the active setting group

NOTE: The settings group switching settings are checked once per cycle. When setting TGR := 0, in order for a transient assertion to be recognized, it should be conditioned to remain asserted for at least one cycle.

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Active Setting Group Selection

The Global settings class contains the SELogic control equation settings SS1 through SS6, as shown in *Table 12.4*.

Table 12.4 Definitions for Active Setting Group Switching SELogic Control Equation Settings SS1 Through SS6

Setting	Definition
SS1	go to (or remain in) setting Group 1
SS2	go to (or remain in) setting Group 2
SS3	go to (or remain in) setting Group 3
SS4	go to (or remain in) setting Group 4
SS5	go to (or remain in) setting Group 5
SS6	go to (or remain in) setting Group 6

The operation of these settings is explained with the following example:

> Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group.
>
> With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6. With settings SS1 through SS6 all deasserted to logical 0, setting Group 3 still remains the active setting group.
>
> With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR (global settings):

TGR	Group Change Delay Setting	(settable from 0 to 54000 cycles)

NOTE: The CHSG Relay Word bit does not operate for settings changes initiated by the serial port or front panel methods.

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group. Relay Word bit CHSG asserts when the TGR timer is picked-up and timing, and also when a setting group change has been initiated.

Active Setting Group Changes

The SEL-487E is disabled for less than 1 second while in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in the specific logic description. For example, local bit (LB01 through LB32), remote bit (RB01 through RB32), and latch bit (PLT01 through PLT32) states are retained during an active setting group change. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group.

After a group change, an automatic message will be sent to any serial port that has setting AUTO := Y.

Active Setting: Nonvolatile State

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, the same setting group is active when power is restored.

Settings Change

If individual settings are changed for the active setting group or one of the other setting groups, the active setting group is retained, much like in the preceding explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group, so the relay is not momentarily disabled.

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1 through SS6, the active setting group can be changed, subject to the newly enabled SS1 through SS6 settings.

SELOGIC Control Equation Capacity

SELOGIC control equation capacity is a measure of how much remaining space you have available for programming. In both protection and automation, SELOGIC control equation capacity includes execution capacity and settings storage capacity.

The relay will reject any setting that exceeds the available settings storage capacity and execution capacity. You can then accept the previous settings you have entered and examine your settings.

Protection

The SEL-487E provides storage space for as many as 250 lines of protection free-form programming. Because the relay executes protection fixed and free-form logic at a deterministic interval, there is a limit to the amount of SELOGIC control equation programming that the relay can execute. The relay calculates total capacity in terms of settings capacity and execution capacity.

Rather than limit parameters to guarantee that your application not exceed the maximum processing requirements, the relay measures and calculates the available capacity when you enter SELOGIC control equations. The relay will not allow you to enter programming that will cause the relay to be unable to complete all protection SELOGIC control equations each protection processing interval.

There are six protection settings groups that can be active. When a protection settings group is active, the relay executes SELOGIC control equations in the Global Settings, Protection Group Settings, Protection Free-Form Settings, Output Settings, and several other settings areas. The relay calculates protection capacities based on the total amount of SELOGIC control equation programming executed when the protection settings group is active. Use the **STATUS S** command to display the remaining settings capacity and execution capacity for protection fixed and free-form logic.

Automation

The SEL-487E provides storage space for 10 blocks of as many as 100 lines of automation free-form programming each. The relay executes automation programming differently than protection logic programming. The result is that automation free-form logic execution time varies with the amount of free-form logic expressions that you enter. As you enter more expressions, the time required for the relay to execute all expressions increases. You can display the peak and average execution time using the **STATUS S** command.

There is a maximum execution capacity and settings storage capacity. If you enter a setting that exceeds maximum capacity, the relay will reject the setting. You will have the opportunity to reenter the setting or save any other settings you entered during that session.

SELOGIC Control Equation Elements

SELOGIC control equation elements are a collection of storage locations, timers, and counters that you can use to customize the operation of your SEL-487E and use the relay to automate substation operation. The elements that you can use in SELOGIC control equations are summarized in *Table 12.5*.

Table 12.5 Summary of SELOGIC Control Equation Elements

Element	Description
Relay Word bits	Boolean value data
Analog quantities	Received, measured, and calculated values
Special condition bits	Bits that indicate special SELOGIC control equation execution conditions
SELOGIC control equation variables	Storage locations for the results of Boolean SELOGIC control equations
SELOGIC control equation math variables	Storage locations for the results of math SELOGIC control equations
Latch bits	Nonvolatile storage for the results of Boolean SELOGIC control equations
Conditioning timers	Pickup and dropout style timers similar to those used in SEL-300 series relays
Sequencing timers	On-delay timers similar to those used in programmable logic controllers
Counters	Counters that count rising edges of Boolean value inputs

Relay Word Bits and Analog Quantities

Data within the relay are available for use in SELOGIC control equations. Relay Word bits are binary data that include protection elements, input status, and output status. *Appendix G: Relay Word Bits* contains a list of Relay Word bits available within the SEL-487E. Analog quantities are analog values within the relay including measured and calculated values. *Appendix H: Analog Quantities* contains a list of analog quantities available within the SEL-487E.

Special Condition Bits

Several Relay Word bits are available for special conditions related to SELOGIC control equation programming in the SEL-487E. You can use these bits in SELOGIC control equation programming to react to these conditions. You can also send these bits to other devices through relay interfaces including MIRRORED BITS communications and DNP3. The special condition bits are shown in *Table 12.6*.

The relay sets the first execution bits AFRTEXA, AFRTEXP, and PFRTEX momentarily to allow you to detect changes in the relay operation. The relay sets these bits and clears them as described in *Table 12.6*, *Table 12.7*, and *Table 12.8*. You can use these bits to force logic and calculations to reset or take a known state on power-up or settings change operations.

Table 12.6 First Execution Bit Operation on Power-Up

Name	Description
AFRTEXA	Relay sets on power-up and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on power-up. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on power up. Relay clears after protection runs for one cycle.

Table 12.7 First Execution Bit Operation on Automation Settings Change

Name	Description
AFRTEXA	Relay sets on settings change and clears after each automation programming block has been executed once.
AFRTEXP	Relay sets on settings change. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets on settings change. Relay clears after protection runs for one cycle.

Table 12.8 First Execution Bit Operation on Protection Settings Change, Group Switch, and Source Selection

Name	Description
AFRTEXA	Relay does not set.
AFRTEXP	Relay sets when listed event occurs. Relay clears after it enables protection and all automation programming blocks have been executed once.
PFRTEX	Relay sets when listed event occurs. Relay clears after protection runs for one cycle.

SELOGIC Control Equation Variables

SELOGIC control equation variables are Boolean storage locations. Each variable equals either logical 1 or logical 0. This manual refers to these variables and the relay displays these as 1 and 0, respectively. Think also of the states 1 and 0 as True and False when you evaluate Boolean logic statements. The quantities of SELOGIC control equation variables available in the different programming areas are listed in *Table 12.9*.

Table 12.9 SELOGIC Control Equation Variable Quantities

Type	Quantity	Name Range
Protection SELOGIC control equation variables	64	PSV01–PSV64
Automation SELOGIC control equation variables	256	ASV001–ASV256

Use the SELOGIC control equation variables in free-form logic statements in any order you want. Use a SELOGIC control equation variable more than once in free-form logic programming, and use SELOGIC control equation variables as arguments in SELOGIC control equations. *Example 12.4* illustrates SELOGIC control equation variable usage.

EXAMPLE 12.4 SELOGIC Control Equation Variables

The equations below show free-form SELOGIC control equation programming examples that use SELOGIC control equation variables. Each line has a comment after the # that provides additional detail.

PSV01 := **1** # Set PSV01 to 1 always.

PSV09 := **PSV54 AND ASV005** # Set to result of Boolean AND.

PSV02 := **PMV05 > 5** # Set if PMV05 is greater than 5

You can use SELOGIC control equation variables more than once in free-form programming. The SELOGIC control equations below use ASV100 and ASV101 to calculate intermediate results.

Remote control 1

ASV100 := **RB14 AND ALT01** # Supervise remote control with ALT01

ASV101 := **RB15 AND PLT07** # Supervise remote control with PLT07

ASV201 := **ASV100 OR ASV101** # Store desired control in ASV201

Remote control 2

ASV100 := **RB18 AND ALT09** # Supervise remote control with ALT09

ASV101 := **RB19 AND PLT13** # Supervise remote control with PLT13

ASV202 := **ASV100 OR ASV101** # Store desired control in ASV202

SELOGIC Control Equation Math Variables

SELOGIC control equation math variables are math calculation storage results. As with protection and automation SELOGIC control equation variables, there are separate storage areas for protection and automation math calculations. The quantities of SELOGIC control equation math variables available in the SEL-487E are shown in *Table 12.10*.

Table 12.10 SELOGIC Control Equation Math Variable Quantities

Type	Quantity	Name Range
Protection SELOGIC control equation math variables	64	PMV01–PMV64
Automation SELOGIC control equation math variables	256	AMV001–AMV256

Use math variables in free-form programming to store the results of math calculations as arguments in math calculations and comparisons. *Example 12.5* illustrates SELOGIC control equation math variable usage.

EXAMPLE 12.5 SELOGIC Control Equation Math Variables

The equations below show free-form SELOGIC control equation programming examples that use SELOGIC control equation math variables. Each line has a comment after the # that provides additional description.

PMV01 := **378.62** # Store 387.62 in PMV01

PMV09 := **5 + IASFM** # Store sum of 5 and A-phase, Winding S, current in PMV09

You can use SELOGIC control equation math variables more than once in free-form programming. Use AMV010 in the following SELOGIC control equations to calculate intermediate results.

Determine if any phase voltage is greater than 13 kV

A-phase

AMV010 := **IASFM/1000** # Winding S, A Phase

ASV010 := **AMV010 > 5** # Set if greater than 5

B-phase

AMV010 := **IASFM/1000** # Winding S, B Phase

ASV011 := **AMV010 > 5** # Set if greater than 5

C-phase

AMV010 := **ICSFM/1000** # Winding S, C Phase

ASV012 := **AMV010 > 5** # Set if greater than 5

Combine phase results

ASV013 := **ASV010 OR ASV011 OR ASV012**

Latch Bits

Latch bits are nonvolatile storage locations for Boolean information. Latch bits are in several settings areas of the relay, as shown in *Table 12.11*. Latch bits have two input parameters, Reset and Set, and one Latched Value, as shown in *Table 12.12*.

Table 12.11 Latch Bit Quantities

Type	Quantity	Name Range
Protection free-form latch bits	32	PLT01–PLT32
Automation latch bits	32	ALT01–ALT32

Table 12.12 Latch Bit Parameters

Type	Item	Description	Setting	Name Examples
Input	Reset	Reset latch when on	Boolean SELOGIC control equation	PLT01R ALT01R
Input	Set	Set latch when on	Boolean SELOGIC control equation	PLT01S ALT01S
Output	Latched Value	Latched Value of 0 or 1	Value for use in Boolean SELOGIC control equations	PLT01 ALT24

Latch bits provide nonvolatile storage of binary information. A latch can have the value of logical 0 or logical 1. Latch bits also retain their state through changes in the active protection settings group. Because storage of latch bits is in nonvolatile memory, the state of latch bits remains unchanged indefinitely, even when power is lost to the relay.

As with logic latches used in digital electronics, each latch bit has a Set input and a Reset input. The relay evaluates the latch bit value at the end of each logic processing interval using the values for Set and Reset calculated during the processing interval. Latch bits are reset dominant. If the Set and Reset inputs are both asserted, the relay will reset the latch.

Latch bits are available in two different programming areas of the SEL-487E. First, there are 32 latch bits, PLT01–PLT32, that are associated with protection settings. Second, there are 32 latch bits, ALT01–ALT32, available in automation free-form programming.

Protection Latch Bits

Program the 32 latch bits, PLT01–PLT32, in the protection free-form SELOGIC control equation programming area. There is a separate protection free-form SELOGIC control equation programming area associated with each protection settings group. The latches in protection can have separate programming for Set and Reset in each protection settings group. While each protection latch value remains unchanged for a change in the active protection settings group, you can enter different Set and Reset programming for each protection settings group.

There are Set and Reset settings for each latch bit available in each group. For example, PLT01R and PLT01S are available in all six free-form settings groups and all control the same Latch Bit, PLT01. This structure allows you to either program each latch to operate in the same way for each group or behave differently based on the active protection settings group. For example, you could program the protection latch to set on IN107 when Protection Settings Group 1 is active and program the latch to set on IN106 when Protection Settings Group 2 is active. If you do not enter a setting for the Reset and Set in a protection settings group, the latch bit will remain unchanged when that protection settings group is active. *Example 12.6* illustrates protection latch bit usage.

EXAMPLE 12.6 Protection Latch Bits

In this example, Remote Bit 2 (RB02) is a blocking command for remote control to the relay. A latch bit stores the incoming command and preserves the state associated with the command through a power cycle. Remote Bit 1 sends the operator-initiated circuit breaker open/close command. Because the protection design uses protection settings groups 1 through 3, the settings shown below are duplicated in protection SELOGIC control equation free-form programming areas associated with protection settings groups 1 through 3.

```
#
# Store incoming remote command block in Protection Latch Bit 2
#
PLT01R := RB02 AND PLT01 # Reset latch if RB02 off and latch set
PLT01S := RB02 AND NOT PLT01 # Set latch if RB02 on and latch not set
#
# Use PSV30, PSV31 to calculate open and close conditions
#
PSV30 := RB01 AND NOT PLT01 # Open if RB01 and not blocked
PSV32 := R_TRIG PSV30 # One processing interval Open command
PSV31 := NOT RB01 AND NOT PLT01 # Close if RB01 off and not blocked
PSV33 := R_TRIG PSV31 # One processing interval Close command
```

In this example, PSV32 and PSV33 are used in the trip and close equations. PSV34 will be set to 1 for an open command and reset to 0 for a trip command. The TRIP and CLOSE equations are shown below:

```
TRS := PSV32 # Remote manual trip RB02 supervised with RB01 enable
TRT := PSV33 # Remote manual close RB02 supervised with RB01 enable
```

Evaluation of the latch bit value occurs at the end of the protection SELOGIC control equation execution cycle. The values evaluated for Reset (PLT*nn*R) and Set (PLT*nn*S) during SELOGIC control equation execution remain unchanged until after the evaluation of all SELOGIC control equations, when the relay evaluates the latch bit value (PLT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the protection free-form area dominates, and the relay uses this equation to evaluate the latch.

Automation Latch Bits

The automation latch bits, ALT01–ALT32, are available in automation free-form settings. Write free-form SELOGIC control equations to set and reset these bits. As with protection latch bits, the relay stores automation latch bits in nonvolatile memory and preserves these through a relay power cycle and group change operations. With protection latch bits, you can implement Set and Reset programming for each protection settings group. Automation SELOGIC control equation programming, however, has only one programming area active for all protection settings groups.

The relay evaluates the latch bit value at the end of the automation free-form SELOGIC control equation execution cycle. The values for Reset (ALT*nn*R) and Set (ALT*nn*S) remain unchanged until evaluation of all SELOGIC control equations, when the relay evaluates the latch (ALT*nn*). For example, if you have multiple SELOGIC control equations for set, the last equation in the automation free-form area dominates, and the relay uses this equation to evaluate the latch.

Conditioning Timers

Use conditioning timers to condition Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state. Conditioning timers are available in the protection free-form area, as shown in *Table 12.13*. Conditioning timers have the three input parameters and one output shown in *Table 12.14*.

Table 12.13 Conditioning Timer Quantities

Type	Quantity	Name Range
Protection free-form conditioning timers	32	PCT01–PCT32

Table 12.14 Conditioning Timer Parameters

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PCT01IN
Input	Pickup Time	Time that the input must be on before the output turns on	Time value in cycles	PCT01PU
Input	Dropout Time	Time that the output stays on after the input turns off	Time value in cycles	PCT01DO
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PCT01Q

A conditioning timer output turns on and becomes logical 1, after the input turns on and the Pickup Time expires. An example timing diagram for a conditioning timer, PCT01, with a Pickup Time setting greater than zero and a Dropout Time setting of zero is shown in *Figure 12.3*. In the example timing diagram, the Input, PCT01IN, turns on and the timer Output, PCT01Q, turns on after the Pickup Time, PCT01PU, expires. Because the Dropout Time setting is zero, the Output turns off when the Input turns off.

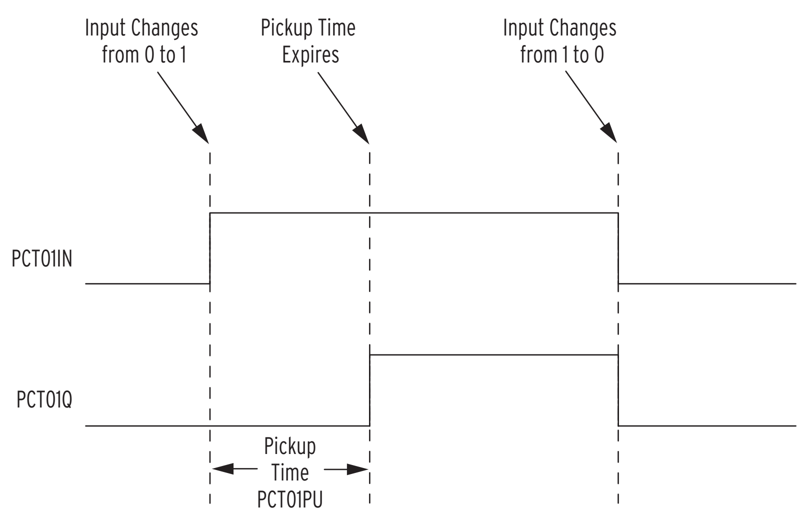

Figure 12.3 Conditioning Timer With Pickup and No Dropout Timing Diagram

If the Pickup Time is not satisfied, the timer Output never turns on, as illustrated in *Figure 12.4*.

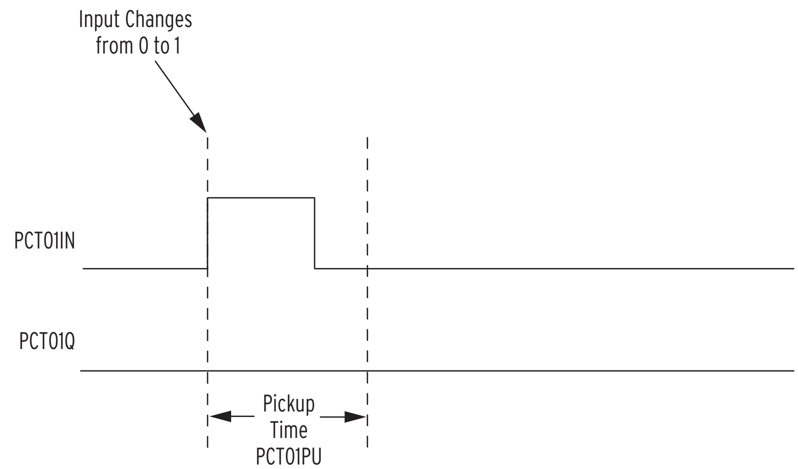

Figure 12.4 Conditioning Timer With Pickup Not Satisfied Timing Diagram

A conditioning timer output turns off when the input turns off and the Dropout Time expires. An example timing diagram for a conditioning timer, PCT02, with a Pickup Time setting of zero and a Dropout Time setting greater than zero is shown in *Figure 12.5*. Because the Pickup Time, PCT02PU, setting is zero, the Output, PCT02Q, turns on when the Input, PCT02IN, turns on. The Output turns off after the Input turns off and the Dropout Time, PCT02DO, expires.

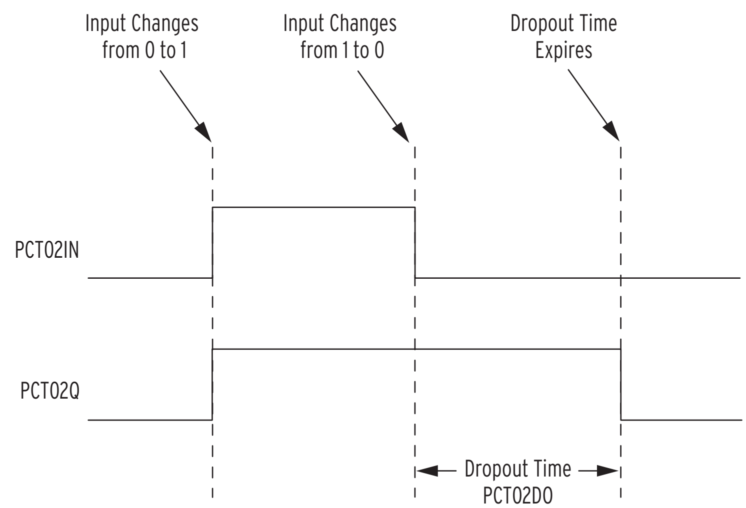

Figure 12.5 Conditioning Timer With Dropout and No Pickup Timing Diagram

Combining the features shown above, *Figure 12.6* illustrates conditioning timer operation for use of both the pickup and dropout characteristics. The Output, PCT03Q, turns on after the Input, PCT03IN, turns on and the Pickup Time, PCT03PU, expires. The Output turns off after the Input turns off and the Dropout Time, PCT03DO, expires.

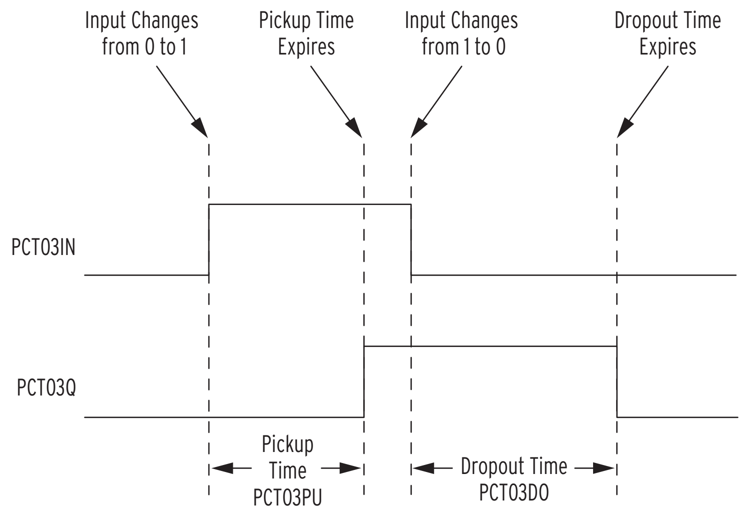

Figure 12.6 Conditioning Timer With Pickup and Dropout Timing Diagram

Set the conditioning timer settings for Pickup and Dropout in cycles and fractions of a cycle (represented in decimal form). The relay processes conditioning timers once for each protection processing interval. The relay asserts the timer output on the first processing interval when the elapsed time exceeds the setting. In the SEL-487E, the protection processing interval is 1/8 cycle. Actual settings, programming, and operation are illustrated in *Example 12.7*.

EXAMPLE 12.7 Conditioning Timer Programming and Operation

This example uses Protection Free-Form Conditioning Timer Seven, PCT07. The free-form settings are as shown here:

PCT07PU := **5.3** # Pickup set to 5.3 cycles

PCT07DO := **6.0** # Dropout set to 6.0 cycles

PCT07IN := **IN101** # Operate on the first input on the main board

PSV29 := **PCT07Q** # Protection SELogic control equation variable follows the timer output

The operation of the timer when IN101 turns on for 7 cycles is shown in the timing diagram in Figure 12.7. Because the pickup setting is an uneven number of protection processing intervals (1/8 cycle), the pickup occurs on the first 1/8th cycle after the Pickup Time of 5.3 cycles expires.

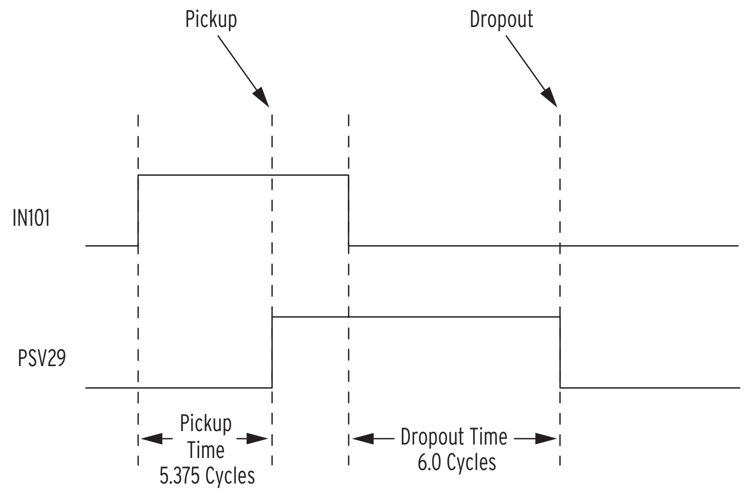

Figure 12.7 Conditioning Timer Timing Diagram for Example 12.7

In protection free-form programming, the relay evaluates the timer at execution of the timer Input SELOGIC control equation (PCT*nn*IN). The relay loads the Pickup Time (PCT*nn*PU) and Dropout Time (PCT*nn*DO) into the timer when the relay observes the appropriate edge in the input. If you enter a math expression for Pickup Time or Dropout Time, the relay uses the value calculated before the Input SELOGIC control equation. If your Pickup Time or Dropout Time equation is below the Input equation (has a higher expression line number), the relay will use the value calculated on the previous SELOGIC control equation execution interval. Because the relay calculates the last value for pickup or dropout in this manner, we recommend for most applications that you enter the Pickup Time, Dropout Time, and Input statements together in the order shown in *Example 12.7*.

Sequencing Timers

Sequencing timers are useful for sequencing operation. There are two main differences between sequencing timers and conditioning timers. First, sequencing timers integrate pulses of the input to count up a total time. Second, the elapsed time a sequencing timer counts is visible; you can use this time in other SELOGIC control equation programming or make this time visible through one of the relay communications protocol interfaces. Sequencing timers are available in the protection free-form area and automation free-form area as shown in *Table 12.15*. Sequencing timers have three input parameters and two outputs listed in *Table 12.16*.

Table 12.15 Sequencing Timer Quantities

Type	Quantity	Name Range
Protection free-form sequencing timers	32	PST01–PST32
Automation free-form sequencing timers	32	AST01–AST32

Table 12.16 Sequencing Timer Parameters (Sheet 1 of 2)

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay times	Boolean SELOGIC control equation setting	PST01IN AST07IN
Input	Preset Time	Time the input must be on before the output turns on	Time value. Protection uses cycles, while automation uses seconds.	PST01PT AST07PT

Table 12.16 Sequencing Timer Parameters (Sheet 2 of 2)

Type	Item	Description	Setting	Name Examples
Input	Reset	Timer reset	Boolean SELOGIC control equation setting	PST01R AST07R
Output	Elapsed Time	Time accumulated since the last reset	Value for math SELOGIC control equations. Protection uses cycles, while automation uses seconds.	PST01ET AST07ET
Output	Output	Timer output	Value for Boolean SELOGIC control equations	PST01Q AST07Q

A sequencing timer counts time by incrementing the Elapsed Time when SELOGIC control equation execution reaches the Input equation if the Reset is off and the Input is on. The Output turns on when the Elapsed Time reaches or exceeds the Preset Time. Whenever the Reset is on, the relay sets the Output to zero, then clears the Elapsed Time, and stops accumulating time (even if Input is on).

Figure 12.8 is a timing diagram for typical sequencing timer operation.

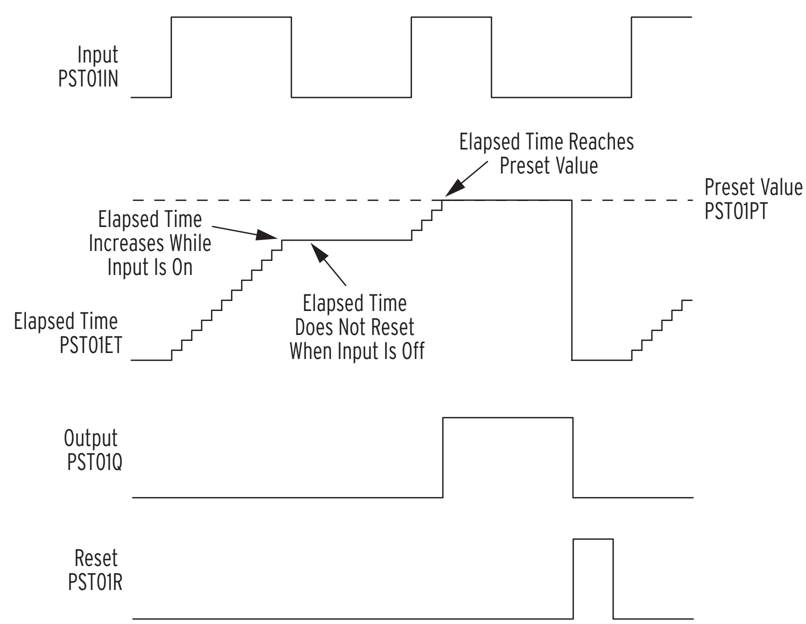

Figure 12.8 Sequencing Timer Timing Diagram

Timers in protection programming operate in cycles, while timers in automation programming operate in seconds. As with sequencing timers, operation depends on the logic processing interval. For protection programming, the logic processing interval is 1/8 cycle, so the relay effectively rounds up all operation to the nearest 1/8 cycle. With automation programming, the execution interval depends on the amount of automation programming. Determine the average automation execution interval with the **STATUS S** command.

The automation timers operate using a real time clock. Each time the relay evaluates the Input (AST*nn*IN) the relay adds the elapsed time since the last execution to the Elapsed Time (AST*nn*ET). The accuracy of the timer in stopping and starting when the input of the timer turns on averages half an automation execution cycle. If you change automation free-form programming, you must also check the new automation average execution cycle to verify that you will obtain satisfactory accuracy for your application. *Example 12.8* describes typical timer programming and describes the resulting operation.

EXAMPLE 12.8 Automation Sequencing Timer Programming

The equations below are an example of programming for an automation sequencing timer, AST01. Each timer input is programmed as a separate statement in automation SELOGIC control equation programming.

Example programming of sequencing timer to time Input IN101 and IN102

AST01PT := **7.5** # Timer Preset Time of 7.5 seconds

AST01R := **RB03** # Reset timer when RB03 turns on

AST01IN := **IN101 AND IN102** # Timing time when IN101 and IN102 are on

ASV001 := **AST01Q** # ASV001 tracks output of timer

AMV256 := **AST01ET** # AMV256 tracks timing progress

In this example, timer AST01 times the quantity IN101 AND IN102 and turns on when the total time reaches 7.5 seconds. If the Input, AST01IN, is on for approximately 1 second every minute, the Output, AST01Q, will turn on during the eighth minute, when the accumulated elapsed time exceeds 7.5 seconds.

In free-form programming, the relay evaluates the timer at the timer Input SELOGIC control equation (PST*nn*IN or AST*nn*IN). If you enter an expression for the timer Reset (PST*nn*R or AST*nn*R) or Preset Time (PST*nn*PT or AST*nn*PT), the values for Reset and Preset Time that the relay uses are the last values that the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset Time value in this manner, we recommend for most applications that you enter the Preset Time, Reset, and Input statements together in the order shown in *Example 12.8*.

Counters

Use counters to count changes or edges in Boolean values. Each time the value changes from logical 0 to logical 1 (a rising edge), the counter Current Value increments. Counters are available in the protection free-form area and automation free-form area, as shown in *Table 12.17*. Counters have three input parameters, Input, Preset Value, and Reset; and two outputs, Current Value and Output as listed in *Table 12.18*.

Table 12.17 Counter Quantities

Type	Quantity	Name Range
Protection counters	32	PCN01–PCN32
Automation counters	32	ACN01–ACN32

Table 12.18 Counter Parameters (Sheet 1 of 2)

Type	Item	Description	Setting	Name Examples
Input	Input	Value that the relay counts	Boolean SELOGIC control equation setting	PCN01IN ACN09IN
Input	Preset Value	Number of counts before the output turns on	Constant or expression for the number of counts	PCN01PV ACN09PV

Table 12.18 Counter Parameters (Sheet 2 of 2)

Type	Item	Description	Setting	Name Examples
Input	Reset	Counter reset	Boolean SELOGIC control equation setting	PCN01R ACN09R
Output	Current Value	Current accumulated count	Value for math SELOGIC control equations	PCN01CV ACN09CV
Output	Output	Counter output	Value for Boolean SELOGIC control equations	PCN01Q ACN09Q

In free-form programming, the relay evaluates the counter at execution of the counter Input SELOGIC control equation (PCN*nn*IN or ACN*nn*IN). If you enter an expression for the counter Reset (PCN*nn*R) or the counter Preset (PCN*nn*PV), the values for Reset and Preset that the relay uses are the last values the relay calculates before the input SELOGIC control equation calculation. Because the relay uses the last values for Reset and Preset in this manner, we recommend for most applications that you enter the Preset, Reset, and Input statements together in the order shown in *Example 12.9*.

EXAMPLE 12.9 Counter Programming

The free-form programming equations that follow demonstrate how to enter settings to control a protection counter in protection free-form SELOGIC control equation programming. Programming for an automation counter is similar.

Protection Counter 1 counts close operations of the circuit breaker associated with the 52A_S element. Initially, the current value, PCN01CV, is zero. The relay increments the current value each time the circuit breaker closes. The relay increases the count value, PCN01CV, each time the circuit breaker closes and the element 52A_S value changes from 0 to 1 (a rising edge). When the count reaches 1000, the timer automatically resets and begins counting again.

```
# Example protection counter programming
#
# This example counts how many times a three-pole circuit breaker closes
# The counter automatically resets every 1,000 operations
PCN01PV := 1000
PCN01R := PCN01Q
PCN01IN := 52A_S
```

The SELOGIC control equations below provide multiple-change detection counting both close and open operations of the circuit breaker. The intermediate value PSV01 turns on for one processing interval each time the circuit breaker closes. The intermediate value PSV02 turns on for one processing interval each time the circuit breaker opens. The OR combination of PSV01 and PSV02 contains a rising edge for each circuit breaker operation, open or closed, that Protection Counter 1 counts.

```
# Example protection counter programming
#
# This example counts how many times a three-pole circuit breaker operates
either open or closed
#
# Detect OPEN and CLOSE and combine
PSV01 := R_TRIG 52A_S # Pulse for each close
```

PSV02 := **F_TRIG 52A_S** # Pulse for each open

PSV03 := **PSV01 OR PSV02** # Pulse for each open or close

#

The counter automatically resets every 1,000 operations

PCN01PV := **1000**

PCN01R := **PCN01Q**

PCN01IN := **PSV03** # Count open and close operations

PSV04 := **PCN01CV >900** # PSV04 signals impending reset

Aliases

Although the SEL-487E provides extensive programming facilities and opportunity for comments, troubleshooting customized programs is sometimes difficult. Aliases provide an opportunity to assign more meaningful names to the generic variable names in order to improve the readability of the program. *Example 12.10* provides examples of assigning aliases.

EXAMPLE 12.10 Assigning and Removing Aliases

The following free-form math SELOGIC control equations show you how to create aliases.

Assign the alias names with the **SET T** command

SET T

PMV01,THETA # Assign the alias “THETA” to PMV01

PMV02,TAN # Assign the alias “TAN” to PMV02

Use the alias names “THETA” and “TAN “ in a free-form SELOGIC control equation:

Calculate the tangent of THETA

TAN := **SIN(THETA)/COS(THETA)**

To remove the alias from the alias setting, issue the **SET T** command and press **<Enter>** until the alias appears; then type **DELETE <Enter>**:

SET T

nn: PMV01,THETA # (where nn = line number)

DELETE

Assign as many as 200 alias names to any Relay Word bit or analog quantity, using the **SET T** command. The maximum length of an alias is seven characters. Valid characters are 0–9, A–Z (only uppercase) and _ (underscore). Make sure no Relay Word bit or analog quantity appears more than once in the alias settings. Each alias name must be unique, i.e., you cannot use the name of an existing Relay Word bit or analog quantity. If you remove the alias name, all settings that referenced that alias revert to the original name.

SELOGIC Control Equation Operators

There are two types of SELOGIC control equations. Boolean SELOGIC control equations comprise the first type. These equations are expressions that evaluate to a Boolean value of 0 or 1. Math SELOGIC control equations constitute the second type. The relay evaluates these equations to yield a result having a numerical value (for example, 6.25 or 1055).

Left value, LVALUE, determines the type of SELOGIC control equation you need for a setting or for writing free-form programming. If the LVALUE is a Boolean type (52A_S, ASV001, etc.) then the type of expression you need is a Boolean SELOGIC control equation. If the LVALUE is a numerical (non-Boolean) value (PMV12, PCT01PV, etc.), the type of expression you need is a math SELOGIC control equation.

Writing SELOGIC control equations requires that you use the appropriate operators and correct SELOGIC control equation syntax to combine relay elements including analog values, Relay Word bits, incoming control points, and SELOGIC control equation elements within the relay. The operators are grouped into two types, according to the type of SELOGIC control equation in which you can apply these operators.

Operator Precedence

When you combine several operators and operations within a single expression, the SEL-487E evaluates the operations from left to right, starting with the highest precedence operators working down to the lowest precedence. This means that if you write an equation with three AND operators, for example PSV01 AND PSV02 AND PSV03, each AND will be evaluated from the left to the right. If you substitute NOT PSV04 for PSV03 to make PSV01 AND PSV02 AND NOT PSV04, the relay evaluates the NOT operation of PSV04 first and uses the result in subsequent evaluation of the expression. While you cannot use all operators in any single equation, the overall operator precedence follows that shown in *Table 12.19*.

Boolean Operators

Use Boolean operators to combine values with a resulting Boolean value. The arguments of the operator may be either numbers or Boolean values, but the result of the operation must be a Boolean value. Combine the operators to form statements that evaluate complex Boolean logic. *Table 12.20* contains a summary of Boolean operators available in the SEL-487E.

Table 12.19 Operator Precedence from Highest to Lowest

Operator	Description
(Expression)	Parenthesis
Identifier (argument list)	Function evaluation
–	Negation
NOT	Complement
R_TRIG F_TRIG	Edge Trigger
SQRT, LN, EXP, LOG, COS, SIN, ACOS, ASIN, ABS, CEIL, FLOOR	Math Functions
*	Multiply
/	Divide
+	Add
–	Subtract
<, >, <=, >=	Comparison
=	Equality
<>	Inequality
AND	Boolean AND
OR	Boolean OR

Table 12.20 Boolean Operator Summary

Operator	Description
( )	Parentheses
NOT	Logical inverse
AND	Logical AND
OR	Logical OR
R_TRIG	Rising-edge trigger
F_TRIG	Falling-edge trigger
>, <, =, <=, >=, <>	Comparison of values

Parentheses

Use paired parentheses to control the execution order of operations in a SELOGIC control equation. Use as many as 14 nested sets of parentheses in each SELOGIC control equation. The relay calculates the result of the operation on the innermost pair of parentheses first and then uses this result with the remaining operations. *Table 12.21* is a truth table for an example operation that illustrates how parentheses can affect equation evaluation.

Table 12.21 Parentheses Operation in Boolean Equation

A	B	C	A AND B OR C	A AND (B OR C)
0	0	0	0	0
0	0	1	1	0
0	1	0	0	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

NOT

Use NOT to calculate the inverse of a Boolean value according to the truth table shown in *Table 12.22*.

Table 12.22 NOT Operator Truth Table

Value A	NOT A
0	1
1	0

AND

Use AND to combine two Boolean values according to the truth table shown in *Table 12.23*.

Table 12.23 AND Operator Truth Table

Value A	Value B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

OR

Use OR to combine two Boolean values according to the truth table shown in *Table 12.24*.

Table 12.24 OR Operator Truth Table

Value A	Value B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

R_TRIG

R_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Figure 12.9*. Use R_TRIG to sense when a value changes from logical 0 to logical 1 and take action only once when the value changes.

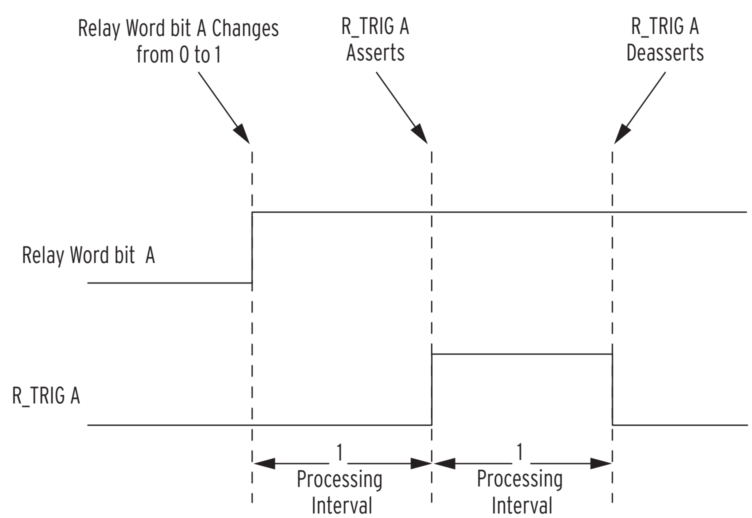

Figure 12.9 R_TRIG Timing Diagram

The argument of an R_TRIG statement must be a single bit within the SEL-487E. An example of the relay detecting a rising edge of a calculated quantity is shown in *Example 12.11*.

EXAMPLE 12.11 R_TRIG Operation

The SELOGIC control equation below is invalid.

PSV15 := **R_TRIG (PSV01 AND PSV23)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the R_TRIG operation on the result, as shown below.

PSV14 := **PSV01 AND PSV23** # Calculate quantity in an intermediate result variable

PSV15 := **R_TRIG PSV14** # Perform an R_TRIG on the quantity

F_TRIG

F_TRIG is a time-based function that creates a pulse when another value changes, as shown in *Example 12.11*. Use F_TRIG to sense when a value changes from logical 1 to logical 0 and take action only after the value changes state.

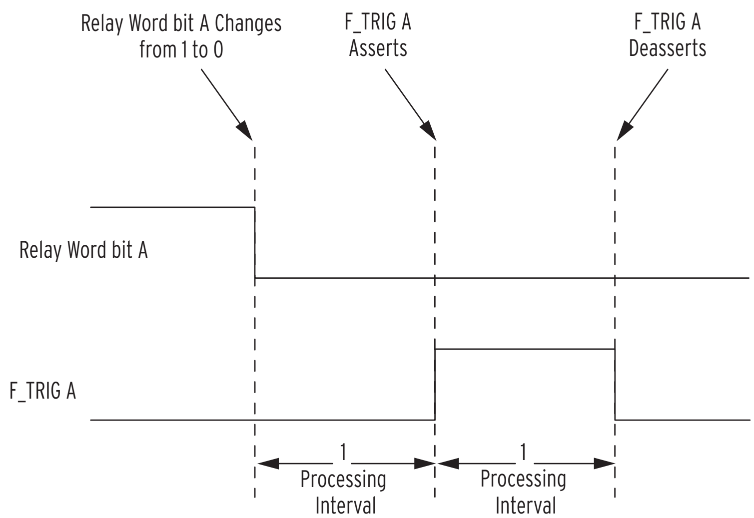

Figure 12.10 F_TRIG Timing Diagram

The argument of an F_TRIG statement must be a single bit within the SEL-487E. An example of the relay detecting a falling edge of a calculated quantity is shown in *Example 12.12*.

EXAMPLE 12.12 F_TRIG Operation

The SELOGIC control equation below shows an invalid use of the F_TRIG operation.

ASV015 := **F_TRIG (ASV001 AND ALT11)** # Invalid statement, do not use

Use a SELOGIC control equation variable to calculate the quantity and then use the F_TRIG operation on the result, as shown below.

ASV014 := **ASV001 AND ALT11** # Calculate quantity in an intermediate result variable

ASV015 := **F_TRIG ASV14** # Perform an F_TRIG on the quantity

Comparison

Comparison is a mathematical operation that compares two numerical values with a result of logical 0 or logical 1. AND and OR operators compare Boolean values; comparison functions compare floating-point values such as currents and other quantities. Comparisons and truth tables for operation of comparison functions are shown in *Table 12.25*.

Table 12.25 Comparison Operations

A	B	A>B	A>=B	A=B	A<>B	A<=B	A<B
6.35	7.00	0	0	0	1	1	1
5.10	5.10	0	1	1	0	1	0
4.25	4.00	1	1	0	1	0	0

Math Operators

Use math operators when writing math SELOGIC control equations. Math SELOGIC control equations manipulate numerical values and provide a numerical base 10 result. *Table 12.26* summarizes the operators available for math SELOGIC control equations.

Table 12.26 Math Operator Summary

Operator	Description
( )	Parentheses
+, –, *, /	Arithmetic
SQRT	Square root
LN, EXP, LOG	Natural logarithm, exponentiation of e, base 10 logarithm
COS, SIN, ACOS, ASIN	Cosine, sine, arc cosine, arc sine
ABS	Absolute value
CEIL	Rounds to the nearest integer towards infinity
FLOOR	Rounds to the nearest integer towards minus infinity
–	Negation

Parentheses

Use parentheses to control the order in which the relay evaluates math operations within a math SELOGIC control equation. Also use parentheses to group expressions that you use as arguments to function operators such as SIN and COS. Include as many as 14 levels of nested parentheses in your math SELOGIC control equation. *Example 12.13* shows how parentheses affect the operation and evaluation of math operations.

EXAMPLE 12.13 Using Parentheses in Math Equations

The free-form math SELOGIC control equations below show examples of parentheses usage.

Examples of parenthesis usage

AMV001 := **AMV005 * (AMV004 + AMV003)** # Calculate sum first, then product

AMV002 := **AMV010 * (AMV009 + (AMV016 / AMV015))** # Nest parentheses

AMV003 := **SIN (AMV037 + PMV42)** # Group terms for a function

Math Error Detection

If a math operation results in an error, the SEL-487E turns on the math error bit, MATHERR, in the Relay Word. A settings change or the **STATUS SC** command provides reset for this bit. For example, if you attempt to take the square root of a negative number (SQRT –5), the math error bit will be asserted until you clear the bit with a **STATUS SC** command or change settings.

Table 12.27 Math Error Examples

Example	Value in PMV01	Type	MATHERR
PMV01 := PMV02 / 0	Infinity	Divide by zero	Yes
PMV01 := LN (0)	0[a]	LN of 0	Yes
PMV01 := LN (-1)	0[a]	LN of negative number	Yes
PMV01 := SQRT (-1)	0[a]	Square root of a negative number	Yes

[a] Evaluation of expression results in an error and prevents storage of new result. In the example, PMV01 remains 0. If the argument were a variable, PMV01 would contain the result of the last evaluation when the argument is valid.

Arithmetic

Use arithmetic operators to perform basic mathematical operations on numerical values. Arguments of an arithmetic operation can be either Boolean or numerical values. In a numerical operation, the relay converts logical 0 or logical 1 to the numerical value of 0 or 1. For example, multiply numerical values by Boolean values to perform a selection operation. Use parentheses to group terms in math SELOGIC control equations and control the evaluation order and sequence of arithmetic operations.

The relay uses IEEE 32-bit floating-point numbers to perform SELOGIC control equation mathematical operations. If an operation results in a quantity that is not a numerical value, the SELOGIC control equation status bit that signals a math error, MATHERR, asserts. The value that the relay stored previously in the specified result location is not replaced. The SEL-487E clears the corresponding math error bits if you change SELOGIC control equation settings (protection or automation), or if you issue a **STATUS SC** command. *Example 12.14* contains examples of arithmetic operations in use.

EXAMPLE 12.14 Using Arithmetic Operations

The free-form math SELOGIC control equations below show examples of arithmetic operator usage.

Arithmetic examples

AMV001 := **AMV005 + AMV034** # Calculate sum

AMV002 := **AMV005 – AMV034** # Calculate difference

AMV003 := **AMV005 * AMV034** # Calculate product

AMV004 := **AMV005 / AMV034** # Calculate quotient

The lines below demonstrate the use of Boolean values with the multiplication operation.

Use of multiplication to select numerical values based on active settings group

Use 7 if protection settings group 1 active

Use 5 if protection settings group 2 active

AMV005 := **7 * SG1 + 5 * SG2**

The lines below demonstrate math calculation error detection.

The line below results in a math error if AMV029 becomes 0

AMV006 := **732 / AMV029**

In the second line, if AMV029 is 6 on the first pass through the automation programming, the relay stores the result 122 in AMV006. If on the next pass AMV029 is 0, the MATHERR bit asserts and the value in AMV006 does not update.

SQRT

Use the SQRT operation to calculate the square root of the argument. Use parentheses to delimit the argument of a SQRT operation. A negative argument for the SQRT operation results in a math error and assertion of the corresponding math error bit described in *Arithmetic on page 12.30*. *Example 12.15* shows examples of the SQRT operator in use.

EXAMPLE 12.15 Using the SQRT Operator

The free-form math SELOGIC control equations below show examples of SQRT operator usage.

SQRT examples

AMV001 := **SQRT (AMV005)** # Single argument version of SQRT

AMV002 := **SQRT (AMV005 + AMV034)** # Calculates the square root of the sum

AMV003 := **SQRT (AMV007)** # Produces a math error if AMV007 is negative

LN, EXP, and LOG

LN and EXP are complementary functions for operating with natural logarithms or logarithms calculated to the natural base e. LN calculates the natural logarithm of the argument. LOG calculates the base 10 logarithm of the argument. A negative or zero argument for the LN and LOG operation results in a math error and assertion of the corresponding math error bit described in *Arithmetic on page 12.30*. EXP calculates the value of e raised to the power of the argument. *Example 12.16* shows examples of expressions that use the LN, EXP, and LOG operators.

EXAMPLE 12.16 Using the LN, EXP, and LOG Operators

The free-form math SELOGIC control equations below are examples of LN, EXP, and LOG operator usage.

LN examples

AMV001 := **LN (AMV009)** # Natural logarithm of AMV009

AMV002 := **LN (AMV009 + AMV034)** # Natural logarithm of the sum

AMV003 := **LN (AMV010)** # Produces error if AMV010 is 0 or negative

EXP examples

AMV004 := **EXP (2)** # Calculates e squared

AMV005 := **EXP (AMV003)** # Calculates e to the power AMV003

AMV006 := **EXP (AMV046 + AMV047)** # e raised to the power of the sum

LOG examples

AMV007 := **LOG (AMV012)** # Base 10 logarithm of AMV012

AMV008 := **LOG (AMV012 + AMV022)** # Base 10 logarithm of the sum

AMV009 := **LOG (AMV100)** # Produces an error if AMV100 is 0 or negative

SIN and COS

Use the SIN or COS operators to calculate the sine or cosine of the argument. SIN and COS operate in degrees, the unit of angular measure the SEL-487E uses to express metering quantities. *Example 12.17* shows examples of SIN and COS.

EXAMPLE 12.17 Using the SIN and COS Operators

The free-form math SELOGIC control equations below are examples of SIN and COS.

SIN examples

AMV001 := **SIN (AMV005)** # Sine of AMV005

AMV002 := **SIN (AMV005 + AMV034)** # Sine of the sum

COS examples

AMV003 := **COS (AMV005)** # Cosine of AMV005

AMV004 := **COS (AMV005 + AMV006)** # Cosine of the sum

ASIN and ACOS

Use the ASIN or ACOS operators to calculate the angle resulting from the trigonometric function equivalent to a given number (the argument), where the function is sine or cosine. ASIN and ACOS operate in degrees. An argument less than –1 or larger than 1 results in a math error and assertion of the corresponding math bit described in *Arithmetic on page 12.30*. *Example 12.18* shows examples of ASIN and ACOS.

EXAMPLE 12.18 Using the ASIN and ACOS Operators

The free-form math SELOGIC control equations below are examples of ASIN and ACOS.

ASIN examples

AMV001 := **ASIN (AMV010)** # Arc sine of AMV010

AMV002 := **ASIN (AMV010 + AMV011)** # Arc sine of the sum

AMV003 := **ASIN (AMV012)** # Produces an error if |AMV012| > 1

ACOS examples

AMV004 := **ACOS (AMV010)** # Arc cosine of AMV010

AMV005 := **ACOS (AMV010 + AMV011)** # Arc cosine of the sum

AMV006 := **ACOS (AMV012)** # Produces an error if |AMV012| > 1

ABS

Use the ABS operation to calculate absolute value of the argument. Use parentheses to group a math expression as the argument of an ABS operation. If the argument of the ABS operation is negative, the result is the value multiplied by –1. If the argument of the ABS operation is positive, the result is the same quantity as the argument. *Example 12.19* contains examples of the ABS operator in use.

EXAMPLE 12.19 Using the ABS Operator

The free-form math SELOGIC control equations below show examples of the ABS operator usage.

ABS examples

AMV001 := **ABS (-6)** # Stores 6 in AMV001

AMV002 := **ABS (6)** # Stores 6 in AMV002

AMV003 := **ABS (AMV009)** # Absolute value of AM009

AMV004 := **ABS (AMV005 + AMV034)** # Absolute value of the sum

CEIL

Use the CEIL operator to round the argument to the nearest integer towards infinity. Use parentheses to group a math expression as the argument of a CEIL operation. *Example 12.20* contains examples of the CEIL operator.

EXAMPLE 12.20 Using the CEIL Operator

The free-form math SELogic control equations below show examples of the CEIL operator usage.

CEIL examples

AMV001 := **CEIL (5.99)** # Stores 6 in AMV001

AMV002 := **CEIL (–4.01)** # Stores -4 in AMV002

FLOOR

Use the FLOOR operator to round the argument to the nearest integer towards minus infinity. Use parentheses to group a math expression as the argument of a FLOOR operation. *Example 12.21* contains examples of the FLOOR operator.

EXAMPLE 12.21 Using the FLOOR Operator

The free-form math SELogic control equations below show examples of the FLOOR operator usage.

FLOOR examples

AMV001 := **FLOOR (5.99)** # Stores 5 in AMV001

AMV002 := **FLOOR (–4.01)** # Stores –5 in AMV002

Negation

Use the negation (–) operation to change the sign of the argument. The argument of the negation operation is multiplied by –1. Negation of a positive value results in a negative value, while negation of a negative value results in a positive value. *Example 12.22* contains examples of expressions that utilize the negation operator.

EXAMPLE 12.22 Using the Negation Operator

The free-form math SELogic control equations below show examples of negation operator usage.

Negation examples

AMV001 := **-AMV009** # If AMV009 is 5, stores -5 in AMV001

AMV002 := **-AMV009** # If AMV009 is -5, stores 5 in AMV002

Effective Programming

This section contains several ideas useful for creating, maintaining, and troubleshooting programming in the SEL-487E protection and automation SELOGIC control equation programming environments.

Planning and Documentation

When you begin to configure the relay to perform a new automation task or customize protection operation, take time to design, document, and implement your project. Scale the planning effort to match the overall size of the project, but spend sufficient time planning to do the following:

- Document the inputs and outputs of your programming. This may include protection elements, physical inputs and outputs, metering quantities, user inputs, and other information within the relay.
- Document the processing or outcome of the programming. List the major tasks you want the relay to perform and provide detail about the algorithm you will use for each task. For example, if you need a timer or a counter, make a note of the requirements and how you will use these elements.
- Work in a top-down method, specifying and moving to more detailed levels, until you have sufficient information to create the settings. For simple tasks, one level may be sufficient. For complex tasks, such as automated station restoration, you may need several levels to move from idea to implementation.

Comments

SELOGIC control equation comments are very powerful tools for dividing, documenting, and clarifying your programming. Even if you completely understand your programming during installation and commissioning, comments will be very helpful if you need to modify operation a year later.

Create these comments in the fixed and free-form SELOGIC control equations, and store these comments in the SEL-487E. Obtain comments to assist you in using the ASCII interface or SEL configuration software, regardless of whether you have the original files downloaded to the relay.

Comments add structure to free-form programming environments such as Visual Basic, C, and free-form SELOGIC control equations. *Example 12.23* shows how to use comments to divide and structure free-form SELOGIC control equation programming.

EXAMPLE 12.23 Comments in Free-Form SELOGIC Control Equation Programming

Use comments to divide and direct your eye through free-form programming.

```
#
# This is a header comment that divides sections of free-form programming
#
AMV003 := 15 * AMV003 # Explain this line here
#
# This comment is a header for the next section.
# Inputs: provide more detail for more complex tasks
# Outputs: describe how the programming affects the relay operation
# Processing: discuss how the programming itself operates
#
ASV004 := ACN01Q AND RB03 # First line of next section
```

Many texts on programming in various computer programming languages suggest that you cannot include too many comments. The main reason to include comments is that something you find obvious may not be obvious to your coworker who will have to work with your programming in the future. Adding comments also gives you the opportunity to think about whether the program performs the function you intended.

Testing

After documentation and comments, the next essential element of an effective approach to programming is testing. Two types of testing are critical for determining if programming for complex tasks operates properly. First, test and observe whether the program performs the function you want under the conditions you anticipated. Second, look for opportunities to create conditions that are abnormal and determine how your program reacts to unusual conditions.

For example, test your system in unanticipated, but possible conditions such as loss of power, loss of critical field inputs, unexpected operator inputs, and conditions that result from likely failure scenarios of the equipment in your system. It is unlikely that you will find every possible weakness, but careful consideration and testing for abnormal conditions will help you avoid a failure and may reveal deficiencies in the normal operation of your system.

Modify your SELOGIC control equations to simulate the process. While you may be unable to change the state of a discrete input easily, such as IN101, you can substitute a logical 1 or logical 0 in your logic to simulate the operation of IN101 and observe the results.

Use the SER capabilities of the relay to monitor and record inputs, internal calculations, and outputs. For operations that occur very quickly, use the SER during testing to reconstruct the operation of your logic.

Use the **MET PMV** or **MET AMV** commands to display the contents of the protection or automation math variables.

SEL-311 and SEL-351 Series Users

You can convert logic that you have used in SEL-311 series relays and SEL-351 series relays to logic for the SEL-487E. In the SEL-311 series relays, SELOGIC control equation programming is restricted to equations where the left side value, LVALUE, is fixed. The SEL-487E uses primarily free-form programming. *Table 12.28* shows comparable features between the SEL-311 series relays and the SEL-487E. Convert programming into either the free-form style or the fixed style of SELOGIC control equations, or whatever combination you deem appropriate for your application.

Table 12.28 SEL-311 Series Relays and SEL-487E SELOGIC Control Equation Programming Features

Feature	SEL-311 Series	SEL-487E Protection Free-Form Style
SELOGIC control equation variables	SV1–SV16	PSV01–PSV64
Timer Input	SV1–SV16	PCT01–PCT32
Timer Pickup settings	SV1PU–SV16PU	PCT01PU–PCT32PU
Timer Dropout settings	SV1DO–SV16DO	PCT01DO–PCT32DO
Timer Outputs	SV1T–SV16T	PCT01Q–PCT32Q
Latch Bit Set Control	SET1–SET16	PLT01S–PLT16S
Latch Bit Reset Control	RST1–RST16	PLT01R–PLT16R
Latch Bit	LT1–LT16	PLT01–PLT16

Table 12.29 shows the SEL-487E Boolean operators compared to the operators used in the SEL-311 series relays.

Table 12.29 SEL-311 Series Relays and SEL-487E SELOGIC Control Equation Boolean Operators

Feature	SEL-311 Series	SEL-487E
Logical AND operator	*	AND
Logical OR operator	+	OR
Logical NOT operator	!	NOT
Parentheses	( )	( )
Rising, falling edge operators	/, \	R_TRIG, F_TRIG

In the SEL-311 series relays, SELOGIC control equation variables and timers are connected. Each SELOGIC control equation variable is the input to a timer. In the SEL-487E, timers and SELOGIC control equation variables are independent.

The SELOGIC control equation Boolean operators in the SEL-487E are different from those used in SEL-300 series relays. For example, if you wish to convert programming from an SEL-311 or SEL-351 series relay for the SEL-487E, you must convert the operators. *Example 12.24* and *Example 12.25* demonstrate conversion of several settings to the SEL-487E setting.

EXAMPLE 12.24 Converting SEL-311 Series Relay SELOGIC Control Equation Variables

If you have the following SELOGIC control equation in an SEL-311 series relay, convert it as shown below.

```
SV1 = IN101 + RB3 * LT4
```

In the SEL-487E, use the line shown below.

PSV01 := **IN101 OR RB03 AND PLT04** # Free-form example

In the example above, first convert the + and * operators in the expression to the OR and AND operators. In the free-form example, use a protection SELOGIC control equation variable for the result. In the protection group settings example, use the input of a timer, as shown in Table 12.25.

EXAMPLE 12.25 Converting SEL-311 Series Relay SELOGIC Control Equation Timers

If you have the following SELOGIC control equation timer in an SEL-311 series relay, convert it as shown below.

```
SV1 = IN101
SV1PU = 5.25
SV1DO = 3.5
OUT101 = SV1T
```

In the SEL-487E, use the format shown below.

#

Free-form programming conversion of timer

#

PCT01PU := **5.25** # Pickup of 5.25 cycles

PCT01DO := **3.5** # Dropout of 3.5 cycles

PCT01IN := **IN101** # Use the timer to monitor IN101

In the output settings, set OUT101 as shown below:

OUT101 := **PCT01Q**

EXAMPLE 12.26 Converting SEL-311 Series Relay Latch Bits

If you have the following SELOGIC control equation latch programming in an SEL-311 series relay, convert it as shown below.

```
SET1 = RB4
RST1 = RB5
OUT101 = LT1
```

In the SEL-487E, use the format shown below.

Protection free-form style settings:

#

Free-form programming conversion of latch bit

#

PLT01S := **RB04** # Set if RB04

PLT01R := **RB05** # Reset if RB05

In the output settings, set OUT101 as shown below:

OUT101 := **PLT01**

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Section 13

ASCII Command Reference

Overview

You can use a communications terminal or terminal emulation program to set and operate the SEL-487E Relay. This section explains the commands that you send to the SEL-487E using SEL ASCII (American National Standard Code for Information Interchange) communications protocol. The relay responds to commands such as settings, metering, and control operations. This section lists ASCII commands alphabetically. Commands, command options, and command variables that you enter are shown in bold. Lowercase italic letters and words in a command represent command variables that you determine based on the application (for example, circuit breaker number *n* = 1 or 2, remote bit number *nn* = 01–32, and *level*).

Tables in this section show the access level(s) where the command or command option is active. Access levels in the SEL-487E are Access Level 0, Access Level 1, Access Level B (breaker), Access Level P (protection), Access Level A (automation), Access Level O (output), Access Level 2, and Access Level C.

A command may be executed from its access level or from a higher access level, as indicated in *Table 13.1*. The relay responds with `Invalid Access Level` if a command is entered from an access level lower than the specified access level for the command. If a command is incorrect or followed by an incorrect parameter, then the relay responds with: `Invalid command`.

Table 13.1 Access Level Passwords

Access Level	Prompt	Default Password	Commands Allowed	Access Command	Access Command
0	=	N/A	0	QUIT	0
1	=>	OTTER	0,1	ACCESS	0
B	==>	EDITH	0,1,B	BACCESS	1
P	P=>	AMPERE	0,1,B,P,2’	PACCESS	1
A	A=>	VOLTA	0,1,B,A,2’	AACCESS	1
O	O=>	WATT	0,1,B,O,2’	OACCESS	1
2	=>>	TAIL	0,1,B,P,A,O,2	2ACCESS	1
C	==>>	Sel-1	0, 1, B, P, A, O, 2, C	CAL	2

The Levels P, A, and O are parallel levels that are subsets of level 2. In general, anything that is available at level 2 is available to these levels, except items that are restricted to one of these three subsets and the **PASSWORD** command. (This common subset is indicated as 2' in *Table 13.1*.)

Command options appear with brief explanations about the command function. Refer to the references listed with the commands for more information on the relay function corresponding to the command or examples of the relay response to the command.

You can simplify the task of entering commands by shortening any ASCII command to the first three characters; for example, **ACCESS** becomes **ACC**. Always send a carriage return **<CR>** character, or a carriage return character followed by a line feed character **<CR><LF>** to command the relay to process the ASCII command. Usually, most terminals and terminal programs interpret the **<Enter>** key as a **<CR>**. For example, to send the **ACCESS** command, type **ACC <Enter>**.

Description of Commands

2ACCESS

Use the **2AC** command to gain access to Access Level 2 (full relay control).

Table 13.2 2AC Command

Command	Description	Access Level
2AC	Go to Access Level 2 (full relay control).	1, B, P, A, O, 2

89CLOSE

The **89CLOSE** command provides a method to assert the Disconnect 89CC*m* (*m* = 1 through 8) Control Relay Word Bits. Use these Relay Word Bits to close up to 8 disconnects.

Table 13.3 89CLOSE Command

Command	Description	Access Level
89CLOSE *m*[a]	Assert Relay Word bits 89CCm.	B, A, P, O, 2

[a] m is the disconnect number (m = 1–8).

89OPEN

The **89OPEN** command provides a method to assert the Disconnect 89OC*m* (*m* = 1 through 8) Control Relay Word Bits. Use these Relay Word Bits to close up to 8 disconnects.

Table 13.4 89OPEN Command

Command	Description	Access Level
89OPEN *m*[a]	Assert Relay Word bits 89OCm.	B, A, P, O, 2

[a] m is the disconnect number (m = 1–8).

AACCESS

Use the **AAC** command to gain access to Access Level A (automation).

Table 13.5 AAC Command

Command	Description	Access Level
AAC	Go to Access Level A (automation).	1, B, P, A, O, 2

ACCESS

Use the **ACC** command to gain access to Access Level 1 (monitor).

Table 13.6 ACC Command

Command	Description	Access Level
ACC	Go to Access Level 1 (monitoring).	0, 1, B, P, A, O, 2

BACCESS

Use the **BAC** command to gain access to Access Level B (breaker).

Table 13.7 BAC Command

Command	Description	Access Level
BAC	Go to Access Level B (breaker).	1, B, P, A, O, 2

BNAME

In response to the **BNA** command, the relay displays the ASCII names of all relay status bits for Fast Meter Compressed ASCII. See *Section 7: Communications, Interfaces, and Protocols* for more information on Fast Meter and the Compressed ASCII command set.

Table 13.8 BNA Command

Command	Description	Access Level
BNA	Display ASCII names of all relay status bits for Fast Meter.	0, 1, B, P, A, O, 2

BREAKER

Use the **BREAKER** command to display circuit breaker reports and the circuit breaker history reports. You can also preload accumulated breaker monitor data. The **BRE** command also resets the circuit breaker monitor data. To use the BRE command, you must enable the circuit breaker monitor with monitor settings EBMON := S, T, U, W, or X.

BRE n

The **BRE *n*** command displays the comprehensive circuit breaker report that includes interrupted currents, number of operations, and mechanical and electrical operating times, among many parameters. The relay displays a listing of breaker monitor alarms with the breaker report.

Table 13.9 BRE n Command[a]

Command	Description	Access Level
BRE *n*	Display the breaker report for the most recent Circuit Breaker *n* operation.	1, B, P, A, O, 2

[a] Parameter n = S, T, U, W, X.

BRE n C and BRE n R

The **BRE *n* C** and **BRE *n* R** commands clear/reset the circuit breaker monitor data. Options **C** and **R** are identical.

Table 13.10 BRE n C and BRE n R Commands[a]

Command	Description	Access Level
BRE *n* C	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2
BRE *n* R	Clear Circuit Breaker *n* data to zero.	B, P, A, O, 2

[a] Parameter n = S, T, U, W, X.

BRE C A and BRE R A

The **BRE C A** and **BRE R A** commands clear all circuit breaker monitor data for both circuit breakers from memory. Options **C A** and **R A** are identical.

Table 13.11 BRE C A and BRE R A Commands

Command	Description	Access Level
BRE C A	Clear all circuit breaker data.	B, P, A, O, 2
BRE R A	Clear all circuit breaker data.	B, P, A, O, 2

BRE n H

Display the circuit breaker monitor history report with the **BRE *n* H** command. The breaker history report is a summary of recent circuit breaker operations.

Table 13.12 BRE n H Command

Command	Description	Access Level
BRE *n* H[a]	Display history data for the last 128 Circuit Breaker *n* operations.	1, B, P, A, O, 2

[a] Parameter n = S, T, U, W, X.

BRE n P

Use the **BRE *n* P** command to preload existing circuit breaker contact wear, operation counts, and accumulated currents to the circuit breaker monitor.

Table 13.13 BRE n P Command

Command	Description	Access Level
BRE *n* P[a]	Preload previously accumulated Breaker *n* data.	B, P, A, O, 2

[a] Parameter n = S, T, U, W, X.

CAL

Use the **CAL** command to gain access to Access Level C. Only go to Level C to modify the default password or under the direction of an SEL employee. The additional commands available at Level C are not intended for normal operational purposes.

Table 13.14 CAL Command

Command	Description	Access Level
CAL	Go to Access Level C.	2, C

CASCII

The **CAS** command produces the Compressed ASCII configuration message. This configuration instructs an external computer on the method for extracting data from other Compressed ASCII commands. See *Section 7: Communications, Interfaces, and Protocols* for an example of the **CAS** command configuration message and for further information on the Compressed ASCII command set.

Table 13.15 CAS Command

Command	Description	Access Level
CAS	Return the Compressed ASCII configuration message.	0, 1, B, P, A, O, 2

CBREAKER

The **CBREAKER** command provides a Compressed ASCII response circuit breaker report that is similar to the **BREAKER** command. You must enable the Breaker Monitor function for at least one breaker to generate the Compressed ASCII report.

CBR

Use the **CBR** command to gather the comprehensive circuit breaker report in Compressed ASCII format.

Table 13.16 CBR Command

Command	Description	Access Level
CBR	Return the most recent circuit breaker reports for Circuit Breaker 1 and Circuit Breaker 2 in Compressed ASCII format.	1, B, P, A, O, 2
CBR *n*[a]	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n = S, T, U, W, X.

CBR TERSE

The **CBR TERSE** command omits the breaker report labels.

Table 13.17 CBR TERSE Command

Command	Description	Access Level
CBR TERSE	Return the most recent circuit breaker report for Circuit Breaker 1 and Circuit Breaker 2 in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2
CBR *n* TERSE[a]	Return the most recent circuit breaker report for Circuit Breaker *n* in Compressed ASCII format; suppress the labels; transmit only the data lines.	1, B, P, A, O, 2

[a] Parameter n = S, T, U, W, X.

CEVENT

The **CEVENT** command provides a Compressed ASCII response similar to the **EVENT** command.

CEV

Use the **CEV** command to gather relay event reports. When parameter *n* is 1 through 9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

Table 13.18 CEV Command

Command	Description	Access Level
CEV	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n*[a]	Return particular *n* event report (including settings and summary) at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

CEV ACK

Use **CEV ACK** to acknowledge viewing the oldest unacknowledged event on the present communications port. View this event with the **CEV NEXT** or **EVE NEXT** commands.

Table 13.19 CEV ACK Command

Command	Description	Access Level
CEV ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2

CEV Lyyy

Command **CEV L*yyy*** returns a specified length event report in Compressed ASCII format, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle to a value including and beyond the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full event report. The **L*yyy*** option overrides the **C** option.

Table 13.20 CEV Lyyy Command

Command	Description	Access Level
CEV L*yyy*	Return *yyy* cycles of the most recent event report (including settings) with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* L*yyy*[a]	Return *yyy* cycles of a particular *n* event report with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (CEV on page 13.5).

CEV NEXT

CEV NEXT returns the oldest unacknowledged event report on the present communications port in Compressed ASCII format.

Table 13.21 CEV N Command

Command	Description	Access Level
CEV N	Return the oldest unacknowledged event report with 4-samples/cycle sampling in Compressed ASCII format.	1, B, P, A, O, 2

CEV NSET

The **CEV NSET** command returns the Compressed ASCII event report with no relay settings.

Table 13.22 CEV NSET Command

Command	Description	Access Level
CEV NSET	Return the most recent event report without settings at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* NSET[a]	Return a particular *n* event report without settings at full length with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (CEV on page 13.5).

CEV Sx

Use the **CEV S*x*** command to specify the sample data resolution of the Compressed ASCII event report. The sample data resolution *x* is either 4 samples/cycle or 8 samples/cycle; the default value is 4 samples/cycle if you do not specify **S*x***. The **S*x*** option overrides the **L** option.

Table 13.23 CEV Sx Command[a]

Command	Description	Access Level
CEV S*x*	Return the most recent event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* S*x*	Return a particular *n* event report at full length with *x*-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (CEV on page 13.5).

CEV TERSE

The **CEV TERSE** command returns a Compressed ASCII event report without the event report labels.

Table 13.24 CEV TERSE Command

Command	Description	Access Level
CEV TERSE	Return the most recent event report at full length without the report labels with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2
CEV *n* TERSE[a]	Return a particular *n* event report at full length without the report labels with 4-samples/cycle data in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

Use the **TERSE** option with any of the **CEV** commands except **CEV ACK**.

CEV Command Option Combinations

You can combine options **NSET**, **NSUM**, **S*x***, and **TERSE** in one command. Enter the options according to the following guidelines:

- The **L*yyy*** option overrides the **C** option
- Enter the options in any order

Table 13.25 lists the choices you can make in the **CEV** command. Combine options on each row, selecting one option from each column, to create a **CEV** command.

Table 13.25 CEV Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Length	Omit
ACK	***n*, NEXT**	**S*x***	**L*yyy***	**NSET, TERSE**

CHISTORY

The **CHISTORY** command is the **HISTORY** command for the Compressed ASCII command set. For a detailed example of the items in the Compressed ASCII history report.

CHI

Use the **CHI** command to gather one-line descriptions of event reports.

Table 13.26 CHI Command

Command	Description	Access Level
CHI	Return the data as contained in the History report for the most recent 20 event reports in Compressed ASCII format (for SEL-2030/2032 compatibility).	1, B, P, A, O, 2
CHI *k*	Return one-line descriptions of the most recent *k* number of event reports in Compressed ASCII format.	1, B, P, A, O, 2
CHI A	Return summary descriptions of available event reports in Compressed ASCII format (returns long form report).	1, B, P, A, O, 2

CHI TERSE

The **CHI TERSE** command returns a Compressed ASCII event report without the event report header label lines.

Table 13.27 CHI TERSE Command

Command	Description	Access Level
CHI TERSE	Return one-line descriptions for the most recent 20 event reports without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CHI *k* TERSE	Return one-line descriptions for the most recent *k* number of event reports without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2

CLOSE n

Use the **CLOSE *n*** command to close a circuit breaker. Be sure that the main board circuit breaker jumper (on connector J18C) is in place, the breaker you want to close is included in the BKMON setting, and the 52_n setting is set to a value other than NA. The **CLOSE S**, **T**, **U**, **W**, and **X** commands assert Relay Word bits CCS, CCT, CCU, CCW, and CCX, respectively.

Table 13.28 CLOSE n Command

Command	Description	Access Level
CLOSE *n*	Command the relay to close Circuit Breaker *n*.	B, P, A, O, 2

If the circuit breaker control enable jumper J18C is in place, the relay responds, `Close breaker (Y/N)?` When you answer **Y <Enter>** (for yes), the relay prompts, `Are you sure (Y/N)?` If you again answer **Y <Enter>**, the relay asserts the Relay Word bit for one processing interval.

If you have assigned a circuit breaker auxiliary contact (52A) to a relay control input (based on the 52_n settings), the relay waits 0.5 second, checks the state of the circuit breaker, and issues either a `Breaker OPEN` or `Breaker CLOSED` message.

If circuit breaker control enable jumper J18C is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. If the relay is disabled, the relay responds, `Command aborted because relay is disabled`.

COMMUNICATIONS

The **COMMUNICATIONS** command displays communications statistics for the MIRRORED BITS® communications channels and for synchrophasor client channels. For more information on MIRRORED BITS communications, see *SEL MIRRORED BITS Communications on page 7.19*. For more information on synchrophasor client communications, see *Section 11: Synchrophasors*.

COM c

Use the **COM *c*** command to view records in the communications buffers for specific relay communications channels.

Table 13.29 COM c Command[a]

Command	Description	Access Level
COM A	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel A.	1, B, P, A, O, 2
COM B	Return a summary report of the last 255 records in the communications buffer for MIRRORED BITS communications Channel B.	1, B, P, A, O, 2
COM M	Return a summary report of the last 255 records in the communications buffer for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	1, B, P, A, O, 2

[a] Parameter c is A, B, or M for Channel A, Channel B, and MIRRORED BITS communications channels, respectively.

The *c* option in the **COM** command is **A** for MIRRORED BITS communications Channel A, **B** for MIRRORED BITS communications Channel B, and **M** for the MIRRORED BITS communications channels in general. If both MIRRORED BITS communications channels are in use, then the **M** option does not function and you must specify **A** or **B**.

COM c C and COM c R

The **COM *c* C** and **COM *c* R** commands clear the communications buffer data for the specified channel ***c***. Options **C** and **R** are identical.

Table 13.30 COM c C and COM c R Command[a]

Command	Description	Access Level
COM A C	Clear communications buffer data for MIRRORED BITS communications Channel A.	P, A, O, 2
COM B R	Clear communications buffer data for MIRRORED BITS communications Channel B.	P, A, O, 2
COM M C	Clear communications buffer data for both MIRRORED BITS communications Channel A or Channel B when only one channel is enabled.	P, A, O, 2

[a] Parameter c is A, B, or M for Channel A, Channel B, and MIRRORED BITS communications channels, respectively.

COM c L m n and COM c L date1 date2

Use **COM *c* L** to list the records in the communications buffer in a specified manner. The relay returns the list of records in rows. You can specify a range of buffer records in forward or reverse chronological order or in forward or reverse date order. Date parameter entries depend on the setting DATE_F format you chose in the relay Global settings.

The relay organizes the records in rows in a 256-entry buffer in newest to oldest time order. The relay puts the newest record in the buffer and discards the oldest record if the buffer is full. *Table 13.31* is a representative list of options for listing records in the communications buffer.

Table 13.31 COM c L Command

Command	Description	Access Level
COM A L	Display all available records from MIRRORED BITS communications Channel A; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM B L *k*[a]	Display the first *k* records for MIRRORED BITS communications Channel B; the most recent record is Row 1 (at the top of the report) and the oldest record is at the bottom of the report.	1, B, P, A, O, 2
COM M L *m n*[b]	Display the records for either MIRRORED BITS communications Channel A or Channel B when only one channel is enabled; show the records with Record *m* at the top of the report through Record *n* at the bottom of the report.	1, B, P, A, O, 2
COM A L *date1*[c]	Display the records from MIRRORED BITS communications Channel A on *date1*.	1, B, P, A, O, 2
COM B L *date1 date2*[c]	Display the records from MIRRORED BITS communications Channel B between *date1* and *date2*. The date listed first, *date1*, is at the top of the report; the date listed second, *date2*, is at the bottom of the report.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of communications buffer records.
[b] Parameters m and n are communications buffer row numbers.
[c] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

COM RTC

Use the **COM RTC** to get a report on the status of the configured synchrophasor client channels.

Table 13.32 COM RTC c Command[a]

Command	Description	Access Level
COM RTC	Return a report describing the communications on all enabled synchrophasor client channels.	1, B, P, A, O, 2
COM RTC A	Return a report describing the communications on synchrophasor client channel A.	1, B, P, A, O, 2
COM RTC B	Return a report describing the communications on synchrophasor client channel B.	1, B, P, A, O, 2

[a] Parameter c is A, B, or absent for channel A, channel B, or all enabled channels, respectively.

COM RTC c C and COM RTC c R

The **COM RTC C** and **COM RTC R** commands clear/reset the maximum packet delay. The C and R options are identical.

Table 13.33 COM RTC c C and COM RTC c R Command

Command	Description	Access Level
COM RTC C	Clear/reset the maximum packet delay on all enabled synchrophasor client channels.	P, A, O, 2
COM RTC A R	Clear/reset the maximum packet delay on synchrophasor client channel A.	P, A, O, 2
COM RTC B C	Clear/reset the maximum packet delay on synchrophasor client channel B.	P, A, O, 2

CONTROL nn

Use the **CONTROL *nn*** command to set, clear, or pulse internal Relay Word bits RB01 through RB96 (Remote Bit 1 through Remote Bit 96). Remote bits in SELOGIC control equations are similar to hardwired control inputs, in that you use these bits to affect relay operation from outside sources. For hard-wired control inputs, external input to the relay comes through the rear panel; in the case of the **CON *nn*** command, external control signals come through the communications ports.

Table 13.34 CON nn Command[a]

Command	Description	Access Level
CON *nn* C	Clear Remote Bit *nn*.	P, A, O, 2
CON *nn* P	Pulse Remote Bit *nn* for one processing cycle.	P, A, O, 2
CON *nn* S	Set Remote Bit *nn*.	P, A, O, 2

[a] Parameter nn is a number from 01 to 32 representing Remote Bit 01–Remote Bit 32.

If you enter **CON *nn*** with no set, clear, or pulse option specified, the relay responds, `Control RBnn:`. You must then provide the control action (set, clear, or pulse) that you want to perform. (The relay checks only the first character; you can type **Set** and **Clear**.) When you issue a valid **CON** command, the relay performs the control action immediately and displays: `Remote Bit Operated`.

COPY

The **COPY** command copies the settings from one class instance to another instance in the same class. For example, you can copy Group settings from Group 1 to Group 2. You cannot copy Group settings to Port settings. This command is limited to the same access level as the **SET** command for the class of settings you are copying. Use the command order specified in *Table 13.35*.

Table 13.35 COPY Command

Command	Description	Access Level
COPY *m n*[a]	Copy settings from instance *m* of the Group settings to instance *n* of the Group settings.	P, A, O, 2
COPY *class m n*[b]	Copy settings from instance *m* of Class *class* to instance *n* of Class *class*.	P, A, O, 2

[a] Parameters m and n are 1 to 6 for the Group class and 1, 2, 3, and F for the Port class.
[b] Parameter class is S, P, L, and Z for group settings, port settings, and protection SELOGIC® control equations, respectively.

The parameters *m* and *n* must be valid and distinct (not the same) instance numbers. The *class* parameter is the class that you can choose from group (S), port (P), protection SELOGIC control equations (L), and zone (Z). The **COPY** command is not available within the Automation class and is not available for the Breaker Monitor settings.

In addition, port settings instances must be compatible; you cannot copy from/to Port 5 and the other communications ports settings. You cannot copy to a port that is presently in transparent communication. If you attempt such a copy, the relay responds, `Cannot copy to a port involved in transparent communication`. In addition, you cannot copy to the present port (the port you are using to communicate with the relay). If you attempt such a copy, the relay responds, `Cannot copy port settings to present port`.

When you enter the **COPY** command with valid parameters, the relay responds, `Are you sure (Y/N)?` Answer **Y <Enter>** (for yes) to complete copying. If the destination instance is the active group, the relay changes to the new settings and pulses the SALARM Relay Word bit.

CPR

Use the **CPR** command to access the Signal Profile data for up to 20 user selectable analog values. Notice that the CPR records are in reverse chronological progression as compared to the PRO reports.

Table 13.36 CPR Command (Sheet 1 of 2)

Command	Description	Access Level
CPR	Displays the first 20 rows of the profile report, with the oldest row at the bottom and the latest row at the top.	1, B, P, A, O, 2
CPR *m*	Displays the first *m* rows of the report.	1, B, P, A, O, 2
CPR *m n* (*m* > *n*)	Displays the row between *m* and *n*, (including *m* and n).	1, B, P, A, O, 2
CPR *date1*	Displays all the rows that were recorded on that date.	1, B, P, A, O, 2
CPR *date1 date2*	Displays all the rows that were recorded on and between (including) ***date1*** and ***date2*** (date1 chronologically precedes ***date2***).	1, B, P, A, O, 2

Table 13.36 CPR Command (Sheet 2 of 2)

Command	Description	Access Level
CPR *date2 date1*	Displays all the rows that were recorded on and between (including) ***date1*** and ***date2*** (***date2*** chronologically precedes ***date1***).	1, B, P, A, O, 2
CPR TERSE	The **CPR TERSE** command omits the report labels.	1, B, P, A, O, 2

CSER

The **CSER** command is the **SER** command for the Compressed ASCII command set. See *SEL ASCII Commands on page 7.6* for information on the Compressed ASCII command set. The default order of the **CSER** command (chronologically newest to oldest from list top to list bottom) is the reverse of the **SER** command (oldest to newest from list top to list bottom).

CSE

Use the **CSE** command to gather Sequential Events Recorder records. You can sort these records in numerical or date order.

Table 13.37 CSE Command

Command	Description	Access Level
CSE	Return all records from the Sequential Events Recorder in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *k*[a]	Return the *k* most recent records from the Sequential Events Recorder in Compressed ASCII format, with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *m n*[b]	Return the Sequential Events Recorder records in Compressed ASCII format from *m* to *n*. If *m* is greater than *n*, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If *m* is less than *n*, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1*[c]	Return the Sequential Events Recorder records in Compressed ASCII format on *date1*.	1, B, P, A, O, 2
CSE *date1 date2*[c]	Return the Sequential Events Recorder records in Compressed ASCII format from *date1* to *date2*.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of SER records.
[b] Parameters m and n indicate an SER record number.
[c] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

CSE TERSE

The **CSE TERSE** command returns a Sequential Events Recorder report in Compressed ASCII format without labels; the relay sends only the data. You can apply the **TERSE** option with any of the **CSE** commands.

Table 13.38 CSE TERSE Command

Command	Description	Access Level
CSE TERSE	Return all Sequential Events Recorder records without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *k* TERSE[a]	Return the *k* most recent Sequential Events Recorder records without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *m n* TERSE[b]	Return the Sequential Events Recorder records in Compressed ASCII format from *m* to *n* without the header label lines in Compressed ASCII format. If *m* is greater than *n*, then records appear with the oldest (highest number) at the beginning of the list and the most recent (lowest number) at the end of the list. If *m* is less than *n*, then records appear with the most recent (lowest number) at the beginning of the list and the oldest (highest number) at the end of the list.	1, B, P, A, O, 2
CSE *date1* TERSE[c]	Return the Sequential Events Recorder records in Compressed ASCII format on *date1* without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSE *date1 date2* TERSE[c]	Return the Sequential Events Recorder records in Compressed ASCII format from *date1* to *date2* without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter k indicates a specific number of SER records.
[b] Parameters m and n indicate an SER record number.
[c] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

CSTATUS

The **CSTATUS** command is the **STATUS** command for the Compressed ASCII command set. The **TERSE** option eliminates the report header label lines. See *Section 7: Communications, Interfaces, and Protocols* for information on the Compressed ASCII command set.

Table 13.39 CST Command

Command	Description	Access Level
CST	Return the relay status in Compressed ASCII.	1, B, P, A, O, 2
CST TERSE	Return the relay status in Compressed ASCII; suppress the header label lines and transmit only the data lines.	1, B, P, A, O, 2

CSUMMARY

The **CSUMMARY** command is the **SUMMARY** command for the Compressed ASCII command set. You can combine the ***n***, **ACK**, **MB**, and **TERSE**.

CSU

Use the **CSU** and **CSU NEXT** commands to gather event report summaries.

Table 13.40 CSU Command

Command	Description	Access Level
CSU	Return the most recent event summary (with header label lines) in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n*[a]	Return a particular *n* event summary (with header label lines) in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

When parameter *n* is 1 through 9999, *n* indicates the order of the event report. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

CSU ACK

Use the **CSU ACK** command to acknowledge an event summary that you recently retrieved with the **CSU NEXT** command on the present communications port.

Table 13.41 CEV ACK Command

Command	Description	Access Level
CSU ACK	Acknowledge the oldest unacknowledged event summary at the present communications port for Compressed ASCII format.	1, B, P, A, O, 2

CSU MB

The **CSU MB** command causes the relay to output the labels for the MIRRORED BITS communications channel data in Compressed ASCII format.

Table 13.42 CSU MB Command

Command	Description	Access Level
CSU MB	Return the MIRRORED BITS communications channel labels.	1, B, P, A, O, 2

CSU NEXT

Use the **CSU NEXT** command to view the oldest unacknowledged event summary in Compressed ASCII format.

Table 13.43 CSU NEXT Command

Command	Description	Access Level
CSU NEXT	View the oldest unacknowledged event summary.	1, B, P, A, O, 2

CSU TERSE

The **TERSE** command option returns an event summary report in Compressed ASCII format without header labels; the relay sends only the data.

Table 13.44 CSU TERSE Command

Command	Description	Access Level
CSU TERSE	Return the most recent event summary report without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU *n* TERSE[a]	Return a particular *n* event summary report without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2
CSU N TERSE	View the oldest unacknowledged event summary without the header label lines in Compressed ASCII format.	1, B, P, A, O, 2

[a] Parameter n indicates event number or serial order.

You can apply the **TERSE** option with any of the **CSU** commands except **CSU ACK** and **CSU MB**.

DATE

Use the **DATE** command to view and set the relay date. The relay can overwrite the date that you enter by using other time sources such as IRIG and DNP. Enter the **DATE** command with a date to set the internal clock date. You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

Set the year in 2-digit form (for dates 2000–2099) or 4-digit form. If you enter the year as 12, the relay date is 2012. Global setting DATE_F sets the date format.

Table 13.45 DATE Command

Command	Description	Access Level
DATE	Display the internal clock date.	1, B, P, A, O, 2
DATE *date*[a]	Set the internal clock date.	1, B, P, A, O, 2

[a] Enter date setting in the same format as specified by Global setting DATE_F.

DNAME X

The **DNA X** command reports the ASCII names of all relay digital I/O (input/output) quantities reported in a Fast Meter message in Compressed ASCII format. See *SEL Fast Meter, Fast Operate, Fast SER Messages, and Fast Message Data Access on page 7.10* for more information on SEL Fast Meter.

Table 13.46 DNA X Command

Command	Description	Access Level
DNA X	Display ASCII names of all relay digital I/O.	0, 1, B, P, A, O, 2

DNP

The **DNP** command is only available if DNP3 has been selected as the protocol on one of the serial ports. Use the **DNP** command to access the DNP3 settings. The **DNP** command is similar to the **SHOW D** and **SET D** commands. Type **DNP <Enter>** to show the relay DNP3 map beginning at the first setting label. Issue the **DNP** command with any parameter *param* to set the DNP3 settings; the relay begins at the first DNP3 setting. For more information, see the **SET D** command and *Appendix E: DNP3 Communications Protocol*.

Table 13.47 DNP Command

Command	Description	Access Level
DNP	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP VIEW	Show the serial port DNP3 settings (same as **SHOW D**).	1, B, P, A, P, O, 2
DNP ***param***	Set the serial port DNP3 settings (same as **SET D**); begin at the first DNP3 setting.	P, A, O, 2

EVENT

Use the **EVENT** command to view the SEL-487E filtered event reports (see *Event Report on page 10.12* for information on event reports).

EVE

The **EVE** command displays the full-length event reports stored in relay memory. When parameter *n* is 1 through 9999, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

Table 13.48 EVE Command

Command	Description	Access Level
EVE	Return the most recent event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE ***n***[a]	Return a particular *n* event report (including settings and summary) at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

EVE A

The **EVE A** command returns only the analog information in the event report.

Table 13.49 EVE A Command

Command	Description	Access Level
EVE A	Return only the analog information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE A ***n***[a]	Return only the analog information for a particular *n* event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (EVE on page 13.17).

EVE ACK

Use **EVE ACK** to acknowledge the oldest unacknowledged event that you recently viewed with the **EVE NEXT** or the **CEV NEXT** commands on the present communications port.

Table 13.50 EVE ACK Command

Command	Description	Access Level
EVE ACK	Acknowledge the oldest unacknowledged event at the present communications port.	1, B, P, A, O, 2

If you attempt to acknowledge an event summary that you have not viewed on the present port with the **EVE NEXT** command, the relay responds, `Event summary number n has not been viewed with the NEXT option`.

EVE C

Use **EVE C** to return a 15-cycle length event report with both analog and digital data. You cannot mix the A and D options with the **EVE C** command. The **L*yyy*** option overrides the **C** option (see **EVE L*yyy***).

Table 13.51 EVE C Command

Command	Description	Access Level
EVE C	Return the most recent event report at a 15-cycle length with 8-samples/cycle data.	1, B, P, A, O, 2
EVE C *n*[a]	Return a particular *n* event report at a 15-cycle length with 8-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (EVE on page 13.17).

EVE D

Use **EVE D** to return only the digital information in the event report.

Table 13.52 EVE D Command

Command	Description	Access Level
EVE D	Return only the digital information for the most recent event report with 4-samples/cycle data.	1, B, P, A, O, 2
EVE D *n*[a]	Return only the digital information for a particular *n* event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (EVE on page 13.17).

EVE DIF[F]

Use **EVE DIF** to display the differential report. You cannot use the A or D options with the **EVE DIFF** command.

Table 13.53 EVE DIF Command

Command	Description	Access Level
EVE DIF	Display the differential report.	1, B, P, A, O, 2

EVE Lyyy

Command **EVE L*yyy*** returns a specified length event report, where **L*yyy*** indicates a length of *yyy* cycles. You can specify *yyy* from 1 cycle up to a value including and exceeding the event report total cycle length. If *yyy* is longer than the total length, the relay returns the full duration event report. The **L*yyy*** option overrides the **C** option.

Table 13.54 EVE Lyyy Command

Command	Description	Access Level
EVE L*yyy*	Return *yyy* cycles of the most recent event report (including settings) with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n* L*yyy*[a]	Return *yyy* cycles of a particular *n* event report with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number.

EVE NEXT

EVE NEXT returns the oldest unacknowledged event report on the present communications port.

Table 13.55 EVE N Command

Command	Description	Access Level
EVE N	Return the oldest unacknowledged event report with 4-samples/cycle data.	1, B, P, A, O, 2

EVE NSET

The **EVE NSET** command returns the event report with no relay settings.

Table 13.56 EVE NSET Command

Command	Description	Access Level
EVE NSET	Return the most recent event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n* NSET[a]	Return a particular *n* event report without settings at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (EVE on page 13.17).

EVE NSUM

The **EVE NSUM** returns the event report with no event summary.

Table 13.57 EVE NSUM Command

Command	Description	Access Level
EVE NSUM	Return the most recent event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2
EVE *n* NSUM[a]	Return a particular *n* event report without the event summary at full length with 4-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (EVE on page 13.17).

EVE Sx

Use the **EVE S*x*** command to specify the sample data resolution of the event report. The sample data resolution *x* is either 4 samples/cycle or 8 samples/cycle; the default value is 4 samples/cycle if you do not specify **S*x***.

Table 13.58 EVE Sx Command

Command	Description	Access Level
EVE Sx	Return the most recent event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2
EVE *n* S*x*[a]	Return a particular *n* event report at full length with *x*-samples/cycle data.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number (see EVE on page 13.17); x is 4 or 8 to represent data at 4 samples/cycle or 8 samples/cycle, respectively.

EVE Command Option Combinations

You can combine options **C**, **L**, **L*yyy***, ***n***, **NSET**, **NSUM**, and **S*x***, in one command. Enter the options according to the following guidelines:

- The **L*yyy*** option overrides the **C** option.
- When choosing option **A** or option **D** as a report type, you cannot use option **C** to specify the report length at 15 cycles.
- You cannot use the A or D options with the **EVE DIFF** command.
- Use option **L*yyy*** at L015 to specify a 15-cycle report.
- Enter the options in any order.

Table 13.59 lists the choices you can make in the **EVE** command. Combine options on each row, selecting one option from each column, to create an **EVE** command.

Table 13.59 EVE Command Option Groups

Acknowledge	Event Number	Data Resolution	Report Type	Report Length	Omit
ACK	***n*, NEXT**	**S*x***	**C, A, D**	**L*yyy*, C**	**NSET, NSUM**

The following examples illustrate some possible option combinations:

Table 13.60 EVE Command Examples

Example	Description
EVE L010 S8	Return 10 cycles of an 8-samples/cycle event report for the most recent event.
EVE L10 A	Return 10 cycles of the analog portion only of the most recent event report at 4-samples/cycle resolution.
EVE 2 C NSUM	For the second most recent event, return the event with 8-samples/cycle data, and omit the event summary.

FILE

Using the Ymodem file transfer protocol, the **FILE** command provides a safe and efficient means of transferring files between intelligent electronic devices (IEDs) and external support software (ESS). The **FILE** commands are especially useful for retrieving high resolution sampled data in binary COMTRADE format from the relay.

Table 13.61 FILE Command

Command	Description	Access Level
FILE DIR [*directory1* *[directory2]]*	Returns a list of filenames in specified directory (*directory1*) and subdirectory (*directory2*). If neither parameter is specified, then the list of files and directories in the root directory is returned.	1, B, P, A, O, 2
FILE READ [*directory1* *[directory2]]* *filename*	Initiates a file transfer of the file *filename* (in the folder *directory1,* subdirectory *directroy2*) from the relay to external support software. The *filename* parameter is required.	1, B, P, A, O, 2
FILE WRITE SETTINGS [*directory1* *[directory2]]* *[filename]*	Initiates a file transfer of the file *filename* (in the folder SETTINGS, subdirectory *directory*) from external support software to the relay. If the *filename* parameter is not specified, the file name must be given in the Ymodem header.	P, A, O, 2

All text enclosed in [brackets] indicate optional command line parameters. The **FILE** command allows access to second level subdirectories as the optional *directory2* parameter. File directories in the SEL-487E are the EVENTS directory, the REPORTS directory, the SETTINGS directory, and the SYNCHROPHASOR directory. For FILE READ operations, specify the *directory1* (and *directory2*) parameters as needed. The **FILE WRITE** command is available only for the SETTINGS directory and its second level subdirectories.

GROUP

Use the **GROUP** command to view the present group number or to change the active group.

Table 13.62 GROUP Command

Command	Description	Access Level
GROUP	Display the presently active group.	1, B, P, A, O, 2
GROUP *n*[a]	Change the active group to Group *n*.	B, P, A, O, 2

[a] Parameter n indicates group numbers 1–6.

When you change the active group, the relay sends the following confirmation prompt: `Are you sure (Y/N)?`. Answer **Y <Enter>** to change the active group. The relay asserts the Relay Word bit SALARM for one second when you change the active group.

If any of the SELOGIC control equations SS1–SS6 are set when you issue the **GROUP *n*** command, the group change will fail. The relay responds `No group change:` SELOGIC `equations SS1-SS6 have priority over GROUP command`. For information on SELOGIC control equations SS1 through SS6, see *Table 12.3* and *Table 12.4*.

HELP

The **HELP** command gives a list of commands available at the present access level. You can also get a description of any particular command; type **HELP** followed by the name of the command for help on each command.

Table 13.63 HELP Command

Command	Description	Access Level
HELP	Display a list of each command available at the present access level with a one-line description.	1, B, P, A, O, 2
HELP *command*	Display information on the command *command*.	1, B, P, A, O, 2

HISTORY

The **HISTORY** command displays a quick synopsis of the last 100 events that the relay has captured. The rows in the **HISTORY** report contain the event serial number, date, time, location, maximum current, active group, and targets.

HIS

Use the **HIS** command to list one-line descriptions of relay events. You can list event histories by number or by date.

Table 13.64 HIS Command

Command	Description	Access Level
HIS	Return event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *k*[a]	Return the *k* most recent event histories with the oldest at the bottom of the list and the most recent at the top of the list.	1, B, P, A, O, 2
HIS *date1*[b]	Return the event histories on *date1*.	1, B, P, A, O, 2
HIS *date1 date2*[b]	Return the event histories from *date1* to *date2*, with *date1* at the bottom of the list and *date2* at the top of the list.	1, B, P, A, O, 2

[a] Parameter k indicates number of events.
[b] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

HIS C and HIS R

The **HIS C** and **HIS R** commands clear the history data and corresponding event report data on the present port. Options **C** and **R** are identical.

Table 13.65 HIS C and HIS R Commands

Command	Description	Access Level
HIS C	Clear event data on the present port only.	1, B, P, A, O, 2
HIS R	Clear event data on the present port only.	1, B, P, A, O, 2

When you issue the **HIS C** and **HIS R** commands, the relay sends the following prompt: `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears the present port history data.

HIS CA and HIS RA

The **HIS CA** and **HIS RA** commands clear all history data and event reports from memory. Use these commands to completely delete high-resolution/ event report data captures.

Table 13.66 HIS CA and HIS RA Commands

Command	Description	Access Level
HIS CA	Clear all event data for all ports.	P, A, O, 2
HIS RA	Clear all event data for all ports.	P, A, O, 2

If you issue the **HIS CA** and **HIS RA** commands, the relay sends the following prompt: `Are you sure (Y/N)?`. If you answer **Y <Enter>**, the relay clears all history data and event reports. The relay resets the event report number to 10000.

ID

Use the **ID** command to extract relay identification codes.

Table 13.67 ID Command

Command	Description	Access Level
ID	Return a list of relay identification codes.	0, 1, B, P, A, O, 2

Each line of the **ID** command report contains an identification code and a line checksum. The relay presents these codes in the following order:

FID: the Firmware Identification string

BFID: the Boot Firmware Identification string

CID: the checksum of the firmware

DEVID: the ID string as stored in the relay settings of the IED

DEVCODE: a unique Device Code (for Modbus® identification purposes)

PARTNO: the Part Number

CONFIG: abcdef

The designator positions indicate a specific relay configuration:
“a” represents the nominal frequency; where 0 = N/A, 1 = 60 Hz, and 2 = 50 Hz.
“b” represents the phase rotation; where 0 = N/A, 1 = ABC, and 2 = ACB.
“c” represents the phase input current scaling; where 0 = N/A, 1 = 5 A, and 2 = 1 A.
“d” = 0.
“e” = 0.
“f” = 0.

SPECIAL: the Special Configuration Designators—a mechanism for anticipating future product enhancements

Figure 13.1 shows a sample.

```
"FID=SEL-487E-R100-V0-Z001001-D20030724","08E1"
"BFID=SLBT-4XX-R100-V0-Z001001-D20030703","0972"
"CID=88D0","0261"
"DEVID=Relay 1","0467"
"DEVCODE=42","030D"
"PARTNO=0487B06512XEXXXXH","06E4"
"CONFIG=101000","0385"
"SPECIAL=00000","039E"
```

Figure 13.1 Sample ID Command Response

If the device supports IEC 61850 ICD or CID files and the IEC 61850 protocol is enabled, the **ID** command will display the following additional information:

- iedName: the IED name (e.g., SEL-487E_OtterTail)
- type: the IED type (e.g., SEL-487E)
- configVersion: the CID file configuration version (e.g., ICD-487E-R100-V0-Z001001-20060512)

The optional Ethernet card provides support for IEC 61850 in the SEL-487E. You must first use the **POR 5** command to establish a transparent session to the Ethernet card, then issue the **ID** command to view the IEC 61850 ID data. A sample **ID** command response from the optional Ethernet card (with IEC 61850 enabled) is shown in *Figure 13.2*.

```
"FID=SEL-2702-R100-V2-Z000000-D20060524","08DA"
"BFID=SLBT-2701-R102-V0-Z000000-D20051107","095B"
"CID=9689h","02C5"
"DEVID=ETHERNET PROCESSOR WITH IEC 61850 AND DNP","0CBE"
"PARTNO=2702C4P","0413"
"CONFIG=000000","0383"
"iedName=SEL_87B_OtterTail","05BC"
"type=SEL_487B","04A4"
"configVersion=ICD-487E-R117-V0-Z001001-D20060524","0698"
```

Figure 13.2 Sample ID Command Response from Ethernet Card

LOOPBACK

Use the **LOOPBACK** command to instruct the relay to receive the transmitted MIRRORED BITS communications data on the same serial port. See *SEL MIRRORED BITS Communications on page 7.19* for more information on MIRRORED BITS communications.

LOOP

The **LOOP** command puts the relay serial port in loopback if you have previously configured the port for MIRRORED BITS communications. If you have enabled both of the MIRRORED BITS communications channels (A and B), then you must specify the channel parameter. If you have only one of the channels enabled, the relay uses that channel, if you do not specify that channel in the command. If you do not specify a timeout period, the relay provides a five-minute timeout.

Table 13.68 LOOP Command

Command	Description	Access Level
LOOP	Begin loopback of a single enabled MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *c*[a]	Begin loopback of MIRRORED BITS communications channel *c* for 5 minutes; ignore input data and force receive bits (RMB) to defaults.	P, A, O, 2
LOOP *t*	Begin loopback of a singleMIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after timeout *t* minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2
LOOP *t c*	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) and end the loopback after timeout *t* minutes; ignore input data and force receive bits (RMB) to defaults; *t* range is 1–5000 minutes.	P, A, O, 2

[a] Parameter c is A or B, representing Channel A or Channel B.

You can enter the options in any order. If you operate the relay using both MIRRORED BITS communications channels (A and B), then you must specify the channel parameter by using the **LOOP A** command and the **LOOP B** command.

When you issue the **LOOP** command, the relay responds with statements about the loopback time, status of the RMB (Receive MIRRORED BITS), and a confirmation prompt: `Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Loopback Mode Started`.

In the loopback mode, ROK drops out and the relay uses LBOK to indicate whether the data transmissions are satisfactory. The relay collects COM data as usual. Time synchronization and virtual terminal modes are not available during loopback. The relay continues passing analog quantities.

LOOP DATA

The **LOOP DATA** command results in the input MIRRORED BITS communications data being passed through to the receive (RMB) bits, as in the nonloopback mode.

Table 13.69 LOOP DATA Command

Command	Description	Access Level
LOOP DATA	Begin loopback of a single MIRRORED BITS communications channel (either Channel A or Channel B) for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA	Begin loopback of MIRRORED BITS communications channel *c* only for 5 minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2
LOOP *c* DATA *t*	Begin loopback of MIRRORED BITS communications channel *c* only for *t* minutes: pass input data to receive data as in nonloopback mode.	P, A, O, 2

The relay ignores received values if you do not specify the **DATA** option. You can enter the options in any order.

LOOP R

The **LOOP R** command terminates the loopback condition on MIRRORED BITS communications channels in loopback. If you do not specify a channel *c*, the relay disables loopback on both channels. If you specify a channel, you can enter the options in any order.

Table 13.70 LOOP R Command

Command	Description	Access Level
LOOP R	Cease loopback on all MIRRORED BITS communications channels. (Reset the channels to normal use.)	P, A, O, 2
LOOP *c* R	Cease loopback on MIRRORED BITS communications channel *c*. (Reset channel c to normal use.)	P, A, O, 2

MAP

Use the **MAP** command to view the organization of the relay database. The **MAP** command in the SEL-487E is very similar to the **MAP** command in the SEL-2020 and SEL-2030 Communications Processors. See *Appendix C: SEL Communications Processors* for more information on the relay database regions and data types.

MAP 1 region and MAP 1 region BL

Use the **MAP 1** command with the *region* option to view the layout of a specific region. Database region names are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, ANALOGS, STATE, and D1.

Table 13.71 MAP 1 Region Command

Command	Description	Access Level
MAP 1 *region*	List the data labels, database address, and data type.	1, B, P, A, O, 2
MAP 1 *region* BL	List the data labels, database address, and data type; list the Bit Labels, if assigned.	1, B, P, A, O, 2

The *region* option is the database region name shown in the simple **MAP 1** command response. The region map consists of columns for data item labels, database address, and data type.

If you specify the **BL** option and the region contains items with bit labels, the relay lists these bit labels in MSB (most significant bit) to LSB (least significant bit) order. ASV256 is an example of a database bit label name.

METER

The **METER** command displays reports about quantities the relay measures in the power system (voltages, currents, frequency, remote analogs, and so on) and internal relay operating quantities (math variables and analog quantities).

MET

Use the **MET** command to view fundamental metering quantities. The relay filters harmonics and sub harmonics to present only measured quantities at the power system fundamental operating frequency. Meter values are display only for those terminals included in the ECTTERM setting, otherwise the relay displays `Winding Not Enabled For Metering`.

For combined windings, meter values are displayed only for those windings included in the ECTTERM setting that also have the same VREF*w* and CTCON*w* settings. If this is not the case, the relay displays `Winding Not Enabled For Metering`. If ECTTERM is set to OFF, then rms, fundamental, and secondary metering are not be available, and the relay displays `No Windings Enabled For Metering`.

Table 13.72 MET Command

Command	Description	Access Level
MET	Display fundamental metering data.	1, B, P, A, O, 2
MET [F] [*n*][a]	Display Terminal *n* fundamental metering quantities	1, B, P, A, O, 2
MET [F] [*n*] [*k*]	Display Terminal *n* fundamental metering quantities successively for *k* times	1, B, P, A, O, 2

[a] n = S, T, U, W, X.

The **MET** command without options shows the fundamental metering data of the winding that appears first in the ECTTERM setting. Specify a specific terminal by using the S, T, U, W, X command options. For example, specify **MET T** to view the fundamental metering quantities of Terminal T.

Some situations require that you repeatedly monitor the power system for a brief period; specify a number after any **MET** command to automatically repeat the command.

MET AMV

The **MET AMV** command lists automation math variables.

Table 13.73 MET AMV Command

Command	Description	Access Level
MET AMV	Display all automation math variables.	1, B, P, A, O, 2
MET AMV *k*	Display the last 16 automation math variables successively for *k* times.	1, B, P, A, O, 2
MET AMV A *k*	Display all automation math variables successively for *k* times.	1, B, P, A, O, 2

The last 16 automation math variables are AMV241 through AMV256. The relay displays three places after the decimal point for these numerals. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET ANA

Use the **MET ANA** command to view the analog quantities from the MIRRORED BITS communications channels.

Table 13.74 MET ANA Command

Command	Description	Access Level
MET ANA	Display the MIRRORED BITS communications analog quantities.	1, B, P, A, O, 2
MET ANA *k*	Display the MIRRORED BITS communications analog quantities successively for *k* times.	1, B, P, A, O, 2

If you have not enabled the MIRRORED BITS communications channels and the remote sources, the relay response to this command will not include any values. If MIRRORED BITS communications is enabled but not communicating, the relay will display `ERROR` under the `RMBA` or `RMBB` entries, depending on settings.

The relay shows the analog quantities with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET BAT

Use the **MET BAT** command to view the station dc monitor quantities for Vdc1.

Table 13.75 MET BAT Command

Command	Description	Access Level
MET BAT	Display station battery measurements.	1, B, P, A, O, 2
MET BAT *k*	Display station battery measurements successively for *k* times.	1, B, P, A, O, 2
MET RBM	Reset station battery measurements.	P, A, O, 2

If you have not enabled the Station DC Battery Monitor, the relay responds, `DC Monitor Is Not Enabled`. (Enable the dc monitor with the Monitor setting EDCMON; see *Section 6: Settings*.)

The reset command, **MET RBM**, resets the dc monitor maximum/minimum metering quantities. When you issue the **MET RBM** command, the relay responds, `Reset Max/Min Battery Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Max/Min Battery Reset`.

MET D

Use the **MET D** command to view the demand and peak demand quantities.

Table 13.76 MET D Command

Command	Description	Access Level
MET D	Display Line demand metering data.	1, B, P, A, O, 2
MET D *k*	Display Line demand metering data successively for *k* times	1, B, P, A, O, 2
MET RD	Reset Line demand metering data.	P, A, O, 2
MET RP	Reset Line peak demand metering data.	P, A, O, 2

The reset command (**MET RD**) resets the Line demand metering quantities. When you issue the **MET RD** command, the relay responds, `Reset Demands (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Demands Reset`.

The reset command, **MET RP**, resets the Line peak demand metering quantities. When you issue the **MET RP** command, the relay responds, `Reset Peak Demands (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Peak Demands Reset`.

MET DIF

Use the **MET DIF** command to view the differential current metering data, in multiples of tap.

Table 13.77 MET DIF Command

Command	Description	Access Level
MET RTD	Displays the differential operate and restraint quantities.	1, B, P, A, O, 2
MET RTD k	Displays the differential operate and restraint quantities successively for k times.	1, B, P, A, O, 2

If the differential is disabled (E87 = OFF), the relay displays the message `Differential Elements Disabled`.

MET E

Use the **MET E** command to view the energy import and export quantities.

Table 13.78 MET E Command

Command	Description	Access Level
MET E	Display Line energy metering data.	1, B, P, A, O, 2
MET E *k*	Display Line energy metering data successively for *k* times.	1, B, P, A, O, 2
MET RE	Reset Line energy metering data.	P, A, O, 2

The reset command, **MET RE**, resets the Line, BK1, and BK2 energy metering quantities. When you issue the **MET RE** command, the relay responds, `Reset Energy Metering (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Energy Metering Reset`.

MET PM

Use the **MET PM** command to view the time-synchronized line quantities. The relay must be in the high-accuracy timekeeping HIRIG mode. For more information on high-accuracy timekeeping, see *Relay Configuration for High-Accuracy Timekeeping on page D.7*.

Table 13.79 MET PM Command (Sheet 1 of 2)

Command	Description	Access Level
MET PM	Display time-synchronized line values.	1, B, P, A, O, 2
MET PM *k*	Display time-synchronized line values successively for *k* times.	1, B, P, A, O, 2

Table 13.79 MET PM Command (Sheet 2 of 2)

Command	Description	Access Level
MET PM *time*	Display time-synchronized line values captured at trigger *time*.	1, B, P, A, O, 2
MET PM HIS	Display time-synchronized line values captured for the previous **MET PM** command.	1, B, P, A, O, 2

If the relay is not in the high-accuracy IRIG (HIRIG) timekeeping mode, it will respond to the **MET PM** command with the following message:

```
Aborted: A High Accuracy Time Source is Required
```

If Global enable setting EPMU := N, the relay will respond to the **MET PM** command with:

```
Synchronized phasor measurement is not enabled
```

To request a report of the synchrophasor data at a specific time, enter the optional *time* parameter as a time of day. For example, the relay will respond to the **MET PM 16:40:10** command with:

```
Synchronized Phasor Measurement Data Will Be Displayed at
16:40:10.000
```

In this example, when the internal clock reaches 16:40:10.000, the relay will display the synchrophasor data from that exact time. If the relay is not in HIRIG mode at that time, it will display the following message:

```
Aborted: A High Accuracy Time Source is Required
```

After the **MET PM *time*** command is issued, other **MET PM** commands may be entered without affecting the timed request, even if the stated time has not arrived. However, issuing a second **MET PM *time*** command while the first command is still pending will cancel the first command request in favor of the newer request.

If you are not connected to the relay when the **MET PM *time*** command issues its timed response, you can use the **MET PM HIS** command to view this response. This permits you to issue **MET PM *time*** to multiple relays using a common time and then go back later to see the results from all the relays at this common instant in time.

See *Section 11: Synchrophasors* for more information on phasor measurement functions, and *View Synchrophasors by Using the MET PM Command on page 11.25* for sample MET PM responses.

MET PMV

Use the **MET PMV** command to view the protection math variables.

Table 13.80 MET PMV Command

Command	Description	Access Level
MET PMV	Display all protection math variables.	1, B, P, A, O, 2
MET PMV *k*	Display the last 16 protection math variables successively for *k* times.	1, B, P, A, O, 2
MET PMV A *k*	Display all protection math variables successively for *k* times.	1, B, P, A, O, 2

The last 16 protection math variables are PMV49 through PMV64. The relay displays three places after the decimal point for these numerals. The relay shows variables with absolute value greater than 99999.999 or less than 0.100 as scientific notation (for example, –1.002E+22).

MET RMS

Use the **MET RMS** command to view fundamental metering quantities.

Table 13.81 MET RMS Command

Command	Description	Access Level
MET RMS	Display RMS metering quantities of the first enabled winding.	1, B, P, A, O, 2
MET RMS [*n*][a]	Display Terminal n RMS metering quantities	1, B, P, A, O, 2
MET RMS [*n*] [*k*]	Display Terminal n RMS metering quantities successively for k times	1, B, P, A, O, 2

[a] n = S, T, U, W, X.

MET RTC

Use the **MET RTC** command to view the data received on all active synchrophasor client channels.

Table 13.82 MET RTC Command

Command	Description	Access Level
MET RTC	Display received synchrophasor client data	1, B, P, A, O, 2
MET RTC *k*	Display received synchrophasor client data *k* times	1, B, P, A, O, 2

MET RTD

Use the **MET RTD** command to view the temperature data from the SEL-2600A RTD Module. This command requires setting PROTO = RTD for the serial port connected to the SEL-2600A RTD Module.

Table 13.83 MET RTD Command

Command	Description	Access Level
MET RTD	Display up to 12 temperature analog values from the SEL-2600A RTD Module.	1, B, P, A, O, 2
MET RTD *k*	Display up to 12 temperature analog values from the SEL-2600A RTD Module successively for *k* times.	1, B, P, A, O, 2

The relay displays the number of RTD channels specified by the RTDNUM Port Setting. If the RTD protocol is not enabled on any of the relay ports, the relay displays the following:

```
No data available
```

If there is a communications failure between the relay and the SEL-2600A, as indicated by the RTDCOMF Relay Word bit, the relay displays the following:

```
Communication Failure
```

If the RTDFL Relay Word bit is set to indicate a SEL-2600A failure, the relay displays the following:

```
SEL-2600 Failure
```

If any of the RTD*x*TY Port Settings are set to NA, the relay displays the following for that channel:

```
Channel Not Used
```

If the RTD*xx*ST Relay Word bit is set for any of the RTDNUM channels being reported, the relay displays the following:

```
Channel Failure
```

MET SEC

Use the **MET SEC** command to view secondary fundamental metering quantities.

Table 13.84 MET SEC Command

Command	Description	Access Level
MET SEC	Display secondary metering quantities of the first enabled winding.	1, B, P, A, O, 2
MET SEC [*n*][a]	Display Terminal *n* secondary metering quantities	1, B, P, A, O, 2
MET SEC [*n*] [*k*]	Display Terminal *n* secondary metering quantities successively for *k* times	1, B, P, A, O, 2

[a] n = S, T, U, W, X.

OACCESS

Use the **OACCESS** command to gain access to Access Level O (output).

Table 13.85 OAC Command

Command	Description	Access Level
OAC	Go to Access Level O (output).	1, B, P, A, O, 2

OPEN n

Use the **OPEN *n*** command to open a circuit breaker(s). The **OPEN S**, **T**, **U**, **W**, and **CLOSE X** commands assert Relay Word bits OCS, OCT, OCU, OCW and OCX, respectively. Usually, you configure these Relay Word bits as part of the SELOGIC control equations that trip the appropriate circuit breaker.

Table 13.86 OPEN n Command

Command	Description	Access Level
OPENE *n*[a]	Change Relay Word bit OC*n* to logical 1	B, P, A, O, 2

[a] n = S, T, U, W, X.

If you have disabled the relay and attempt an **OPEN *n*** command, the relay responds, `Command aborted because the relay is disabled`. If the circuit breaker control enable jumper J18C is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`.

For example, when you issue the **OPEN S** command, and the circuit breaker control enable jumper is in place, the relay responds, `Open breaker (Y/N)?` If you answer **Y <Enter>**, the relay responds, `Are you sure (Y/N)?` If you answer **Y <Enter>**, the relay asserts OCS for one processing interval. Circuit Breaker S opens if you have programmed Relay Word bit OCS in the TRS SELOGIC control equation.

If you have assigned auxiliary contact 52A inputs for this circuit breaker (based on settings 52_*n*), the relay waits 0.5 seconds, checks the state of the breaker auxiliary contacts, and responds, `Breaker OPEN` or `Breaker CLOSED`, as appropriate.

PACCESS

Use the **PACCESS** command to gain access to Access Level P (protection).

Table 13.87 PAC Command

Command	Description	Access Level
PAC	Go to Access Level P (protection).	1, B, P, A, O, 2

PASSWORD

Use the **PASSWORD** command to control password protection for relay access levels.

PAS level new_password

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

The relay changes the existing password for the specified access level to a *new_password* that you specify when you issue the **PAS *level new_password*** command.

Table 13.88 PAS level new_password Command

Command	Description	Access Levels
PAS *level*[a] *new_password*	Set a password *new_password* for Access Level *level*.	2

[a] Parameter level represents the relay access levels 1, B, P, A, O, or 2.

Relay access levels that have passwords are 1, B, P, A, O, and 2. Valid passwords are character sequences of as many as 12 characters. Valid characters are any printable ASCII character. HMI password entry is limited to upper- and lower-case letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel.

All passwords are case sensitive. When you successfully enter a new password, the relay pulses the Relay Word bit SALARM for one second, and responds, `Set`.

PAS level DISABLE

Issuing the **PAS *level* DISABLE** command disables password checking for the specified access level. You must type **DISABLE** in uppercase.

Table 13.89 PAS level DISABLE Command

Command	Description	Access Levels
PAS *level* DISABLE	Disable password protection for the Access Level *level*.[a]	2

[a] Parameter level represents the relay access Levels 1, B, P, A, O, or 2.

When you successfully disable password checking, the relay pulses the SALARM Relay Word bit for one second, and responds, `Password Disabled`. SEL does not recommend disabling passwords.

PORT

The **PORT** command can be used to connect to either an installed Ethernet card or a remote relay.

PORT p

The **PORT *p*** command connects a relay serial or Ethernet port to another device through a virtual terminal session. In the SEL-487E, serial port virtual terminal capability is available in MIRRORED BITS communications. You must have previously configured the serial port for MIRRORED BITS communications operation, set port setting MBNUM less than 8, and have at least one virtual terminal session available (set MBNUMVT to 0 or greater). Choosing MBNUMVT to 0 uses virtual terminal within the synchronization channel only.

If an Ethernet card is installed, you can use the **PORT** command to initiate a virtual terminal session with the communications card by specifying port number *p* as 5.

Table 13.90 PORT p Command

Command	Description	Access Level
PORT *p*[a]	Connect to a remote device through Port *p* (over MIRRORED BITS communications virtual terminal mode).	1, B, P, A, O, 2

[a] Parameter p is 1, 2, 3, 5, and F to indicate Communications Port 1 through Port 3, Port 5, and Port F.

When the relay establishes a connection, the relay responds, `Transparent session to Port p established`. To quit the transparent connection, type the control string that you specify in port setting TERSTRN; the default is **<Ctrl+E>**. Only one transparent port connection to each MIRRORED BITS communications port is possible at one time. If you issue a **PORT *p*** command when the selected session is already active, the relay responds, `Transparent session already in use`.

If you issue the **PORT *p*** command to ports 1, 2, 3, or F and you have not properly configured the MIRRORED BITS communications port or the MBNUMVT is not set to 1 or larger, then the relay responds, `Invalid destination port`.

PORT KILL n

It is possible to forcefully disconnect a transparent session from another port (a port not involved in the present transparent connection) by using the **PORT KILL *n*** command.

Table 13.91 PORT Kill n Command

Command	Description	Access Level
PORT KILL *n*[a]	Terminate the virtual terminal connection with a remote device through Port *n* by using a port not involved in the connection.	P, A, O, 2

[a] Parameter n is 1, 2, 3, 5, and F to indicate Communications Port 1 through Port 3, Port 5, and Port F; *n* is not the present port.

The port parameter *n* can refer to either of the ports involved in the session you want to kill. When you issue the **PORT KILL *n*** command, the relay responds, `Kill connection between ports m and n (Y/N)?` Answer **Y**

<Enter> to terminate the connection. The relay sends a character sequence to the remote relay (to make sure the remote device is left in a known state) and responds, `Connection between ports m and n disconnected`.

PROFILE

Use the PROFILE (**PRO**) command and **CPR** commands to access the Signal Profile data for up to 20 user-selectable analog values.

Table 13.92 PUL OUTnnn Command

Command	Description	Access Level
PRO	Displays the first 20 rows of the profile report, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *m*	Displays the first ***m*** rows of the report, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *m n* (*m* > *n*)	Displays the row between *m* and *n*, (including *m* and *n*) with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *date 1*	Displays all the rows that were recorded on that date, with the oldest row at the top and the latest row at the bottom.	1, B, P, A, O, 2
PRO *date 1 date 2*	Displays all the rows that were recorded on and between (including) ***date1*** and ***date 2*** (***date1*** chronologically precedes ***date 2***, with the oldest row (***date 1***) at the top and the latest row (***date 2***) at the bottom.	1, B, P, A, O, 2
PRO *date 2 date 1*	Displays all the rows that were recorded on and between (including) ***date1*** and ***date 2*** (***date2*** chronologically precedes ***date 1***, with the oldest row (***date 2***) at the top and the latest row (***date 1***) at the bottom.	1, B, P, A, O, 2
PRO D	Displays, for each port, the maximum number of days data may be acquired with the present settings before data overwrite occurs.	1, B, P, A, O, 2
PRO C or R	Clears the signal profile data from non-volatile memory on a per-port basis. The data is still be visible to other ports and to file transfer accesses and is cleared independently for those points-of-view.	B, P, A, O, 2
PRO CA or RA	Completely clears all signal profile data from non-volatile memory.	P, A, O, 2

PULSE

Use the **PULSE OUT*nnn*** command to pulse any of the relay control outputs for a specified time. This function aids you in relay testing and commissioning. If the output is open, the **PUL** command momentarily closes the output; if the output is closed, the **PUL** command momentarily opens the output. The control outputs are **OUT*nnn***, where ***nnn*** represents the 100-series, 200-series, and 300-series addresses.

Table 13.93 PUL OUTnnn Command

Command	Description	Access Level
PUL OUT*nnn*[a]	Pulse output OUT*nnn* for 1 second.	B, P, A, O, 2
PUL OUT*nnn s*[b]	Pulse output OUT*nnn* for *s* seconds.	B, P, A, O, 2

[a] Parameter nnn is a control output number.
[b] Parameter s is time in seconds, with a range of 1 through 30.

If the circuit breaker control enable jumper J18C is not in place, the relay aborts the command and responds, `Aborted: the breaker jumper is not installed`. See *Jumpers on page 2.14* for more information on relay jumpers.

When you issue the **PUL** command and the breaker jumper is in place, the relay responds, `Pulse contact OUTnnn for s seconds (Y/N)?` If you answer **Y <Enter>**, the relay asserts OUT*nnn* for the time you specify.

During the **PUL** operation, the Relay Word bit corresponding to the control output you specified (OUT*nnn*) asserts; Relay Word bit TESTPUL asserts also during any **PUL** command, so you can monitor pulse operation by programming TESTPUL into event triggers and alarm outputs.

QUIT

Use the **QUIT** command to revert to Access Level 0 (exit relay control).

Table 13.94 QUIT Command

Command	Description	Access Level
QUIT	Go to Access Level 0 (exit relay control).	0, 1, B, P, A, O, 2

Access Level 0 is the lowest access level; the relay performs no password check to descend to this level (or remain at this level).

RTC

Use the **RTC** command to display a description of all data being received on synchrophasor client channels. This report will list the analog quantity and Relay Word bits the data gets stored in locally, matched up with a label provided by the sending PMU. Use this information as aid to understanding the local values.

Table 13.95 RTC Command

Command	Description	Access Level
RTC	Display report of all configured synchrophasor client data labels.	1, B, P, A, O, 2

SER

The **SER** command retrieves SER (Sequential Events Recorder) records. The relay SER captures state changes of Relay Word bit elements and relay conditions. Relay conditions include power up, relay enable/disable, group changes, settings changes, memory queue overflow, and SER autoremoval/reinsertion.

SER

The default order of the **SER** command is oldest to newest from list top to list bottom. You can view the SER records in numerical or date order.

Table 13.96 SER Command (Sheet 1 of 2)

Command	Description	Access Level
SER	Return the 20 most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2
SER ***k***	Return the *k* most recent records from the SER, with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list.	1, B, P, A, O, 2

Table 13.96 SER Command (Sheet 2 of 2)

Command	Description	Access Level
SER *m n*[a]	Return the SER records from *m* to *n*. If *m* is greater than *n*, records appear with the oldest (highest number) at the top of the list and the most recent (lowest number) at the bottom of the list. If *m* is less than *n*, records appear with the most recent (lowest number) at the top of the list and the oldest (highest number) at the bottom of the list.	1, B, P, A, O, 2
SER *date1*[b]	Return the SER records on *date1*.	1, B, P, A, O, 2
SER *date1 date2*[b]	Return the SER records from *date1* at the top of the list, to *date2* at the bottom of the list.	1, B, P, A, O, 2

[a] Parameters m and n indicate an SER event number, where 1 is the latest event.
[b] Enter date1 and date2 in the same format as specified by Global setting DATE_F.

SER C, SER R, SER CV, and SER RV

The **SER C** and **SER R** commands clear the SER records for the present port. Options **C**, **R**, **CV** and **RV** are identical.

Table 13.97 SER C and SER R Commands

Command	Description	Access Level
SER C	Clear SER records on the present port.	1, B, P, A, O, 2
SER R	Clear SER records on the present port.	1, B, P, A, O, 2

The relay prompts: `Clear the sequential events recorder. Are you sure (Y/N)?` when you issue the **SER C** or **SER R** command. If you answer **Y <Enter>**, the relay clears the particular port SER records.

SER CA and SER RA

The **SER CA** and **SER RA** commands are clear all SER records from memory.

Table 13.98 SER CA or SER RA Commands

Command	Description	Access Level
SER CA or **SER RA**	Clear SER data for all ports.	I, B, P, A, O, 2

If you issue the **SER CA** or **SER RA** command, the relay prompts: `Clear the sequential events recorder for all ports. Are you sure (Y/N)?`

If you answer **Y <Enter>**, the relay clears all SER records viewed from this port. The data are still visible to other ports and to file transfer accesses, and they must be cleared independently for those ports. Data not yet viewed remain available.

SER D

The **SER D** command shows a list of SER items that the relay has automatically removed. These are chattering elements. You can automatically remove chattering SER elements in the SER Chatter Criteria category of the Report settings; the enable setting is ESERDEL.

Table 13.99 SER D Command

Command	Description	Access Level
SER D	List chattering SER elements that the relay is removing from the SER records.	1, B, P, A, O, 2

If you issue the **SER D** command and you have not enabled automatic removal of chattering SER elements (Report setting ESERDEL), the relay responds, `Automatic removal of chattering SER elements not enabled`.

SET

Use the **SET** command to change relay settings. The SEL-487E settings structure is ordered and contains these items (in structure order): classes, instances, categories, and settings. An outline of the relay settings structure is as follows:

Classes (Global, Group, Zone Configuration, Protection, Automation, Outputs, Front Panel, Report, DNP, and Ports)

Instances (some classes have instances: Group = 1–6; Protection = 1–6; Automation = 1–10; Ports = 1–3, F, 5)

Categories (collections of similar settings)

Settings (specific relay settings with values)

The **SET** and **SHOW** commands contain these settings structure items, which you must specify in order from class to instance (if applicable) to setting. The order that specific settings appear in the relay settings structure is factory programmed.

SET

The **SET** command with no options or parameters accesses the relay settings Group class and the instance corresponding to the active group. To set a different instance, specify the instance number (1–6).

Table 13.100 SET Command Overview

Command	Description	Access Level
SET	Set the Group relay settings, beginning at the first setting in the active group.	P, 2
SET *n*[a]	Set the Group *n* relay settings, beginning at the first setting in the group.	P, 2
SET *label*	Set the active group settings beginning at setting *label*.	P, 2
SET *n label*[a]	Set the Group *n* relay settings beginning at setting *label*. Note: free-form settings will not be recognized as valid labels.	P, 2

[a] Parameter n = 1–6, representing Group 1 through Group 6.

The relay validates your settings entries as you enter each setting. At the end of a settings instance session, the relay responds with a readback of all the settings in the settings instance; then prompts: `Save settings (Y,N)?`

If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait...........`

The relay saves the new settings, then responds, `Settings Saved.`

If you answer **N <Enter>**, the relay responds, `Settings aborted.`

SET A

Use the **SET A** command to set the Automation SELOGIC control equations.

Table 13.101 SET A Command

Command	Description	Access Level
SET A	Set the Automation SELOGIC control equation relay settings in Block 1.	A, 2
SET A *n*[a]	Set the Automation SELOGIC control equation relay settings in Block *n*.	A, 2

[a] Parameter n = 1–10 for Block 1 through Block 10.

The relay presents text-edit mode entry format for the free-form SELOGIC control equations you program in the Automation SELOGIC control equations settings area.

SET B

Use the **SET B** command to configure the transformer bay for display on and control from the front panel. Choose the appropriate HV, LV and transformer representations to configure the one-line diagram applicable to your application.

Table 13.102 SET B Command

Command	Description	Access Level
SET B	Bay control settings, beginning at the first setting in this class.	P, B, 2
SET B *label*	Bay control settings, beginning at the setting *label*.	P, B, 2

SET D

Issue the **SET D** command to remap serial port DNP3 values. To set the general DNP settings, use the Port settings for the appropriate port. There is only one instance of the serial port DNP3 remapping settings. The relay must have the optional serial port DNP3 protocol installed to access these settings.

Table 13.103 SET D Command

Command	Description	Access Level
SET D	Set the serial port DNP3 remapping settings, beginning at the first setting in this class.	P, A, O, 2
SET D *label*	Set the serial port DNP3 remapping settings, beginning at setting *label*.	P, A, O, 2

SET F

Use the **SET F** command to set the relay front-panel settings.

Table 13.104 SET F Command

Command	Description	Access Level
SET F	Set the Front Panel relay settings, beginning at the first setting in this class.	P, A, O, 2
SET F *label*	Set the Front Panel relay settings, beginning at the settings *label*.	P, A, O, 2

SET G

Use the **SET G** command to the Global class settings. There is only one instance for the Global class.

Table 13.105 SET G Command

Command	Description	Access Level
SET G	Set the Global relay settings, beginning at the first setting in this class.	P, A, O, 2
SET G *label*	Set the Global relay settings, beginning at the setting *label*.	P, A, O, 2

SET L

Use the **SET L** command to set the Protection SELOGIC control equations.

Table 13.106 SET L Command

Command	Description	Access Level
SET L	Set the Protection SELOGIC control equation relay settings for the active group.	P, 2
SET L *n*[a]	Set the Protection SELOGIC relay settings for Group *n*.	P, 2

[a] Parameter n is 1–6 for Protection Groups 1 through 6.

The relay presents text-edit mode entry format for the free-form SELOGIC control equations you program in the Protection SELOGIC control equation settings area.

SET M

Use the **SET M** command to set monitoring for up to five circuit breakers, one battery system, transformer through-fault, and transformer thermal monitors.

Table 13.107 SET M Command

Command	Description	Access Level
SET M	Monitor settings, beginning at the first setting in this class.	P, M, 2
SET M *label*	Monitor settings, beginning at the setting *label*.	P, M, 2

SET N

Use the **SET N** command to leave a message in the relay.

Table 13.108 SET N Command

Command	Description	Access Level
SET N	Enter text using the text-edit format.	P, N, 2

SET O

Use the **SET O** command to set the Output SELOGIC control equations.

Table 13.109 SET O Command

Command	Description	Access Level
SET O	Set the Output SELOGIC control equation relay settings, beginning at OUT101.	O, 2
SET O *label*	Set the Output SELOGIC control equation relay settings, beginning at the output *label*.	O, 2

SET P

Use the **SET P** command to configure the relay communications ports; each port is a settings instance. The SEL-487E communications ports include serial ports at Port F, Port 1, Port 2, and Port 3. Port 5 is the communications card port into which the optional Ethernet card or other communications cards can be installed.

Table 13.110 SET P Command

Command	Description	Access Level
SET P	Set the port presently in use, beginning at the first setting for this port.	P, A, O, 2
SET P *label*	Set the port presently in use, beginning at the setting *label*.	P, A, O, 2
SET P *p*[a]	Set the communications Port relay settings for Port *p*, beginning at the first setting for this port.	P, A, O, 2
SET P *p label*	Set the communications Port relay settings for Port *p*, beginning at the setting *label*.	P, A, O, 2

[a] Parameter p = 1–3, F, or 5, corresponding to Port 1–Port 3, Port F, or Port 5.

SET R

Use the **SET R** command to set Report settings and to program SER points and Reporting, Set State, and Clear State names. You can also set event report parameters and program event report digital elements. There is only one instance for the Report settings.

Table 13.111 SET R Command

Command	Description	Access Level
SET R	Set the Report relay settings, beginning at the first setting for this class.	P, A, O, 2
SET R *label*	Set the Report relay settings, beginning at the setting *label*.	P, A, O, 2

Report settings are a mix of traditional settings entry mode and text-edit entry mode.

SET T

Use the **SET T** command to set aliases for Relay Word bits, Analog quantities, terminal names, or bus-zone names. There is only one instance for the alias settings.

Table 13.112 SET T Command

Command	Description	Access Level
SET T	Set the alias settings.	P, A, O, 2

SET TERSE

Use the **TERSE** option to inhibit the relay from sending the settings class or instance readback when you end a settings session. SEL recommends that you use the **TERSE** option sparingly; you should review the readback information to confirm that you have entered the settings that you intended.

Table 13.113 SET TERSE Command Examples

Command	Description	Access Level
SET TERSE	SET Group relay settings for the active group, beginning at the first setting in this instance; omit settings readback.	P, 2
SET 3 TE *label*[a]	SET Group 3 settings, beginning at the settings label *label*; omit settings readback.	P, 2
SET P *p label* TERSE	Set the communications Port relay settings for Port *p*, beginning at the settings label *label*; omit readback.	P, A, O, 2

[a] TERSE may be entered as TE as shown in this example.

You can use the **TERSE** option in any **SET** command at any position after typing **SET**. When you end the settings edit session, the relay responds, `Save settings (Y,N)?` If you answer **Y <Enter>**, the relay pulses the Relay Word bit SALARM, and responds, `Saving Settings, Please Wait...........` The relay saves the new settings, then responds, `Settings Saved`. If you answer **N <Enter>** to the save settings prompt, the relay responds, `Settings aborted`.

SHOW

The **SHOW** command shows the relay settings. When showing settings, the relay displays the settings label and the present value from nonvolatile memory.

The relay organizes settings in classes, instances, categories, and specific settings; see *SET on page 13.38* for information on settings organization. The relay displays each setting in the order specified in the settings tables in *Section 6: Settings*. When you are using a terminal and you specify a setting in the middle of a settings category, the relay displays the category title, then proceeds with the class or instance settings from the setting that you specified.

SHO

The **SHO** command with no options or parameters accesses the relay settings Group class and the instance corresponding to the active group. To show a different instance, specify the instance number (1–6).

Table 13.114 SHO Command Overview

Command	Description	Access Level
SHO	Show the Group relay settings, beginning at the first setting in the active group.	1, B, P, A, O, 2
SHO *n*[a]	Show the Group *n* relay settings, beginning at the first setting in each instance.	1, B, P, A, O, 2
SHO *label*	Show the Group relay settings, beginning at the active group settings label *label*.	1, B, P, A, O, 2
SHO *n label*	Show the Group *n* relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

[a] Parameter n = 1–6, representing Group 1 through Group 6.

SHO A

Use the **SHO A** command to show the Automation SELOGIC control equations.

Table 13.115 SHO A Command

Command	Description	Access Level
SHO A	Show the Automation SELOGIC control equation relay settings in Block 1.	1, B, P, A, O, 2
SHO A *n*[a]	Show the Automation SELOGIC control equation relay settings in Block *n*.	1, B, P, A, O, 2

[a] Parameter n = 1–10 for Block 1 through Block 10.

SHO B

Use the **SHO B** command to show the transformer bay settings.

Table 13.116 SHO B Command

Command	Description	Access Level
SHO B	Show the Bay control settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO B *label*	Show Bay control settings, beginning at the setting *label*.	1, B, P, A, O, 2

SHO D

NOTE: This does not display mapping information for DNP LAN/WAN.

The **SHO D** command shows the serial port DNP3 remapping settings. To view the general serial port DNP3 settings, use the Port settings (see *SHO P on page 13.45*). There is only one instance of the serial port DNP3 remapping settings. The relay must have the optional serial port DNP3 protocol installed to access these settings.

Table 13.117 SHO D Command

Command	Description	Access Level
SHO D	Show the serial DNP3 remapping settings.	1, B, P, A, O, 2
SHO D *label*	Show the serial DNP3 remapping settings, beginning at setting *label*.	1, B, P, A, O, 2

SHO F

Use the **SHO F** command to show the relay front-panel settings. There is only one instance for the Front Panel settings.

Table 13.118 SHO F Command

Command	Description	Access Level
SHO F	Show the Front Panel relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO F *label*	Show the Front Panel relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO G

Use the **SHO G** command to show the Global class settings. There is only one instance for the Global class.

Table 13.119 SHO G Command

Command	Description	Access Level
SHO G	Show the Global relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO G *label*	Show the Global relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO L

Use the **SHO L** command to show the Protection SELogic control equations.

Table 13.120 SHO L Command

Command	Description	Access Level
SHO L	Show the Protection SELogic control equation relay settings for the active group.	1, B, P, A, O, 2
SHO L *n*[a]	Show the Protection SELogic control equation relay settings for Group *n*.	1, B, P, A, O, 2

[a] Parameter n is 1–6 for Group 1 through Group 6.

SHO M

Use the **SHO M** command to show the monitor settings. There is only one instance for the Breaker Monitor class.

Table 13.121 SHO M Command

Command	Description	Access Level
SHO M	Show the Monitor relay settings, beginning at the first setting in this class.	1, B, P, A, O, 2
SHO M *label*	Show the Monitor relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO N

Use the **SHO N** command to show notes in the relay.

Table 13.122 SHO N Command

Command	Description	Access Level
SHO N	Show notes in the relay.	1, B, P, A, O, 2

SHO O

Use the **SHO O** command to show the Output SELOGIC control equations.

Table 13.123 SHO O Command

Command	Description	Access Level
SHO O	Show the Output SELOGIC control equation relay settings, beginning at OUT101.	1, B, P, A, O, 2
SHO O *label*	Show the Output SELOGIC control equation relay settings, beginning at the output label *label*.	1, B, P, A, O, 2

SHO P

Use the **SHO P** command to configure the relay communications ports; each port is a settings instance. The SEL-487E communications ports include serial ports at Port F, Port 1, Port 2, and Port 3. Port 5 is the communications card port into which you can install the optional Ethernet card or other communications cards.

Table 13.124 SHO P Command

Command	Description	Access Level
SHO P	Show the relay settings for the port presently in use, beginning at the first setting.	1, B, P, A, O, 2
SHO P *label*	Show the relay settings for the port presently in use, beginning at the settings label *label*.	1, B, P, A, O, 2
SHO P *p*[a]	Show the communications Port relay settings for Port *p*, beginning at the first setting for this port.	1, B, P, A, O, 2
SHO P *p label*	Show the communications Port relay settings for Port *p*, beginning at the settings label *label*.	1, B, P, A, O, 2

[a] Parameter p = 1–3, F, and 5 which corresponds to PORT 1–PORT 3, PORT F, and PORT 5.

The **SHO P** command with no options and parameters shows the settings for the active serial port.

SHOW R

Use the **SHO R** command to show Report settings and to program SER Points and Aliases. You can also show event report parameters and program Event Report Digital Elements. There is only one instance for the Report settings.

Table 13.125 SHO R Command

Command	Description	Access Level
SHO R	Show the Report relay settings, beginning at the first setting for this class.	1, B, P, A, O, 2
SHO R *label*	Show the Report relay settings, beginning at the settings label *label*.	1, B, P, A, O, 2

SHO T

Use the **SHO T** command to show aliases for Relay Word bits, Analog quantities, terminal names, or bus-zone names. There is only one instance for the alias settings.

Table 13.126 SHO T Command

Command	Description	Access Level
SHO T	Show the alias settings.	1, B, P, A, O, 2

SNS

In response to the **SNS** command, the relay sends the name strings of the Sequential Events Recorder elements. This is a comma-delimited string used to support the SEL Fast SER report.

Table 13.127 SNS Command

Command	Description	Access Level
SNS	Send the name strings of SER elements.	0, 1, B, P, A, O, 2

STATUS

The **STATUS** command reports relay status information that the relay derives from internal diagnostic routines and self-tests.

STA

The **STA** command with no options displays a short-form relay status report. Items in the STA report are the header, failures, warnings, SELOGIC control equation programming environment errors, and relay operational status.

Table 13.128 STA Command

Command	Description	Access Level
STA	Return the relay status.	1, B, P, A, O
STA	Return the relay status and show a new hardware configuration prompt.	2

If you change an I/O interface board, the relay detects the new configuration and initiates a status warning. When you issue the **STA** command at Access Level 2, the relay responds to this situation, `Accept new hardware configuration (Y/N)?` If you answer **Y <Enter>**, the relay responds, `New configuration accepted`. If you answer **N <Enter>**, the relay responds, `Command aborted`.

STA A

Use the **STA A** command to view the entire relay status report. Items in the full status report include the short-form status report items plus data on A/D (analog/digital) channel offsets, power supply voltages, temperature, communications interfaces, and time-source synchronization.

Table 13.129 STA A Command

Command	Description	Access Level
STA A	Display all items of the status report.	1, B, P, A, O, 2

STA C and STA R

The **STA C** and **STA R** commands reboot the relay. Thus, these commands clear a transient failure should this unlikely event occur. Options **C** and **R** are identical. Contact your Technical Service Center or the SEL Factory before using this command.

Table 13.130 STA C and STA R Command

Command	Description	Access Level
STA C	Reset the relay.	2
STA R	Reset the relay.	2

STA S

Use the **STA S** command to view all SELOGIC control equation operating errors.

Table 13.131 STA S Command

Command	Description	Access Level
STA S	Display detailed SELOGIC control equation error information.	1, B, P, A, O, 2

STA SC and STA SR

The **STA SC** and **STA SR** commands clear the SELOGIC control equation operating errors from the status report if the errors are no longer present. In addition, these commands reset the Automation SELOGIC Peak and Average Execution Cycle Time statistics.

Table 13.132 STA SC and STA SR Command

Command	Description	Access Level
STA SC	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2
STA SR	Clear SELOGIC control equation errors and reset SELOGIC cycle time statistics.	P, A, O, 2

SUMMARY

The **SUMMARY** command displays a summary event report.

SUM

Use the **SUM** command to view the event summary reports in the relay memory.

Table 13.133 SUM Command

Command	Description	Access Level
SUM	Return the most recent event summary.	1, B, P, A, O, 2
SUM *n*[a]	Return an event summary for event *n*.	1, B, P, A, O, 2

[a] Parameter n indicates event order or serial number; see the event history report (HIS on page 13.22).

When parameter *n* is 1 through 100, *n* indicates the order of the event report. The most recent event report is 1, the next most recent report is 2, and so on. When parameter *n* is 10000 through 42767, *n* indicates the absolute serial number of the event report.

SUM ACK

Use **SUM ACK** to acknowledge an event summary that you recently viewed with the **SUM NEXT** command on the present communications port. Acknowledge the oldest summary (specify no event number).

Table 13.134 SUM ACK Command

Command	Description	Access Level
SUM ACK	Acknowledge the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

If you attempt to acknowledge an event summary that you have not viewed on the present port with the **SUM NEXT** command, the relay responds, `Event summary number n has not been viewed`.

SUM NEXT

Use the **SUM NEXT** command to view the oldest (next) unacknowledged event summary.

Table 13.135 SUM NEXT Command

Command	Description	Access Level
SUM NEXT	View the oldest unacknowledged event summary at the present communications port.	1, B, P, A, O, 2

TARGET

The **TARGET** command displays the elements for a selected row in the Relay Word bit table. See *Appendix G: Relay Word Bits*.

TAR

Use the **TAR** command to view a row of Relay Word bits or the alias names of the Relay Word bits. When using the **TAR** command, you can specify the row number or element name.

Table 13.136 TAR Command

Command	Description	Access Level
TAR	Display Row 0 or display the most recently viewed row.	1, B, P, A, O, 2
TAR *n*	Display Row *n*.	1, B, P, A, O, 2
TAR *n k*[a]	Display Row *n* and repeat for *k* times; the repeat count *k* must follow the row number.	1, B, P, A, O, 2
TAR *name*	Display the row with the element *name*.	1, B, P, A, O, 2
TAR *name k*	Display the row with the element *name* and repeat for *k* times; the repeat count *k* can be before or after the *name* option.	1, B, P, A, O, 2

[a] Parameter k is the repeat count from 1-32767.

The relay memorizes the latest row input conditioned by your present access level. The relay displays Row 0 if you have not specified a row since power up, the access level has timed out, or you have issued the **QUIT** command.

If you specify the repeat count *k* at a number greater than eight, the relay displays the repeated rows on the terminal screen in groups of eight, with the row elements listed above each grouping.

TAR ALL

Use the **TAR ALL** command to display all of the Relay Word bits.

Table 13.137 TAR ALL Command

Command	Description	Access Level
TAR ALL	Display all target rows.	1, B, P, A, O, 2

TAR R

The **TAR R** command has two functions. Use this command to reset any latched relay targets resulting from a tripping event. Also employ the **TAR R** command to reset to Row 0 the memorized target row that the relay reports when you issue a simple **TAR** command.

Table 13.138 TAR R Command

Command	Description	Access Level
TAR R	Reset latched targets and return memorized row to Row 0.	1, B, P, A, O, 2

TAR X

Use the **TAR X** command to view a different row in the Relay Word bit table than the row in the memory. This function is useful for relay testing.

Table 13.139 TAR X Command

Command	Description	Access Level
TAR *n* X	Display Row *n*, but do not memorize Row *n*.	1, B, P, A, O, 2
TAR X *n k*[a]	Display Row *n* and repeat for *k* times; do not memorize Row *n*. The repeat count *k* must follow the row number.	1, B, P, A, O, 2
TAR *name* X	Display the row with the element *name*; do not memorize the row number.	1, B, P, A, O, 2
TAR *name* X *k*	Display the row with the element *name* and repeat for *k* times; do not memorize the row number. The repeat count *k* can be at any position in the command after **TAR**.	1, B, P, A, O, 2

[a] Parameter k is the repeat count from 1–32767.

You can place the **X** option at any position in the **TAR** command.

TEST DB

Use Fast Message Data Access operations in conjunction with the **TEST DB** command to write temporary values to the communications card in order to verify the database values. The relay contains a database that describes the relay to external devices. When other devices access the relay via the communications card, the relay appears as a virtual device described by the database. The SEL-487E is Virtual Device 1.

The virtual database of any installed Ethernet card is accessible to master stations of supported Ethernet protocols (DNP3, IEC 61850) connected to the Ethernet network. You can therefore test the read functionality of all protocols in the Ethernet interface with this command.

Use the **TEST DB 1** command to override any value in the relay database. You must understand the relay database structure to effectively use the **TEST DB** command.

Values you enter in the relay database are override values. Use the **TEST DB** command to write override values in the database accessed through the communications card.

Table 13.140 TEST DB Command

Command	Description	Access Level
TEST DB	Display present override values by virtual device number and address.	1, B, P, A, O, 2
TEST DB 1 *addr value1*	Write new data *value1* to the database at an address *addr*.	B, P, A, O, 2
TEST DB 1 *addr value1 M D Y h m s*	Write new data value1 to the database at an address *addr* and include the provided date/time stamp *M D Y h m s*	B, P, A, O, 2

The database address *addr* can be any legitimate decimal or hexadecimal address. (A hexadecimal address is a numeral with an “h” suffix or a “0x” prefix.)

You can enter the override value *value1* as an integer, a floating-point number (which overrides two registers), a character (which must be in single quotes), or a string (which must be in double quotes and overrides the number of registers corresponding to the length of the string).

If a date/time stamp is also provided (*M D Y h m s*), the relay will change the static state given and, for any bits being changed by this operation, queued entries will be pushed with the provided date/time stamp. If no queue is associated with the database region (determined by *addr*), the date/time stamp will be ignored.

The order that the date should be entered on the command line depends upon the DATE_F (Global) setting. For example, if DATE_F := DMY, you would enter **TEST DB *vdev addr value D M Y h m s***.

While there are active test data, the relay asserts Relay Word bit TESTDB.

TEST DB OFF

Use the **TEST DB OFF** command to end the testing session and remove the override values. The relay returns the database registers to the pretest values.

Table 13.141 TEST DB OFF Command

Command	Description	Access Level
TEST DB OFF	Clear all override testing values from all virtual devices.	B, P, A, O, 2
TEST DB OFF 1	Clear all override testing values from Virtual Device 1 (the relay).	B, P, A, O, 2
TEST DB OFF 1 *region*	Clear all override testing values from the region region in Virtual Device 1 (the relay).	B, P, A, O, 2

TEST DNP

The **TEST DNP** command is for testing the DNP interface.

TEST DNP

Values you enter in the DNP map are override values. Use the **TEST DNP** command to write override values in the DNP map.

Table 13.142 TEST DNP Command

Command	Description	Access Level
TEST DNP	Display present override values.	1, B, P, A, O, 2
TEST DNP *type n*[a] *value*	Write new data *value* of *type* to the DNP map at DNP point number *n*.	B, P, A, O, 2

[a] Parameter type is A for analog, B for binary, or C for counter inputs.; n is a DNP point number.

When displaying DNP test data overrides with the **TEST DNP** command, the relay shows the report header, then the DNP Object Type, Index, and Override Value for binary inputs, counters, and analog inputs.

To force a value, use the **TEST DNP *type n value1*** command. The type is A for analog inputs, B for binary inputs, or C for counter inputs. The point number *n* is based on the active DNP map. The override value *value1* is a value you specify. The point number and override value must be valid for the given data type.

When you have successfully added a new DNP test value (for example, **TEST DNP A 17 -357**), the relay responds, `Override Added`. The relay asserts Relay Word bit TESTDNP while any DNP test data are present in the relay.

DNP Status Bytes

Whenever a DNP value is overridden and the value is read via DNP, the status byte for the overridden value indicates that the bit is locally forced to a test value.

TEST DNP OFF

Use the **TEST DNP OFF** command to remove override values. The relay returns the database registers to the pretest values.

Table 13.143 TEST DNP OFF Command

Command	Description	Access Level
TEST DNP *type n*[a] OFF	Clear the override testing value of *type* from the DNP point number *n*.	B, P, A, O, 2
TEST DNP OFF	Clear all override testing values from the DNP map.	B, P, A, O, 2

[a] Parameter n is a DNP point number; type is A for analog, B for binary, or C for counter inputs.

When you have successfully removed a DNP test value (for example, **TEST DNP A 17 OFF**), the relay responds, `Override Removed`. When an attempt to remove a DNP test value fails, the relay responds, `Override Not Found`. When removing all DNP test values (for example, **TEST DNP OFF**), the relay responds, `All Overrides Removed`.

TEST FM

The **TEST FM** command overrides normal Fast Meter quantities for testing purposes. You can only override reported Fast Meter values (per-phase voltages and currents).

TEST FM

Values you enter in Fast Meter storage are override values. Use the **TEST FM** command to display override values and write override values in the Fast Meter report.

Table 13.144 TEST FM Command

Command	Description	Access Level
TEST FM	Display present override values.	1, B, P, A, O, 2
TEST FM *label value*	Write new data *value* to the Fast Meter report at the item *label*.	B, P, A, O, 2

When displaying Fast Meter data overrides with the **TEST FM** command, the relay shows the item label and override values.

To force a value, use the **TEST FM *label value1 value2*** command. The item label *label* is any analog channel label in the Fast Meter configuration (if available), any digital element label (from the **DNA** command), and any status element label (from the **BNA** command) except the TEST and FMTEST items.

The value *value1* can be logical 0 or logical 1 for digital and status elements, or a floating-point value for all meter quantities. All meter values are in primary units. For meter items that report a pair of values in the Fast Meter message, *value1* is the magnitude and *value2*, if provided, is the angle. If you do not specify *value2*, the relay uses an angle of 0.

When you have successfully added a new Fast Meter test value (for example, **TEST FM IA1 3.7 0.0**), the relay responds, `Override Added`. The relay asserts Relay Word bit TESTFM while any Fast Meter override data are present in the relay.

Fast Meter Status Byte

Bits labeled TEST and FMTEST reside in the Fast Meter status byte. If any item within the Fast Meter message is in test mode, the relay sets the TEST bit. Similarly, if any item in any Fast Meter message is in test mode, the FMTEST is set in all three Fast Meter responses.

TEST FM DEM

Use the **TEST FM DEM** command to insert override values in Fast Meter demand metering.

Table 13.145 TEST FM DEM Command

Command	Description	Access Level
TEST FM DEM *label value1*	Write new data *value1* to the Fast Meter demand meter report at the item label *label*.	B, P, A, O, 2

TEST FM OFF

Use the **TEST FM OFF** command to remove override values. The relay returns the Fast Meter registers to the pre-test values.

Table 13.146 TEST FM OFF Command

Command	Description	Access Level
TEST FM *label* OFF	Clear the override values for the Fast Meter item *label*.	B, P, A, O, 2
TEST FM OFF	Clear all override testing values from Fast Meter.	B, P, A, O, 2

When you have successfully removed a Fast Meter test value (for example, **TEST FM IA1 OFF**), the relay responds, `Override Removed`. When an attempt to remove an FM test value fails, the relay responds, `Override Not Found`. When removing all FM test values (for example, **TEST FM OFF**), the relay responds, `All Overrides Removed`.

TEST FM PEAK

Use the **TEST FM PEAK** command to insert override values in Fast Meter peak demand metering.

Table 13.147 TEST FM PEAK Command

Command	Description	Access Level
TEST FM PEAK *label value1*	Write new data *value1* to the Fast Meter peak demand meter report at the item label *label*.	B, P, A, O, 2

TFE

Use the **TFE** command to display, set and clear through-fault data.

Table 13.148 TFE Command

Command	Description	Access Level
TFE	Displays up to 20 of the most recent through-faults	Level 1 and higher
TFE A	Display all through-faults records.	Level 1 and higher
TFE *nnnn*[a]	Displays *nnnn* through faults.	Level 1 and higher
TFE P	Preloads through-fault values.	Level 1 and higher
TFE R or C	Clears accumulated values and deletes the history.	Level 1 and higher

[a] (nnnn = 1–1200).

THE

Use the **THE *n***, (*n* = 1–5) command to display up to five saved thermal reports of the transformer(s) monitored by the relay. For example, **THE 1** displays the most recent event report while **THE 5** displays the oldest thermal event report. Reports are saved in a FIFO type buffer where the newest event will overwrite the oldest report.

Table 13.149 TFE Command

Command	Description	Access Level
THE[*n*][a]	Generates thermal monitor report	Level 1 and higher
THE P	Load preset value of accumulated insulation Loss Of Life for transformer	Level 1 and higher
THE D [*x* [*y*]][b]	Retrieves daily profile data from day *x* to day *y*	Level 1 and higher
THERM H	Retrieves hourly profile data	Level 1 and higher
THERM R	Resets all stored thermal data archives and the value of total Loss Of Life	Level 2 and higher
THERM C	Clears all stored thermal data archives	Level 2 and higher

[a] n = 1–5.
[b] D = mm:dd:yy if setting DATE_F = MDY
yy:mm:dd if setting DATE_F = YMD
dd:mm:yy if setting DATE_F = DMY

TIME

Use the **TIME** command to view and set the relay time clock. The ASCII interface is just one source by which you can set the internal clock. Other sources can override the ASCII **TIME** command; overriding occurs in IRIG time mode and when using DNP.

Use the **TIME *hh:mm*** and **TIME *hh:mm:ss*** commands to set the relay internal clock time. The value hh is for hours from 0–23; the value *mm* is for minutes from 0–59; the value ss is for seconds from 0–59. If you enter a valid time, the relay updates and saves the time in the nonvolatile clock, and displays the time you just entered. If you enter an invalid time, the relay responds, `Invalid Time`. Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

Table 13.150 TIME Command

Command	Description	Access Level
TIME	Display the present relay internal clock time.	1, B, P, A, O, 2
TIME *hh:mm*	Set the relay internal clock to *hh:mm*.	1, B, P, A, O, 2
TIME *hh:mm:ss*	Set the relay internal clock to *hh:mm:ss*.	1, B, P, A, O, 2

TIME Q

The **TIME Q** command returns detailed information on the relay internal clock. Use this command to query the status of high-accuracy time source inputs and the present clock time mode.

Table 13.151 TIME Q Command

Command	Description	Access Level
TIME Q	Display detailed information about the internal relay clock; query relay time.	1, B, P, A, O, 2

When you issue the **TIME Q** command, the relay reports statistics on the relay time sources. These statistics include the present time source and the last time value update source.

TRIGGER

The **TRIGGER** command initiates data captures for high-resolution oscillography and event reports.

TRI

Use the **TRI** command to trigger the SEL-487E to record data for high resolution oscillography and event reports.

Table 13.152 TRI Command

Command	Description	Access Level
TRI	Trigger relay data capture.	1, B, P, A, O, 2

When you issue the **TRI** command, the relay responds, `Triggered`. If the event did not trigger within one second, the relay responds, `Did not trigger`.

VERSION

The **VERSION** command displays the relay hardware and software configuration.

VER

Use the **VER** command to list the part numbers, serial numbers, checksums, software release numbers, and other important relay configuration information.

Table 13.153 VER Command

Command	Description	Access Level
VER	Display the hardware and software configurations.	1, B, P, A, O, 2

When you issue the **VER** command, the relay displays the latest release numbers for the following items:

- FID
- Part number
- Serial number
- SELBOOT BFID
- Mainboard memory types and sizes
- Front-panel hardware

- Analog inputs ratings
- Fiber port (installed or absent)
- Interface board inputs and outputs
- Power supply ratings
- Communications card IDs and part number
- Extended relay features list (optional DNP communications capability)

Figure 13.3 shows a sample **VER** command response.

```
=>VER <Enter>
FID=SEL-487E-R100-V0-Z001001-D20080424
CID=5054
Part Number:  0487E0X41111XXB4H74444X
Serial Number:  2008005065
SELboot:
    BFID= SLBT-4XX-X027-V0-Z001002-D20080418
    Checksum:  FD43
Mainboard:
    Code FLASH Size:   12 MB
    Data FLASH Size:   20 MB
    RAM Size:          16 MB
    EEPROM Size:      128 kB
Front Panel: installed
Analog Board A:
    S:  Currents:  5 Amp
    T:  Currents:  5 Amp
    U:  Currents:  5 Amp
    V:  Voltage:   67 Volts
Analog Board B:
    W:  Currents:  5 Amp
    X:  Currents:  5 Amp
    Y1: Currents:  5 Amp
    Y2: Currents:  5 Amp
    Y3: Currents:  5 Amp
    Z:  Voltage:   67 Volts
Interface Boards:
    Board 1:  24 inputs   8 outputs
    Board 2:  24 inputs   8 outputs
Communications Card:
    not installed
Extended Relay Features:
    None

If the above information is not as expected, contact SEL for assistance.

=>
```

Figure 13.3 Sample VER Command Response

If an item is not installed, the **VER** report indicates `Not installed` at the appropriate line. If a detected hardware configuration does not match the component part number, the relay adds the statement `Warning - hardware does not match part number` on the corresponding line.

VIEW

Use the **VIEW** command to examine data within the relay database. You can view these data in three ways:

- Region
- Register item
- Bit

The **VIEW** command in the SEL-487E is very similar to the **VIEW** command in SEL Communications Processors. SEL-487E regions are LOCAL, METER, DEMAND, TARGET, HISTORY, BREAKER, STATUS, and ANALOGS; view this list with the **MAP 1** command.

The SEL-487E is Virtual Device 1; all commands begin **VIEW 1**. In all database views, if a data item is in test mode, the relay displays an asterisk (*) mark following the data value.

VIEW 1 Commands—Region

Use the commands in *Table 13.154* to view the contents of the database regions.

Table 13.154 VIEW 1 Commands—Region

Command	Description	Access Level
VIEW 1 *region*	Display the data in the relay database in the region *region*.	1, B, P, A, O, 2
VIEW 1 *region* BL	Display the data in the region *region* and include bit labels.	1, B, P, A, O, 2

VIEW 1 Commands—Register Item

Use the commands in *Table 13.155* to view register items in the relay database. Examples of register items in the METER region are IA1, I0_1, VB, and PF. Examples of register items in the LOCAL region are FID, SER_NUM, and PART_NUM.

Table 13.155 VIEW 1 Commands—Register Item

Command	Description	Access Level
VIEW 1 *addr*	Display the data in the relay database at register address *addr*.	1, B, P, A, O, 2
VIEW 1 *addr* NR *m*[a]	Display the data beginning at register address *addr* and continue for *m* registers.	1, B, P, A, O, 2
VIEW 1 *region item_label*	Display the data for the addresses in the *region item_label* area of the database.	1, B, P, A, O, 2
VIEW 1 *region item_label* NR *m*[a]	Display the data for addresses in the *region item_label* area of the database; begin at the start of *item_label* and proceed for *m* registers.	1, B, P, A, O, 2
VIEW 1 *region offset*	Display the data for the address in the database region *region* at the offset *offset* from the beginning of the region.	1, B, P, A, O, 2
VIEW 1 *region offset* NR *m*[a]	Display the data for the addresses in the database region *region*; begin at the offset *offset* from the beginning of the region and proceed for *m* registers.	1, B, P, A, O, 2

[a] Parameter m is an integer value representing the number of registers.

In the **VIEW 1 *addr*** commands, option *addr* is the register address. Use the **MAP 1 *region*** command to find the register address. You can specify register addresses as a decimal or hexadecimal number. (A hexadecimal address is a numeral with an “h” suffix or a “0x” prefix.) If you specify the data by address or by offset with the *addr* and *offset* options, the relay returns the data in hexadecimal number format. The **NR** option specifies the number of registers *m* that the relay includes in the data listing.

VIEW 1 Commands—Bit

Use commands in *Table 13.156* to inspect a specific bit in the relay database. The relay displays bit data as the bit label or number and the value logical 1 or logical 0. An example of a relay response for bit commands is `1:TARGET:ALTI = 0`, where `ALTI` is the bit label and `0` is the bit value. Other examples of bit labels are P87R1, 27P32, and ASV256.

Table 13.156 VIEW 1 Commands—Bit[a]

Command	Description	Access Level
VIEW 1 *addr bit*	Display the value at register address *addr* for the bit number *bit*.	1, B, P, A, O, 2
VIEW 1 *bit_label*	Display the value for the bit with the bit label *bit_label*.	1, B, P, A, O, 2
VIEW 1 *region bit_label*	Display the value for the particular bit with the bit label *bit_label* in the region *region*.	1, B, P, A, O, 2
VIEW 1 *region offset bit*[b]	Display the value for the bit *bit* in the region *region* that is offset from the beginning of the region by offset *offset*.	1, B, P, A, O, 2

[a] Parameter bit is a number from 0–15, with 0 as the LSB (least significant bit).
[b] Parameter offset is a decimal or hexadecimal number to indicate the offset.

The command option *bit* is the bit number. If you access bit data, the relay displays the bit label or number and the value (logical 0 or logical 1). If you reference the data by label with the **BL** and *bit_label* options, the relay returns the data according to the data type.

Use the **VIEW 1 *bit_label*** command as a shorthand method to inspect a specific data bit in the relay database. The relay searches the entire relay database structure for the bit label you specified; this process takes more time and processing than narrowing the search by using the **VIEW 1 *region*** command and the **VIEW 1 *addr*** command with the bit label option *bit_label*.

Section 14

Testing and Troubleshooting

Overview

This section provides guidelines for determining and establishing test routines for the SEL-487E. Follow the standard practices of your company in choosing testing philosophies, methods, and tools. The relay incorporates self tests to help you diagnose potential difficulties should these occur. SEL-487E self-tests and troubleshooting procedures are shown at the end of the section.

Topics, tests, and troubleshooting procedures presented in this section include the following:

The SEL-487E is factory calibrated; this section contains no calibration information. If you suspect that the relay is out of calibration, contact your Technical Service Center or the SEL factory.

When you receive your new SEL-487E relay, all functions are fully checked and calibrated so that the relay operates correctly and accurately. You can perform tests on the relay to verify proper relay operation, but you do not need to test every relay element, timer, and function in this evaluation. In general, the following checks are valuable for confirming proper SEL-487E connections and operation:

- ➤ AC connection check (metering)
- ➤ Commissioning tests
- ➤ Functional tests
- ➤ Element verification

An ac connection check uses relay metering to verify that the relay current and voltage inputs are the proper magnitude and phase rotation. Commissioning tests help you verify that you have properly connected the relay to the power system and all auxiliary equipment. These tests confirm proper connection of control inputs and control outputs as well. Brief functional tests and element verification confirm correct internal relay processing.

Testing Philosophy

Protective relay testing generally consists of three categories: acceptance testing, commissioning testing, and maintenance testing. The categories differ in testing complexity and according to when these activities take place in the life of the relay.

Each testing category includes particular details as to when to perform the test, the testing goals at that time, and the relay functions that you need to test. This information is a guide to testing the SEL-487E; be sure to follow the practices of your company for relay testing.

Acceptance Testing

SEL performs detailed acceptance testing on all new relay models and versions. We are certain that your SEL-487E meets published specifications. Even so, you can perform acceptance testing on a new relay model to become familiar with the relay operating theory and settings; this familiarity helps you apply the relay accurately and correctly. A summary of acceptance testing guidelines is presented in *Table 14.1*.

Table 14.1 Acceptance Testing

Details	Description
Time	Test when qualifying a relay model for use on the utility system.
Goals	a) Confirm that the relay meets published critical performance specifications such as operating speed and element accuracy.
	b) Confirm that the relay meets the requirements of the intended application.
	c) Gain familiarity with relay settings and capabilities.
Test	Test all protection elements and logic functions critical to your intended application.

Commissioning Testing

SEL performs a complete functional check and calibration of each SEL-487E before shipment so that your relay operates correctly and accurately. You should perform commissioning tests to verify proper connection of the relay to the power system and all auxiliary equipment. Check control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection test to verify that the relay current and voltage inputs are the proper magnitude and phase rotation.

Brief fault tests confirm that the relay settings and protection scheme logic are correct. You do not need to test every relay element, timer, and function in these tests.

At commissioning, use the relay **METER** command to verify the ac current and voltage magnitude and phase rotation. Use the **PUL** command to pulse relay control output operation. Use the **TAR** command to view relay targets and verify that control inputs are operational. Use **TEST FM**, **TEST DNP**, and **TEST DB** to check SCADA interfaces. *Table 14.2* lists guidelines for commissioning testing.

Table 14.2 Commissioning Testing

Details	Description
Time	Test when installing a new protection system.
Goals	a) Validate all system ac and dc connections.
	b) Confirm that the relay functions as intended using your settings.
	c) Check that all auxiliary equipment operates as intended.
	d) Check SCADA interface.
Tests	Test all connected/monitored inputs and outputs, and the polarity and phase rotation of ac connections. Make simple checks of protection elements. Test communications interfaces.

Maintenance Testing

The SEL-487E uses extensive self-testing routines and features detailed metering and event reporting functions. These features reduce your dependence on routine maintenance testing. When you want to perform maintenance testing, follow the recommendations in *Table 14.3*.

Table 14.3 Maintenance Testing

Details	Description
Time	Test at scheduled intervals or when there is an indication of a problem with the relay or power system.
Goals	a) Confirm that the relay is measuring ac quantities accurately.
	b) Check that scheme logic and protection elements function correctly.
	c) Verify that auxiliary equipment functions correctly.
Tests	Test all relay features/power system components that did not operate during an actual fault within the past maintenance interval.

You can use the SEL-487E reporting features as maintenance tools. Periodically compare the relay **METER** command output to other meter readings on a line to verify that the relay measures currents and voltages correctly and accurately. Use the circuit breaker monitor, for example, to detect slow breaker auxiliary contact operations and increasing or varying breaker pole operating times.

Each occurrence of a fault tests the protection system and relay application. Review relay event reports in detail after each fault to determine the areas needing your attention. Use the event report current, voltage, and relay element data to determine that the relay protection elements and communications channels operate properly. Inspect event report input and output data to determine whether the relay asserts outputs at the correct times and whether auxiliary equipment operates properly.

At each maintenance interval, the only items to be tested are those that have not operated (via fault conditions and otherwise) during the maintenance interval. The basis for this testing philosophy is simple: you do not need to perform further maintenance testing for a correctly set and connected relay that measures the power system properly and for which no relay self-test has failed.

The SEL-487E is based on microprocessor technology; the relay internal processing characteristics do not change over time. For example, if time-overcurrent element operating times change, these changes occur because of alterations to relay settings and/or differences in the signals applied to the relay. You do not need to verify relay element operating characteristics as a part of maintenance checks.

SEL recommends that you limit maintenance tests on SEL relays according to the guidelines listed in *Table 14.3*. You will spend less time checking relay operations that function correctly. You can use the time you save to analyze event data and thoroughly test systems needing more attention.

Connecting and Applying Power

Connect external power to the SEL-487E to perform the initial checkout and familiarization procedures in this section. For complete information on power connections, see *Power Connections on page 2.23*.

Figure 14.1 shows the portion of the relay rear panel where you connect the power input.

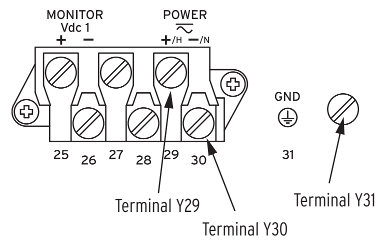


Figure 14.1 Power Connection Area of the Real Panel

Observe the following precautions when connecting power to the SEL-487E:

⚠DANGER
Contact with instrument terminals can cause electrical shock that can result in injury or death.

Step 1. Always attach a safety ground as the first connection you make to the SEL-487E.

Step 2. Connect the grounding terminal (#Y31) labeled **GND** on the rear panel to a rack frame ground or main station ground for proper safety and performance.

Step 3. Use 16 AWG (1.5 mm2) wire (or heavier) to connect to the **POWER** terminals, observing the following:

- When you use a dc power source, you must connect the source with the proper polarity, as indicated by the **+** (Terminal #Y29) and **–** (Terminal #Y30) symbols on the power terminals.
- You can use ac input for the 48/125 Vdc power supply and the 125/250 Vdc power supply.
- The relay operates from 30 to 120 Hz (nominal 50/60 Hz) when alternating current supplies the **POWER** input.

Upon connecting power, you will see information on the front-panel LCD (liquid crystal display) and the **ENABLED** LED (light-emitting diode) will illuminate.

Establishing Communication

Front Port

Once you have successfully applied the correct power input, you are ready to operate the relay. Use the relay front panel and the communications ports to communicate with the relay.

Front-panel control of relay functions involves use of a menu system that you access through the LCD and the six navigational pushbuttons shown in *Figure 14.2*.

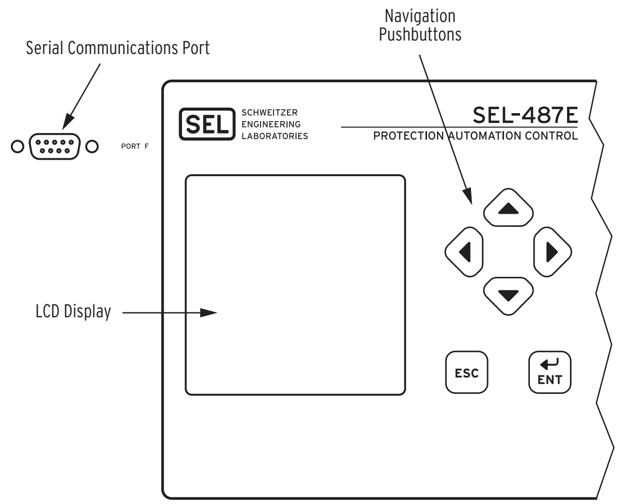


Figure 14.2 PORT F, LCD Display, and Navigation Pushbuttons

Fast and efficient communication with the relay is available through communications ports such as PORT F, also shown in *Figure 14.2*. A design philosophy for all SEL relays is that an ASCII or open terminal is all that you need to communicate with the relay. Many off-the-shelf computer programs provide terminal emulation. These programs are inexpensive and widely available. Use the cable connections appropriate for your terminal configuration.

All ASCII commands you send to the relay must terminate with a carriage return or carriage return/line feed; the terminal emulation program appends the necessary carriage return when you press **<Enter>**. You can truncate commands to the first three characters: **EVENT 1 <Enter>** becomes **EVE 1 <Enter>**. Use upper- and lower-case characters without distinction, except in passwords, which are case sensitive. For a list of ASCII commands see *Section 13: ASCII Command Reference*.

Help

When you are using a terminal, you can access built-in relay help for each ASCII command. Relay help is access-level sensitive; you see only the ASCII commands for the present access level when you type **HELP <Enter>**. For in-depth information on a particular ASCII command, enter the command name after typing **HELP**. For example, for help on the **EVENT** ASCII command, type **HELP EVE <Enter>**.

When you are using ACSELERATOR QuickSet® SEL-5030 Software, press **<F1>** to get help, or select the Help menu from the ACSELERATOR QuickSet toolbars. The help information in ACSELERATOR QuickSet gives detailed information and sample screens in a GUI format.

Making an EIA-232 Serial Port Connection

The following steps use any popular computer terminal emulation software and SEL serial cables to connect to the SEL-487E.

Use an SEL Cable C234A to connect a 9-pin computer serial port to the SEL-487E. Use an SEL Cable C227A to connect a 25-pin computer serial port to the relay. These and other cables are available from SEL. Contact the factory or your local distributor for more information.

Step 1. Connect the computer and the SEL-487E using the serial communications cable.

Use the 9-pin serial port labeled PORT F on the relay front panel.

Step 2. Apply power to both the computer and to the relay.

Step 3. Start the computer terminal emulation program.

Step 4. Set your computer terminal emulation program serial communications parameters. The default SEL-487E communications port settings are listed in *Table 14.4*.

Also set the terminal program to emulate either VT100 or VT52 terminals. These terminal emulations work best with SEL relays.

Table 14.4 General Serial Port Settings

Name	Description	Default
PROTO	Protocol (SEL, DNP[a], MBA, MBB, RTD, PMU)	SEL
SPEED	Data speed (300 to 57600, SYNC[b])	9600
DATABIT	Data bits (7, 8 bits)	8
PARITY	Parity (Odd, Even, None)	N
STOPBIT	Stop bits (1, 2, bits)	1
RTSCTS	Enable Hardware Handshaking (Y, N)	N

[a] DNP protocol is an ordering option.
[b] SYNC setting is only available when PROTO := MBA or MBB.

Step 5. To check the communications link, press **<Enter>** to confirm that you can communicate with the relay. You will see the Access Level 0 = prompt at the left side of your computer screen (column 1). If you do not see the prompt, check the cable connections and confirm the settings for the default communications parameters of *Table 14.4* in your terminal emulation program.

Step 6. Type **QUIT <Enter>** to view the relay report header. You will see a computer screen display similar to *Figure 14.3*. (Text that you type is emphasized in bold letters.) If you see jumbled characters, change the terminal emulation type in the computer terminal program.

```
=>QUIT <Enter>

Relay 1                                    Date: 11/02/2004  Time: 11:25:50.460
Station A                                  Serial Number: 2008030645
=
```

Figure 14.3 Report Header

Communications Ports Access Levels

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

When you communicate with the relay at the Access Level 0 = prompt, you are in security Access Level 0 (see *Figure 14.4*). You cannot control relay functions at this level. Higher access levels are password protected and allow increased control over relay operation.

Entrance to the higher security levels is sequential. You must first enter a correct password to move from Access Level 0 to Access Level 1. To enter Access Levels B, P, A, O, and 2, you must enter a correct password from Access Level 1. For example, to go to the O (Output) Access Level from Access Level 1, type **OAC <Enter>**. At the `Password: ?` prompt, type your Access Level O password.

To enter Access Level C, you must enter a correct password from Access Level 2.

Use the relay **QUIT** command from any access level to return the relay to Access Level 0. To reestablish control at a previous access level from Access Level 1, you must use the access level commands and passwords to log in to that previous access level.

When a connection with the SEL-487E times out, the relay reduces the access level to Access Level 0 for that communications port connection.

The MAXACC port setting can be used to limit the maximum access level permitted on a port. This can be useful to restrict what remote users can do.

Access Levels

Access levels control whether you can perform different operations within the SEL-487E. These security levels are labeled 0, 1, B, P, A, O, 2, and C. *Figure 14.4* presents an overview of the general access level structure in the relay.

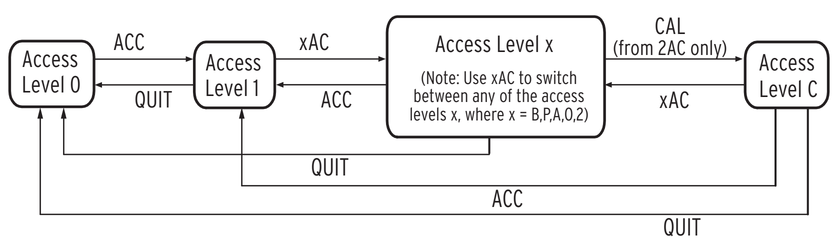


Figure 14.4 Access Level Structure

Access Level 0 is the least secure and most limited access level, and Access Level 2 is the most secure level where you have total relay functionality. (Access Level C is reserved for SEL factory operations. Only go to Access Level C to change the Level C password or under the direction of an SEL employee.) For example, from Access Level 1 you can view settings; you cannot change settings unless you are at a higher access level. *Table 14.5* lists access levels and operator functions for the SEL-487E.

Table 14.5 SEL-487E Access Levels and Operator Functions (Sheet 1 of 2)

Access Level	Prompt	Allowed Operations
0	=	Log in to Access Level 1; some test diagnostics.
1	=>	View data and status information.
B	==>	Access Level 1 functions plus breaker control and data.
P	P=>	Access Level B functions plus protection settings.
A	A=>	Access Level B functions plus automation settings.
O	O=>	Access Level B functions plus output settings.

Table 14.5 SEL-487E Access Levels and Operator Functions (Sheet 2 of 2)

Access Level	Prompt	Allowed Operations
2	=>>	Perform all relay access level functions.
C	==>>	SEL calibration-specific functions. For a list of commands available, contact SEL.

The SEL-487E performs command interpretation and execution according to your validated access level. Each access level has a password that the relay must verify before you can control the relay at that level. *Table 14.6* lists the access level commands with corresponding passwords.

Table 14.6 SEL-487E Access Level Commands and Passwords

Access Level	Command	Factory Default Password
0	**QUIT**	(None)
1	**ACCESS**	OTTER
B	**BACCESS**	EDITH
P	**PACCESS**	AMPERE
A	**AACCESS**	VOLTA
O	**OACCESS**	WATT
2	**2ACCESS**	TAIL
C	**CAL**	Sel-1

ACCESS Command

Enter the **ACCESS** (**ACC**) command to change to Access Level 1. Passwords are case sensitive; you must enter a password exactly as set. If you enter the password correctly, the SEL-487E moves to Access Level 1 and the Access Level 1 => prompt appears. If you are at a higher access level (B, P, A, O, and 2), you can reduce the access level to Access Level 1 by entering the **ACC** command. The relay performs no password validation to reduce the present access level.

Higher Access Level Commands

Enter the commands in *Table 14.6* to enter access levels above Access Level 1. For example, enter the **2ACCESS** (**2AC**) command to change to Access Level 2.

If you are presently at Access Level 1, B, P, A, or O, typing **2AC <Enter>** causes the SEL-487E to prompt you to type the Access Level 2 password. If the present level is Access Level 0, the SEL-487E responds with Invalid Access Level. The relay asserts alarm Relay Word bit SALARM when entering Access Level B, P, A, O, and 2 from a lower access level.

If you are unable to enter the correct password after the third failed attempt, the SEL-487E asserts the BADPASS and SALARM Relay Word bits for one second and displays on a communications terminal screen the following error message:

```
WARNING: ACCESS BY UNAUTHORIZED PERSONS STRICTLY PROHIBITED
```

In addition, you cannot make further access level entry attempts for 30 seconds. The relay terminates the communications connection after the third failed attempt when you use Ethernet via an Ethernet card, DNP3 (Distributed Network Protocol Version 3.0), and MIRRORED BITS® communications virtual terminal mode. For more information on these protocols, see *Section 7: Communications, Interfaces, and Protocols* and *Appendix E: DNP3 Communications Protocol*.

If your connection to the SEL-487E has an inactivity time-out (in the **SET P** port settings), the SEL-487E automatically closes the communications connection and changes to Access Level 0 when the time-out occurs.

Passwords

It is extremely important that you change the factory default passwords programmed in the SEL-487E. Setting unique passwords for the relay access levels increases the security of your substation and the power system. This subsection begins with information on the access level/password system in the SEL-487E and includes an example of changing the default passwords.

Valid passwords are character sequences of as many as 12 characters. Valid password characters are any printable ASCII characters. HMI password entry is limited to upper- and lower-case letters, numbers, underscore, and period, so you must limit your password to these characters if you need to do privileged operations from the front panel. Passwords are case sensitive.

Use strong passwords. Strong passwords contain a mix of the valid password characters in a combination that does not spell common words in any portion of the password.

Changing the Default Passwords: Terminal

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Step 1. Confirm that the relay is operating.

Step 2. Establish communication with the SEL-487E (see *Making an EIA-232 Serial Port Connection* to learn how to use a terminal to communicate with the relay).

Step 3. Enter Access Level C (Level 2 is sufficient except when changing Level C password).

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password **OTTER** and press **<Enter>**. You will see the Access Level 1 => prompt.

c. Type **2AC <Enter>**.

d. At the password prompt, type **TAIL <Enter>**.

e. Type **CAL <Enter>**.

f. At the password prompt, type **Sel-1 <Enter>**.

You will see the Access Level C ==>> prompt.

Step 4. To set a new password for Access Level 2, type the following:

PAS 2 nE2Pw- <Enter>

(**nE2Pw-** becomes the new strong password.)

The relay will return the word `Set` and the Access Level 2 =>> prompt.

Step 5. Set new passwords for each access level. In a similar manner as the previous step, create new strong passwords for each access level.

Step 6. Commit these passwords to memory, permanently record your new passwords, and store this permanent record in a secure location.

To eliminate password verification for an access level, enter **DISABLE** in place of the new password. This action will disable the password of that level; therefore, the relay does not check for a password upon entering that access level.

Using **DISABLE** is not recommended. Always set a unique, strong password in the relay for each access level. Failure to do this can severely jeopardize the security of your substation and the power system.

After you enter a new password, the relay pulses the Relay Word bit SALARM for one second and responds Set. The relay responds with the message Password Disabled if you used the **DISABLE** parameter.

If you forget a password, or encounter difficulty changing the default passwords in *Changing the Default Passwords: Terminal*, you can temporarily disable password verification. See *Jumpers on page 2.14* for information on the password disable jumper J21PASSWORD.

Checking Relay Status

With continual self-testing, the SEL-487E monitors the internal operation of all circuits to verify optimal performance of relay functions. If an internal circuit, protection algorithm, or automation algorithm enters an out-of-tolerance operating range, the relay reports a status warning. In the unlikely event that an internal failure occurs, the relay reports a status failure.

You can check relay status through a communications port by using a terminal, terminal emulation computer program, or ACSELERATOR QuickSet. In addition, you can use the relay front panel to view status information.

Checking Relay Status: Terminal

The procedure in the following steps assumes that you have successfully established communication with the relay. In addition, you must be familiar with relay access levels and passwords.

Step 1. Enter Access Level 1.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**. You will see the Access Level 1 => prompt.

Step 2. Type **STA <Enter>**. The relay returns a status terminal screen similar to that in *Figure 14.5*.

Step 3. Type **STA A <Enter>** to view all relay status entries.

```
=>>STA <Enter>

Relay 1                                    Date: 04/11/2008  Time: 21:16:00.625
Station A                                  Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080411      CID=0x15c5

Failures
  No Failures

Warnings
  No Warnings

SELOGIC Relay Programming Environment Errors
  No Errors

Relay Enabled

=>>
```

Figure 14.5 Relay Status

Making Simple Settings Changes

Making Text-Edit Mode Settings Changes

Some SEL-487E settings present multiple input lines to your terminal; you use basic line text editing commands to construct the setting. For display, the relay references each line of the setting by line number, not by the setting name.

While in the text-edit mode, you see a prompt consisting of the line number and the present setting for that line. You can keep the setting, enter a new setting, or delete the setting. *Table 14.7* lists the commands for text-edit mode.

Table 14.7 Actions at Text-Edit Mode Prompts

Action	Relay Response
<Enter>	Accept the setting and move to the next line; if at the last line or at a blank line, exit settings.
>*n* <Enter>	Move to line *n*. If this is beyond the end of the list, move to a blank line following the last line.
^ <Enter>	Move to the previous line; if at the first line, stay at the present line.
< <Enter>	Move to the first line.
> <Enter>	Move to a blank line following the last line.
LIST <Enter>	List all settings and return to the present action prompt.
DELETE [*n*] <Enter>	Delete the present line and subsequent lines for a total of n lines; *n* = 1 if not provided. Lines after deletion shift upward by the number of lines deleted.
INSERT <Enter>	Insert a blank line at the present location; the present line and subsequent lines shift downward.
END <Enter>	Go to the end of the present settings session. Prepare to exit settings via the `Save settings (Y,N) ?` prompt.
<Ctrl+X>	Abort editing session without saving changes.

Use commas to separate the items in a text-edit mode setting when you are entering multiple items per line. After you enter each line, the relay checks the validity of the setting. If the entered setting is invalid, the relay responds with an error message and prompts you again for the setting.

The procedure in the following steps familiarizes you with basic text-edit mode line editing. For this example, assume you are testing a transformer, but you will be away for a few days. You want to leave your colleague, Marius, a note telling him where you left the drawings and settings. Use the Notes function in the relay to leave the note, as shown in *Figure 14.6*.

All relevant procedures in this section assumes that you have successfully established communication with the relay In addition, you must be familiar with relay access levels and passwords to change the default access level passwords. Furthermore, Step 1 below applies to all relevant tests, and is not repeated for each test.

Step 1. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 `=>` prompt.

c. Type the **2AC <Enter>** command.

d. Type the correct password to go to Access Level 2.

You will see the Access Level 2 `=>>` prompt.

Step 2. Access the display point settings.

a. Type **SET N <Enter>** to access the Notes settings.

b. At the Line 1 settings `?` prompt, type the Line 1 text shown in *Figure 14.6* (up to 70 characters), and press **<Enter>**. The relay verifies that this is a valid entry, then responds with the next line prompt `2:` followed by the settings `?` prompt.

Step 3. At the Line 2 settings `?` prompt, type the Line 1 text shown in *Figure 14.6*. Because there are more than 70 characters, the relay rejects the entry.

Re-enter the text, but keep the number of characters below 70.

Step 4. After the last entry, type **END <Enter>**. This tells the relay that you have completed the setting change.

Step 5. Enter **Y <Enter>** at the prompt `Save settings (Y,N)` to save the settings.

```
=>>SET N <Enter>
Notes

1:
?   Marius, this is the relay for CARR substation <Enter>
2:
?   The transformer drawings and setting sheets are in the top drawer in the sub\
station. <Enter>
Note cannot exceed 70 chars

2:
?   The transformer drawings and settings are in the <Enter>
3:
?   desk at the substation. <Enter>
4:
?   END <Enter>
Notes
.
.
.
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved
```

Figure 14.6 Leave a Note in the Relay

Examining Metering Quantities

The SEL-487E features high-accuracy power system metering. You can view fundamental voltage, current and power, and rms voltage and current quantities by using a communications terminal, ACSELERATOR QuickSet, or the front panel. You may test the relay in either of two ways: by applying ac current and voltage signals to the relay inputs or by applying low magnitude ac voltage signals to the low-level test interface.

Low-Level Test Interface

The SEL-487E Relay has a low-level test interface between the calibrated input module and the separately calibrated processing module. Access the test interface by removing the relay front panel.

Figure 14.7 shows the front low-level interface connections and signal scaling factors. The rear interface has the same scaling factors as the front interface, but with the channel allocation shown in *Figure 14.8*. Remove the ribbon cable between the two modules to access the outputs of the input module and the inputs to the processing module (relay main board). You can test the relay processing module using signals from the SEL-RTS Low-Level Relay Test System. Never apply voltage signals greater than 9 V peak-to-peak to the low-level test interface.

⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

You can test the input module two different ways:

Measure the outputs from the input module with an accurate voltmeter, and compare the readings to accurate instruments in the relay input circuits, or
Replace the ribbon cable, press the front-panel {**METER**} button, and compare the relay readings to other accurate instruments in the relay input circuits.

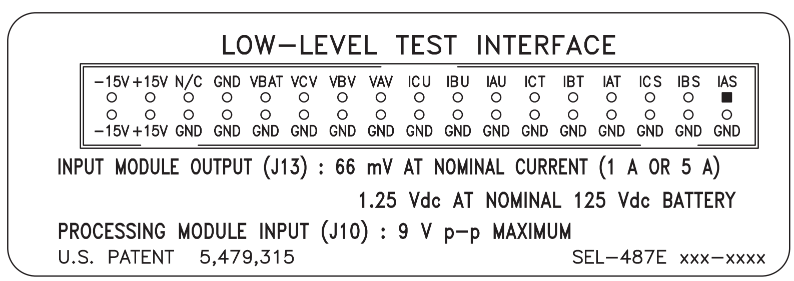


Figure 14.7 Low-Level Test Interface Front Connector

Main Board Processing Module Tests

Use signals from the Low-Level Relay Test System to test the relay processing module. These signals simulate power system conditions, taking into account PT ratio and CT ratio scaling. Use relay metering to determine whether the applied test voltages and currents produce correct relay operating quantities. The UUT Database entries for the SEL-487E in the SEL-5401 Relay Test System Software are shown in *Table 14.8*, *Table 14.9*, *Table 14.10*, and *Table 14.11*.

Table 14.8 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Y)—5 A Relay

Channel	Label	Scale Factor	Unit
1	IAS	75	A
2	IBS	75	A
3	ICS	75	A
4	IAT	75	A
5	IBT	75	A
6	ICT	75	A
7	IAU	75	A
8	IBU	75	A
9	ICU	75	A
10	VAV	150	V
11	VBV	150	V
12	VCV	150	V

Table 14.9 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—5 A Relay

Channel	Label	Scale Factor	Unit
1	IAW	75	A
2	IBW	75	A
3	ICW	75	A
4	IAX	75	A
5	IBX	75	A
6	ICX	75	A
7	IY1	75	A
8	IY2	75	A
9	IY3	75	A
10	VAZ	150	V
11	VBZ	150	V
12	VCZ	150	V

Table 14.10 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Y)—1 A Relay (Sheet 1 of 2)

Channel	Label	Scale Factor	Unit
1	IAS	15	A
2	IBS	15	A
3	ICS	15	A
4	IAT	15	A
5	IBT	15	A
6	ICT	15	A
7	IAU	15	A
8	IBU	15	A
9	ICU	15	A

Table 14.10 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Y)—1 A Relay (Sheet 2 of 2)

Channel	Label	Scale Factor	Unit
10	VAV	150	V
11	VBV	150	V
12	VCV	150	V

Table 14.11 UUT Database Entries for SEL-5401 Relay Test System Software (Analog Input Board Z)—1 A Relay

Channel	Label	Scale Factor	Unit
1	IAW	15	A
2	IBW	15	A
3	ICW	15	A
4	IAX	15	A
5	IBX	15	A
6	ICX	15	A
7	IY1	15	A
8	IY2	15	A
9	IY3	15	A
10	VAZ	150	V
11	VBZ	150	V
12	VCZ	150	V

Using an Injection Set

Figure 14.8 shows the test set and relay connections for three-phase current injection.

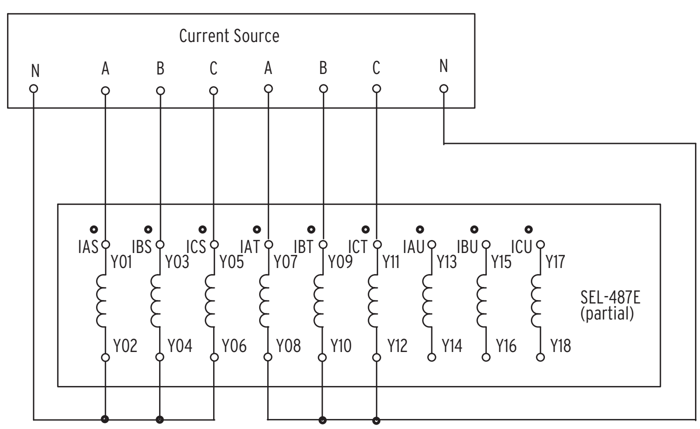


Figure 14.8 Test Connections for Balanced Load With Three-Phase Current Sources

Figure 14.9 shows the test set and relay connections for three-phase voltage injection.

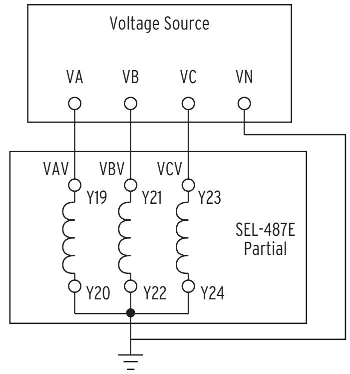


Figure 14.9 Voltage Test Connections

The TERSE Option

You can avoid viewing the entire class settings summary the relay displays when you type **END <Enter>** midway through a settings class or instance. On slow data speed links, waiting for the complete settings readback can clog your automation control system or take too much of your time for a few settings changes. Eliminate the settings readback by appending **TERSE** to the **SET** command.

View Metering: Terminal

The procedure in the following steps shows how to use a terminal or terminal emulation computer program to view power system metering for Terminal S and Terminal T. In this example, you connect specific voltages and currents for a 5 A, 60 Hz relay. Scale these quantities appropriately for a 1 A relay.

To avoid you having to work through settings of terminals and functions that are irrelevant to your application, the default values of most functions are set to OFF. Therefore, to use the functions, you must first enable the appropriate terminal(s), and then enable specific functions for that terminal. Although Terminal S and Terminal T are enabled by default, most of the protections and metering functions remain hidden.

Enable the PT terminals and the CT terminals with the **SET** (Group settings) command, as shown in *Figure 14.10*. There are five settings involved in this step: ECTTERM, EPTTERM, EPCAL, VREFS, and VREFT. ECTTERM enables the CTs of the appropriate transformer windings (S and T in this example), and EPTTERM enables the PT of the appropriate transformer windings (V in this example). S and T are enabled by default, but you must still enable the PT (V or Z). For this example, select V, i.e., set EPTTERM = V. Furthermore, use the EPCAL setting to specify the windings for which the relay must calculate the power quantities. In this example, set EPCAL = S T, so that the relay calculates power quantities for Terminal S and Terminal T only (not for Terminals U, W, or X).

```
=>>SET <Enter>
Group 1

Relay Configuration

Enable Current Terminals (OFF or combo of S,T,U,W,X)
ECTTERM := "S,T"  ? <Enter>
Enable Voltage Terminals (OFF or combo of V,Z)       EPTTERM := OFF    ?V <Enter>
Enable Diff Elem. Prot. Terms (OFF or combo of S,T)
E87     := OFF    ? <Enter>
Enable Restricted Earth Fault Element (N,1-3)        EREF    := N      ? <Enter>
Enable Def. Time Dir. O/C Ele. (OFF or combo of S,T)
E50     := OFF    ?
Enable Inverse Time Overcurrent Elements (N, 1-10)   E51     := N      ? <Enter>
Enable Current Unb. Elements (OFF or combo of S,T)   E46     := OFF    ? <Enter>
Enable Over Voltage Elements (N,1-5)                 E59     := N      ? <Enter>
Enable Under Voltage Elements (N,1-5)                E27     := N      ? <Enter>
Enable Frequency Elements (N,1-6)                    E81     := N      ? <Enter>
Enable Volts per Hertz Element (Y,N)                 E24     := N      ? <Enter>
Enable Breaker Fail. Prot. (OFF or combo of S,T)     EBFL    := OFF    ? <Enter>
Enable Power Calc. Term (OFF or combo of S,T)       EPCAL  := OFF    ?S,T <Enter>
Enable Over/Under Power Elements (N, 1-10)           E32     := N      ? <Enter>
Enable Demand Metering (N, 1-10)                     EDEM    := N      ? <Enter>

Current Transformer Data

Current Trans. Ratio Terminal S (1-50000)            CTRS    := 100    ?> <Enter>

Potential Transformer Data

Potential Trans. Ratio Terminal V (1-10000)         PTRV    := 2000   ?> <Enter>

Voltage Reference Terminal Selection

Voltage Reference For Terminal S (OFF,V)            VREFS   := OFF    ?V <Enter>
Voltage Reference For Terminal T (OFF,V)            VREFT   := OFF    ?V <Enter>


Trip Logic

Trip Transformer (SELogic Eqn)
TRXFMR := 87R OR REFF1
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.10 Enable PT and CT Terminals

Set settings VREFS = VREFT = V to tell the relay which PT (V or Z) to use to calculate the power quantities, particularly when both PTs are enabled.

Table 14.12 shows the current and voltage quantities for this test. Refer to *Figure 14.8* and note that, because of this specific wiring, the current through Terminal S and Terminal T is in the same sense. This wiring is appropriate for power quantity testing only; do not test the differential elements with this wiring.

Table 14.12 Current and Voltage Values

Current		Voltage
IAS = 5∠–30°	IAT = 5∠–30°	VA = 67∠0°
IBS = 5∠–150°	IBT = 5∠–150°	VB = 67∠–120°
ICS = 5∠90°	ICT = 5∠90°	VC = 67∠120°

Use the default CT ratio (500/5, i.e., 100/1) and PT ratio (2000/1) settings for this example. Observe all safety regulations and inject the quantities shown in *Table 14.12* into the relay.

To see the Terminal S fundamental quantities, type **MET <Enter>**, as shown in *Figure 14.11*. See *Section 5: Monitoring and Metering* for more metering examples. (You do not need to add the S, the relay defaults to Terminal S).

```
=>>MET <Enter>

Relay 1                                         Date: 05/13/2008  Time: 12:11:24.283
Station A                                       Serial Number: 2008030537


Fundamental Meter: Winding S

               Phase Currents                   Sequence Currents
           IA        IB        IC           I1        3I2       3I0
MAG(A,pri)  499.43    498.47    500.16       499.34      2.01      1.33
ANG(deg)    -30.23   -150.13     89.77       -30.19   -138.65     17.69

            Phase Voltages - PT V               Sequence Voltages
           VA        VB        VC           V1        3V2       3V0
MAG (kV)   134.029   133.832   133.998      133.953     0.245     0.159
ANG(deg)     0.00   -120.03   120.01         0.00    -31.97     83.00

Power Quantities
Active Power P (MW,pri)
     PA          PB          PC          3P
    57.84       57.72       57.89      173.45

Reactive Power Q (MVAr,pri)
     QA          QB          QC          3Q
    33.70       33.45       33.75      100.91

Apparent Power  S (MVA,pri)
     SA          SB          SC          3S
    66.94       66.71       67.02      200.67

Power factor
Phase A     Phase B     Phase C     3-Phase
 0.86 Lag    0.87 Lag    0.86 Lag    0.86 Lag

Line-to-Line Voltage
                   PT - V                              PT - Z
           VAB       VBC       VCA          VAB       VBC       VCA
MAG (kV)   232.007   231.892   232.136      -------   -------   -------
ANG(deg)    29.96    -89.98    150.01       ------    ------    ------

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   115.72          V/Hz      -----%

=>>
```

Figure 14.11 Result of the MET Command

Table 14.13 through *Table 14.17* shows the expected and measured current, voltage, active, reactive and apparent power quantities for the current and voltage values of *Table 14.12*.

Table 14.13 Expected/Measured Current

Expected Current (A) Iprimary = Isecondary • CTR	Measured Current	Sequence Current (A)	Measured Current
IA = 5∠–30° • 100 = 500∠–30°	IA = 503.54∠–30.1°	I1 = 500∠–30°	I1 = 500.02∠–30.07°
IB = 5∠–150° • 100 = 500∠–150°	IB = 502.92∠–150.05°	3I2 = 0∠–100°	3I2 = 2.24∠–108.66°
IC = 5∠90° • 100 = 500∠90°	IC = 503.52∠89.75°	3I0 = 0∠100°	3I0 = 1.174∠–114.72°

Table 14.14 Expected/Measured Voltage

Expected Voltage (kV) Vprimary = Vsecondary • PTR	Measured Voltage	Sequence Values (kV)	Measured Values (kV)
VA = 67∠0° • 2000 = 134∠0°	VA = 134.036∠–0.13°	V1 = 134∠0°	V1 = 134.049∠0.00°
VB = 67∠–120° • 2000 = 134∠–120°	VB = 134.068∠–120.05°	3V2 = 0∠0°	3V2 = 0.654∠–40.44°
VC = 67∠120° • 2000 = 134∠120°	VC = 134.039∠120.20°	3V0 = 0∠0°	3V0 = 0.721∠–138.14°

Table 14.15 Expected/Measured Apparent Power

Expected Apparent Power (MVA) S = Vprimary • Iprimary (per phase)	Measured Value (MVA) (phase)
SA = 0.500 • 134 = 67	67.97
SA = 0.500 • 134 = 67	67.63
SA = 0.500 • 134 = 67	67.12
3S = 3 • 67 = 201 (3 – phase)	201.72

Table 14.16 Expected/Measured Real Power

Expected Real Power (MW) P = Vprimary • Iprimary • cos φ (per phase)	Measured Value (MW) (phase)
PA = 0.500 • 134 • 0.87 = 58.3	57.88
PA = 0.500 • 134 • 0.87 = 58.3	57.89
PA = 0.500 • 134 • 0.87 = 58.3	57.57
3P = 3 • 58.3 = 174.9 (3 – phase)	173.57

Table 14.17 Expected/Measured Reactive Power

Expected Reactive Power (MVAR) Q = Vprimary • Iprimary • sin φ (per phase)	Measured Value (MVAR) (phase)
QA = 0.500 • 134 • 0.5 = 33.75	33.69
QA = 0.500 • 134 • 0.5 = 33.75	33.46
QA = 0.500 • 134 • 0.5 = 33.75	33.84
3Q = 3 • 33.75 = 101.25 (3 – phase)	100.58

To see the results for Terminal T, type **MET T**. The relay must display similar results. To see the secondary values for Terminal T, type **MET T SEC**, as shown in *Figure 14.12*.

```
=>>MET T SEC <Enter>

Relay 1                                    Date: 05/13/2008  Time: 12:13:43.938
Station A                                  Serial Number: 2008030537



  Secondary Meter: Winding T

               Phase Currents                Sequence Currents
           IA         IB         IC          I1         3I2        3I0
MAG(A,sec)    4.99       5.00       4.99        4.99       0.02       0.01
ANG(deg)    -30.22    -150.22      89.74      -30.23      84.02    -112.30

            Phase Voltages - PT V            Sequence Voltages
           VA         VB         VC          V1         3V2        3V0
MAG(V,sec)  67.015     66.907     67.014      66.979      0.145      0.096
ANG(deg)     0.00    -120.04     120.02        0.00     -39.15      91.09

Line-to-Line Voltage
                  PT - V                               PT - Z
           VAB        VBC        VCA         VAB        VBC        VCA
Mag(V,sec) 115.997    115.946    116.086     -------    -------    -------
ANG(deg)    29.95     -89.98     150.01      ------     ------     ------

FREQ (Hz) 59.991          Frequency Tracking = Y
VDC (V)   114.92          V/Hz       -----%

=>>
```

Figure 14.12 Result of the MET T SEC Command

Selected Element Tests

This subsection discusses tests of selected functions in the SEL-487E relay. These test are designed to show a method of testing a function in an easy way while at the same time familiarizing you with other functions such as programming logic functions, SER and the front panel. Each test starts with the default settings to avoid unexpected results from previous programming when testing other functions. This subsection provides tests for the following relay elements:

- Volts/Hertz Elements
- TOC (IDMT) Overcurrent Elements
- REF Elements
- Unrestrained-Phase Differential Element
- Restrained-Phase Differential Elements
- Negative-Sequence Differential Elements
- Negative-Sequence Directional Elements—Phase Elements

The paragraphs below describe when each type of test is performed, the goals of testing at that time, and the relay functions that you need to test at each point. This information is intended as a guideline for testing SEL relays.

Testing Methods and Tools

Test Features Provided by the Relay

The following features assist you during relay testing:

METER Command: The **METER** command shows the currents and voltages presented to the relay in primary values. Compare these quantities against other devices of known accuracy.

METER SEC Command: The **METER SEC** command shows the currents, voltages, and phase angles presented to the relay in secondary values. Compare these quantities against other devices of known accuracy.

EVENT Command: The relay generates an event report in response to faults or disturbances. Each report contains current information, relay element states, and input/output contact information. If you question the relay response or your test method, use the **EVENT** command to display detailed information.

TARGET Command: Use the **TARGET *n*** (*n* = 1 through 9999) command to view the state of relay control inputs, relay outputs, and relay elements individually during a test.

SER Command: Use the Sequential Events Recorder for timing tests by setting the SER trigger settings to trigger for specific elements asserting or deasserting. View the SER with the **SER** command.

Programmable Outputs: Programmable outputs allow you to isolate individual relay elements. Use the **SET O** command to set output contacts.

Volts/Hertz

Although the V/Hz element offers definite-time and user-defined elements, this test shows how to test the user-defined function. For this test, you program a SELOGIC variable to assert LEDs on the front panel to indicate the status of the V/Hz element. You also program the SER to record the status of the V/Hz element, and then use these recorded values to calculate the element operating time(s).

Figure 14.13(a) shows a curve with four points defined, and *Figure 14.13*(b) shows an intermediate point Pt(107,?) between Point 24U01 and Point 24U02.

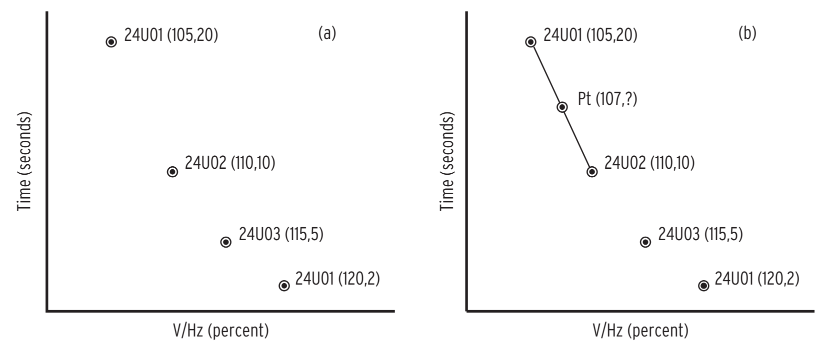


Figure 14.13 User-Defined V/Hz Curve

Because the relay linearly interpolates these data points, use *Equation 14.1* to calculate the operating time for a V/Hz value of 107 percent.

$$t = \left[\frac{t1 - t2}{P1 - P2}\right] \bullet Pt + \left[\frac{t1 \bullet P2 - t2 \bullet P1}{P2 - P1}\right] \qquad \textbf{Equation 14.1}$$

where:

t1 = the operate time value of 24U01 (20)
P1 = the percentage V/Hz value of 24U01 (105)
t2 = the operate time value of 24U02 (10)
P2 = the percentage V/Hz value of 24U02 (110)
Pt = the percentage V/Hz value of 107 percent

$$t = \left[\frac{20 - 10}{105 - 110}\right] \bullet 107 + \left[\frac{20 \bullet 110 - 10 \bullet 105}{110 - 105}\right]$$

$$t = 16 \text{ seconds} \qquad \textbf{Equation 14.2}$$

Table 14.18 Settings to Test the V/Hz Elements (Sheet 1 of 2)

Setting	Setting Category	Comments
EPTTERM = V	Group (SET)	Enable PT V; makes E24 settings available
E24 = Y	Group	Enable the V/Hz elements
24TC = 0	Group	Disable the-definite time V/Hz elements
24CCS = UI	Group	Select User-defined curve
24U1NP = 4	Group	Specify a curve with 4 points
24U101 = 105,20	Group	Co-ordinates for Point 1
24U102 = 110,10	Group	Co-ordinates for Point 2
24U103 = 115,5	Group	Co-ordinates for Point 3
24U104 = 120,2	Group	Co-ordinates for Point 4

Table 14.18 Settings to Test the V/Hz Elements (Sheet 2 of 2)

Setting	Setting Category	Comments
PSV01 = 24RPU > 105	Protection Logic (SET L)	PSV01 asserts when V/Hz exceeds 105 percent
PSV02 = 24RPU > 107	Protection Logic	PSV02 asserts when V/Hz exceeds 107 percent
PB1_LED = PSV01	Front panel (SET F)	Pushbutton LED 1 reports the status of PSV01
PB1_COL = AG	Front panel	LED is amber when PSV01 asserts, and green when PSV01 deasserts
PB2_LED = PSV02	Front panel	Pushbutton LED 2 reports the status of PSV02
PB2_COL = AG	Front panel	LED is amber when PSV02 asserts, and green when PSV02 deasserts
PSV01,"V/Hz picked up"	Report (SER) (SET R)	Reports and timestamps when PSV01 asserts
24U1T,"V/Hz timed out"	Report (SER)	Reports and timestamps when V/Hz elements times out

Figure 14.14 shows the group settings (Group 1) for this test.

```
=>>SET <Enter>
Group 1

Relay Configuration

Enable Current Terminals (OFF or combo of S,T,U,W,X)
ECTTERM := "S,T"  ? <Enter>
Enable Voltage Terminals (OFF or combo of V,Z)       EPTTERM := OFF    ?V <Enter>
Enable Diff Elem. Prot. Terms (OFF or combo of S,T)
E87     := OFF    ? <Enter>
Enable Restricted Earth Fault Element (N,1-3)        EREF    := N      ? <Enter>
Enable Def. Time Dir. O/C Ele. (OFF or combo of S,T)
E50     := OFF    ? <Enter>
Enable Inverse Time Overcurrent Elements (N, 1-10)   E51     := N      ? <Enter>
Enable Current Unb. Elements (OFF or combo of S,T)   E46     := OFF    ? <Enter>
Enable Over Voltage Elements (N,1-5)                 E59     := N      ? <Enter>
Enable Under Voltage Elements (N,1-5)                E27     := N      ? <Enter>
Enable Frequency Elements (N,1-6)                    E81     := N      ? <Enter>
Enable Volts per Hertz Element (Y,N)                 E24     := N      ?Y <Enter>
Enable Breaker Fail. Prot. (OFF or combo of S,T)     EBFL    := OFF    ? <Enter>
Enable Power Calc. Term (OFF or combo of S,T)        EPCAL   := OFF    ? <Enter>
Enable Demand Metering (N, 1-10)                     EDEM    := N      ? <Enter>

Current Transformer Data

Current Trans. Ratio Terminal S (1-50000)            CTRS    := 100    ?> <Enter>

Potential Transformer Data

Potential Trans. Ratio Terminal V (1-10000)          PTRV    := 2000   ?> <Enter>

Voltage Reference Terminal Selection

Voltage Reference For Terminal S (OFF,V)             VREFS   := OFF    ?> <Enter>

Volts per Hertz Element

Level 1 Volts/Hertz P/U (100-200%)                   24D1P   := 110    ? <Enter>
Level 1 Time Delay (0.04 - 400 sec)                  24D1D   := 10.00  ? <Enter>
Volts/Hertz Torque control (SELogic Eqn)
24TC  := 1
? 0 <Enter>
Level 2 composite Curve (OFF,DD,U1,U2)               24CCS   := OFF    ?U1 <Enter>

Volts per Hertz Level 2, User Defined Curve 1

User Defined Curve 1 Torque Control (SELogic Eqn)
24U1TC := 1 <Enter>
?
Number of Point on User 1 Curve (3-20)               24U1NP  := 3      ?4 <Enter>
User Def. Curve 1, Point 1 (100 - 200%, 0.04 - 400 sec)
24U101 := 200, 400.00
? 105,20 <Enter>
User Def. Curve 1, Point 2 (100 - 200%, 0.04 - 400 sec)
24U102 := 200, 400.00
? 110,10 <Enter>
User Def. Curve 1, Point 3 (100 - 200%, 0.04 - 400 sec)
24U103 := 200, 400.00
? 115,5 <Enter>
User Def. Curve 1, Point 4 (100 - 200%, 0.04 - 400 sec)
24U104 := 200, 400.00
? 120,2 <Enter>
User Def. Curve 1 Reset Time (0.01 - 400 sec)        24U1CR  := 0.01   ? <Enter>


Trip Logic

Trip Transformer (SELogic Eqn)
TRXFMR := 87R OR REFF1
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.14 Group Settings for the V/Hz Test

Figure 14.15 shows the Protection Logic setting for the test. Protection SELOGIC variable PSV01 asserts when the analog output (24RPU, see *Volts/Hertz Settings on page 4.80*) exceeds 105 percent, and PSV02 asserts when 24RPU exceeds 107 percent.

```
=>>SET L TE <Enter>
Protection 1

1: # BREAKER S OPEN AND CLOSE CMD
? >
15:
?  PSV01:=24RPU > 105 <Enter>
16:
?  PSV02:=24RPU > 107 <Enter>
17:
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.15 Logic Settings for the V/Hz Test

Program the front panel push button LEDs to indicate the status of PSV01 and PSV02. Set the LED to show amber when PSV01 (PB1_LED) and PSV02 (PB2_LED) are asserted, and to show green when PSV01 and PSV02 are deasserted. *Figure 14.16* shows the front panel LED programming.

```
=>>SET F TE <Enter>
Front Panel

Front Panel Settings

Front Panel Display Time-Out (OFF,1-60 mins)        FP_TO   := 15     ?
Enable LED Asserted Color (R,G)                     EN_LEDC := G      ?
Trip LED Asserted Color (R,G)                       TR_LEDC := R      ?
Pushbutton LED 1 (SELOGIC Equation)
PB1_LED := NA
?  PSV01 <Enter>
PB1_LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB1_COL := AO     ?AG <Enter>
Pushbutton LED 2 (SELOGIC Equation)
PB2_LED := NA
?  PSV02 <Enter>
PB2_LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB2_COL := AO     ?AG <Enter>
Pushbutton LED 3 (SELOGIC Equation)
PB3_LED := NA
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 14.16 Front-Panel Settings for the V/Hz Test

Use the sequential event recorder (SER) to record the exact time when PSV01 and PSV02 assert, and when the output from the V/Hz element (24U1T) asserts. Calculate the operating time of the V/Hz element by finding the difference between these two times. *Figure 14.17* shows the SER programming.

```
=>>SET R TE <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N      ? <Enter>

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1:
? PSV01,"V/Hz picked up 105" <Enter>
2:
? PSV02,"V/Hz picked up 107" <Enter>
3:
?  24U1T,"V/Hz timed out" <Enter>
4:
? END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.17 SER Settings for the V/Hz Test

This concludes the settings and programming. At this point, pushbutton PB1_LED and PB2_LED must both show green.

Step 1. Connect an injection set as shown in *Figure 14.9* to the PT V terminals.

Step 2. Start off by injecting the voltage values shown in the Initial Voltage (105%) column in *Table 14.19*.

Step 3. Slowly increase the A-phase voltage until PB1_LED changes from green to amber. Record this voltage value in *Table 14.19*.

Step 4. Turn off the injection set.

Step 5. Clear the SER by typing **SER C <Enter>**. Enter **Y <Enter>** at the prompt: `Are you sure (Y/N)?`

Table 14.19 Voltage Values

Initial Voltage (105%)	Recorded Voltage	Initial Voltage (107%)	Recorded Voltage
VA = 68 ∠0°	VA =	VA = 71∠0°	VA =
VB = 63.5∠–120°	VB = 63.5∠–120°	VB = 63.5∠–120°	VB = 63.5∠–120°
VC = 63.5∠120°	VC = 63.5∠120°	VC = 63.5∠120°	VC = 63.5∠120°

Step 6. Inject the relay with the recorded voltages for at least 22 seconds (Verify that PB1_LED is amber, and PB2_LED is green).

Step 7. Stop the injection and turn the test set off. Type **SER <Enter>** to see the element assert and operate times, as shown in *Figure 14.18*.

```
=>>SER <Enter>

Relay 1                                     Date: 06/03/2008  Time: 04:40:38.976
Station A                                   Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080602

#     DATE        TIME           ELEMENT             STATE
2    06/03/2008  04:40:36.8201  V/Hz picked up 105  Asserted
1    06/03/2008  04:40:56.7316  V/Hz timed out      Asserted

=>>
```

Figure 14.18 Element Assert and Operate Times (105%)

Because we are testing point (105,20), we expect the V/Hz element to assert after 20 seconds. Calculate the trip time as follows:

Trip time = 56.7316 – 36.8201 = 19.91 seconds.

This result is within the tolerance range of the V/Hz element.

Step 8. With the test set connected, repeat *Step 1* through *Step 5*, noting the voltage when PB2_LED changes from green to amber in *Step 3* (PB1_LED also changes from green to amber).

Step 9. Inject the relay with the recorded voltages for at least 18 seconds (Verify that both PB1_LED and PB2_LED are amber).

Step 10. Stop the injection and turn the test set off. Type **SER <Enter>** to see the element assert and operate times, as shown in *Figure 14.19*.

```
=>>SER <Enter>

Relay 1                                     Date: 06/03/2008  Time: 12:01:00.135
Station A                                   Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080602

#     DATE        TIME           ELEMENT             STATE
3    06/03/2008  12:00:42.3249  V/Hz picked up 105  Asserted
2    06/03/2008  12:00:42.3334  V/Hz picked up 107  Asserted
1    06/03/2008  12:00:58.2694  V/Hz timed out      Asserted

=>>
```

Figure 14.19 Element Assert and Operate Times (107%)

Because we are testing point (107,16), we expect the V/Hz element to assert after 16 seconds. Calculate the trip time as follows:

Trip time = 12:00:58.2694 - 12:00:42.3334 = 15.936 seconds

This result is within the tolerance range of the V/Hz element. This concludes the V/Hz tests for this example; use similar tests to test more points on the curve.

Adaptive Inverse-Time Overcurrent

This example tests the Element 01 set to the C1 curve (see *Figure 14.20*), using the A-phase current from Terminal S. Use the same procedure to test all inverse-time overcurrent elements for each winding.

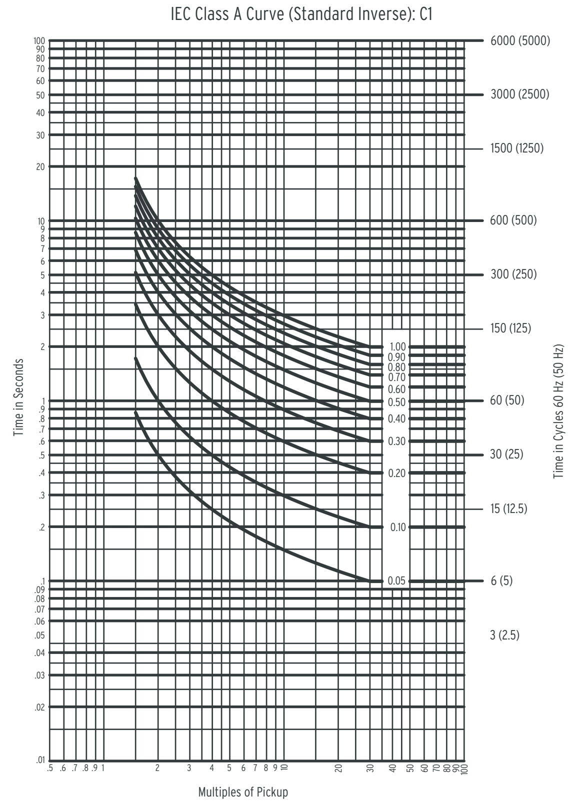


Figure 14.20 C1 Curve

For this test, you use remote bits to dynamically change the relay time dial setting. You also program the SER to record the status of the 51 element, and then use these recorded values to calculate the element operating time.

Be sure to enable each overcurrent element in two places: the ECTTERM and E51 settings. Enable the winding by including the particular winding in the ECTTERM setting, then select the number of 51 elements with the E51 setting.

Because the inverse-time overcurrent elements are adaptive, test three time dial values, viz. arbitrary values of TD = 0.3 and TD = 0.6, and a third value of TD = 1.4. Setting TD = 1.4 exceeds the limit of the time dial range, causing the relay to clamp the time dial setting to the upper limit of the range. Use two remote bits (RB01 and RB02) to change the time setting from the default value of 0.3 to 0.6 and to 1.4

Step 1. Use *Equation 14.3* to determine the expected operate time of the overcurrent element. *Table 14.20* shows the pickup and time dial settings for the three tests.

$$\mathrm{Tp} = \mathrm{TD} \bullet \left[\frac{0.14}{\mathrm{M}^{0.02} - 1}\right] \qquad \textbf{Equation 14.3}$$

In all cases, inject a current of 10A into the relay. With a pickup setting of 1.5 and current of 10A, M = 6.667 (M = IMAXSF/51P01).

Table 14.20 Time Overcurrent Element Settings

Setting	Setting Category	Comment
E51 = 1	Group	Enable one 51 element.
51P01 = 1.5	Group	Pickup (plug) setting.
51TD01 = 0.3 + (RB01 • 0.3) + (RB02 • 0.8)	Group	Time dial (multiplier) setting, resulting in trip times of 1.086, 2.172 and 3.620 seconds, respectively

Step 2. Use the Group setting **SET** command to enable one 51 element, and apply the pickup and time dial settings as shown in *Table 14.20*. Save the settings, as shown in *Figure 14.21*.

```
=>>SET <Enter>
Group 1

Relay Configuration

Enable Current Terminals (OFF or combo of S,T,U,W,X)
ECTTERM := "S,T"  ? <Enter>
Enable Voltage Terminals (OFF or combo of V,Z)       EPTTERM := OFF    ? <Enter>
Enable Diff Elem. Prot. Terms (OFF or combo of S,T)
E87     := OFF    ?
Enable Restricted Earth Fault Element (N,1-3)        EREF    := N      ? <Enter>
Enable Def. Time Dir. O/C Ele. (OFF or combo of S,T)
E50     := OFF    ?
Enable Inverse Time Overcurrent Elements (N, 1-10)   E51     := N      ?1 <Enter>
Enable Current Unb. Elements (OFF or combo of S,T)   E46     := OFF    ? <Enter>
Enable Breaker Fail. Prot. (OFF or combo of S,T)     EBFL    := OFF    ? <Enter>
Enable Demand Metering (N, 1-10)                     EDEM    := N      ? <Enter>

Current Transformer Data

Current Trans. Ratio Terminal S (1-50000)           CTRS    := 100    ?> <Enter>

Inverse Time Overcurrent Element 01

Inv.Time O/C 1 Operate Quantity                      51O01   := IMAXSF ? <Enter>
Inv.Time O/C 1 Pickup Value (SEL Math Eqn.)
51P01  := 1.000000
? 1.5 <Enter>
Inv.Time O/C 1 Curve Selection (U1-U5, C1-C5)        51C01   := U1     ?C1 <Enter>
Inv.Time O/C 1 Time Dial (SEL Math Eqn)
51TD01  := 1.000000
? 0.3+(RB01*0.3)+(RB02*0.8) <Enter>
Inv.Time O/C 1 EM Reset (Y, N)                       51RS01  := N      ?
Inv.Time O/C 1 Torque control (SELogic Eqn)
51TC01  := 1
? <Enter>

Trip Logic

Trip Transformer (SELOGIC Eqn)
TRXFMR  := 87R OR REFF1
?   END<Enter>
Group 1

.
.
.

CFD     := 4.00
Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.21 Group Settings for the 51 Tests

Step 3. Set the SER to check the operate time of the element, as shown in *Figure 14.22*. When using the TERSE option (**SET TE**), there is no read back, so that the setting change is much faster.

```
=>>SET R TE <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N      ? <Enter>

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1:
?  51S01 "51 Asserted"<Enter>
2:
?  51T01 "51 Timed out"<Enter>
3:
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.22 Setting the SER

Step 4. Use the **SER C** command to clear the SER before starting the test, as shown in *Figure 14.23*.

```
=>>SER C<Enter>

Clear the sequential events recorder for this port.
Are you sure (Y/N)?Y <Enter>

SER records for this port are cleared
```

Figure 14.23 Clearing the SER

Step 5. Inject 10A into the relay for at least two seconds, then stop the injection and turn the injection set off. Issue the **SER** command to see the results of the test, as shown in *Figure 14.24*. Use the bold SER entries to calculate the operating time: 39.4516 – 38.3598 = 1.092 seconds. This value compares favorably with the expected value of 1.086 seconds.

```
=>>SER <Enter>

Relay 1                                    Date: 01/07/2000  Time: 04:52:44.740
Station A                                  Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080211

#     DATE        TIME            ELEMENT             STATE
4     01/07/2008  04:52:38.3598   51 ASSERTED         Asserted
3     01/07/2008  04:52:39.4516   51 TIMED OUT        Asserted
2     01/07/2008  04:52:41.7520   51 TIMED OUT        Deasserted
1     01/07/2008  04:52:41.7520   51 ASSERTED         Deasserted

=>>
```

Figure 14.24 SER Results

Step 6. To dynamically change the time dial (time multiplier) setting from 0.3 to 0.6, assert RB01. *Figure 14.25* shows how to assert RB01 by means of the **CON** (control) command.

```
=>>CON 01 S <Enter>
Remote Bit Operated
```

Figure 14.25 RB01 Asserted

Step 7. Inject 10A into the relay for at least three seconds, then stop the injection and turn the injection set off. Issue the **SER** command to see the results of the test, as shown in *Figure 14.26*. Use the bold SER entries to calculate the operating time: 35.0417 – 32.8581 = 2.184 seconds. This value compares favorably with the expected value of 2.172 seconds.

```
=>>SER <Enter>

Relay 1                                               Date: 01/07/2008 Time: 04:56:30.007
Station A                                             Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080211

#     DATE        TIME            ELEMENT               STATE
8     01/07/2008  04:52:38.3598  51 ASSERTED           Asserted
7     01/07/2008  04:52:39.4516  51 TIMED OUT          Asserted
6     01/07/2008  04:52:41.7520  51 TIMED OUT          Deasserted
5     01/07/2008  04:52:41.7520  51 ASSERTED           Deasserted
4     01/07/2008  04:55:32.8581  51 ASSERTED           Asserted
3     01/07/2008  04:55:35.0417  51 TIMED OUT          Asserted
2     01/07/2008  04:55:37.3755  51 TIMED OUT          Deasserted
1     01/07/2008  04:55:37.3755  51 ASSERTED           Deasserted
```

Figure 14.26 Test 2 SER Results

Step 8. To dynamically change the time dial (time multiplier) settings from 0.6 to 1.4, assert RB02, as shown in *Figure 14.27*.

```
=>>CON 02 S <Enter>
Remote Bit Operated
```

Figure 14.27 RB02 Asserted

Step 9. Inject 10A into the relay for at least five seconds, then stop the injection and turn the injection set off. Issue the **SER** command to see the results of the test, as shown in *Figure 14.28*. Use the bold SER entries to calculate the operating time: 6.8780 – 3.2357 = 3.642 seconds. This value compares favorably with the expected value of 3.62 seconds.

```
=>>SER <Enter>

Relay 1                                               Date: 01/07/2008 Time: 04:58:20.106
Station A                                             Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080211

#     DATE        TIME            ELEMENT               STATE
12    01/07/2008  04:52:38.3598  51 ASSERTED           Asserted
11    01/07/2008  04:52:39.4516  51 TIMED OUT          Asserted
10    01/07/2008  04:52:41.7520  51 TIMED OUT          Deasserted
9     01/07/2008  04:52:41.7520  51 ASSERTED           Deasserted
8     01/07/2008  04:55:32.8581  51 ASSERTED           Asserted
7     01/07/2008  04:55:35.0417  51 TIMED OUT          Asserted
6     01/07/2008  04:55:37.3755  51 TIMED OUT          Deasserted
5     01/07/2008  04:55:37.3755  51 ASSERTED           Deasserted
4     01/07/2008  04:58:03.2357  51 ASSERTED           Asserted
3     01/07/2008  04:58:06.8780  51 TIMED OUT          Asserted
2     01/07/2008  04:58:09.1242  51 TIMED OUT          Deasserted
1     01/07/2008  04:58:09.1242  51 ASSERTED           Deasserted

=>>
```

Figure 14.28 Test 3 SER Results

Restricted Earth Fault (REF) Test

The REF is a directional element, comparing the angle between the neutral current and the residual current from one or more windings. *Figure 14.29* (a) shows the element characteristic, an internal fault being the shaded area.

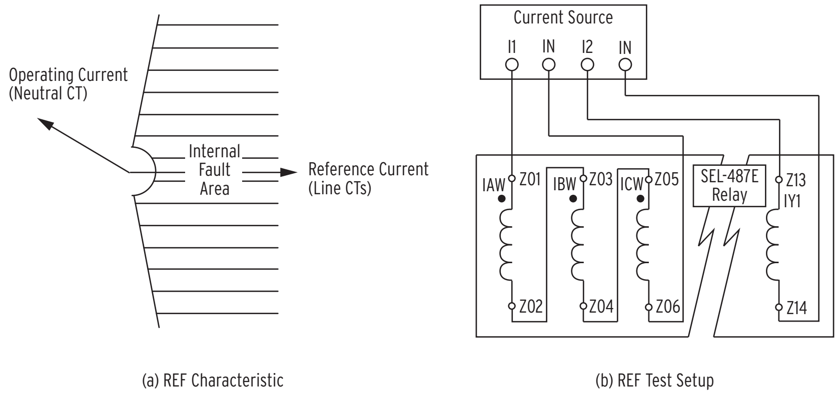


Figure 14.29 REF Characteristic and Test Setup

Figure 14.29(b) shows the test setup for the REF test. For this example, we test one REF element, configured between the W-Terminal currents and the IY1 neutral current.

Step 1. Apply the following settings

SET:
ECTTERM = W
EREF = 1
REFRF1 = W
REF50G1 = 0.05
TCREF1 = 1
CTRW = 100
CTRY1 = 50
CTCONW = Y

Step 2. Wire the relay as shows in *Figure 14.29*, i.e., connect the three elements of the W-Terminal in series, and connect to a current source. Connect the Y-Terminal to a separate phase of the current source (or a different current source).

Inject the following signals:

I1 = 1.0∠0°

I2 = 1.5∠180°`

Because the two currents are opposite in phase, the element should not operate. To verify this, enter the **TAR REF1FP** command. Both Relay Word bits REF1FP and REF1RP are in this row. With the currents applied as above, the element should calculate a reverse fault, asserting Relay Word bit REF1RP.

Change the angle of I2 to any value within ±75 degrees of I1 (I2 = 1.5∠60°, for example) to move the fault to within the internal fault area, causing the REF element to operate. To verify this, again enter the **TAR REF1FP** command. This time, Relay Word bit REF1FP (forward fault) must be asserted and Relay Word bit REF1RP deasserted.

U87P Unrestrained Phase-Differential Element

In this test, you test the unrestrained differential element operation by injecting current in Winding S. *Table 14.21* shows the setting for this test.

Table 14.21 Time Overcurrent Element Settings

Setting	Setting Category	Comment
E87 = S, T	Group	Enable Windings S and T in the differential calculations
CTRS = 100	Group	Winding S CT ratio (default setting)
CTRT = 100	Group	Winding T CT ratio (default setting)
E87TS = 1	Group	Winding S torque equation
E87TT = 1	Group	Winding T torque equation
MVA = 132	Group	Transformer MVA rating
VTERMS = 275	Group	Winding S rated voltage (default setting)
VTERMT = 132	Group	Winding T rated voltage
U87P = 4	Group	Unrestrained Element Current pickup

Figure 14.30 shows the setting change in the Group category, using the **TE**(ERSE) option.

```
=>>SET U87P TE <Enter>
Group 1

Differential Element Configuration and Data

Unrestrained Element Current PU (1.00-20)          U87P    := 8.00   ?4 <Enter>
Incr. Operate Current Threshold p.u. (0.10-10)     DIOPR   := 1.20   ?END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 14.30 Group Settings

Use the **TAR 87U 999** (the 999 repeat the display 999 time on the screen) command to view the line in the relay that shows the status of the elements, as shown below:

```
=>>TAR 87U 999 <Enter>

87UA    87UB    87UC    87U     *       *       *       *
0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0
```

Step 1. Calculate the required current to pick up the unrestrained differential element (setting 4 per unit).

$$IAS = 4 \cdot TAPS \qquad \textbf{Equation 14.4}$$

$$IAS = 4 \cdot 2.1pu \qquad \textbf{Equation 14.5}$$

$$IAS = 8.4A \qquad \textbf{Equation 14.6}$$

⚠CAUTION
The continuous rating of the current inputs is 3 • I_{NOM}. For this test, you may want to chose low values of U87P and TAPn, in order to limit the required test current to a safe value.

Step 2. Start by injecting 7 A three-phase current, and enter TAR 87U 999. Slowly increase the current until the unrestrained differential elements assert, as shown below:

87UA	87UB	87UC	87U	*	*	*	*
1	1	1	1	0	0	0	0
1	1	1	1	0	0	0	0
1	1	1	1	0	0	0	0
1	1	1	1	0	0	0	0

87RA, 87RB and 87RC Restrained Differential Elements

This section provides tests to show the operation of the restraint differential element under the following system conditions (for ease of testing consider only two windings [Winding S and Winding T]):

➤ Internal fault

➤ External fault with heavy CT saturation

➤ Evolving fault, causing the relay to trip on Slope 2

In general, the relay uses *Equation 14.7* and *Equation 14.8* to calculate the operational operating current (IOP_{OP}) and the restraint current (IRT).

$$IOP_{OP} = \left|\overrightarrow{IAS} + \overrightarrow{IAT}\right| \qquad \textbf{Equation 14.7}$$

$$IRT = |IAS| + |IAT| \qquad \textbf{Equation 14.8}$$

Equation 14.7 calculates the absolute value of the vector sum of $\overrightarrow{IAS}$ and $\overrightarrow{IAT}$, and *Equation 14.8* calculates the sum of the absolute values of $\overrightarrow{IAS}$ and $\overrightarrow{IAT}$.

Equation 14.9 is the third equation that the differential element uses to make a trip/no trip decision.

$$IOP(IRT) = \frac{SLP}{100} \bullet IRT \qquad \textbf{Equation 14.9}$$

Equation 14.9 provides the reference value (from the slope setting) for various restraint values, as shown in *Figure 14.31*.

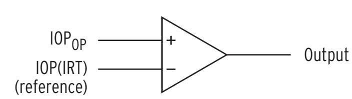


Figure 14.31 Differential Element Comparator

Each processing interval, the relay calculates IRT (*Equation 14.8*), uses this calculated IRT value to calculate IOP(IRT) (*Equation 14.9*), and compares this calculated IOP(IRT) value with the result of *Equation 14.7* (IOP_{OP}).

Figure 14.32 shows the characteristic of the differential element, together with IOP_{OP}. In *Figure 14.32*, the shaded area (area below the SLP line) is the non-operating or restraint area, and the area above the SLP line is the operating or tripping area.

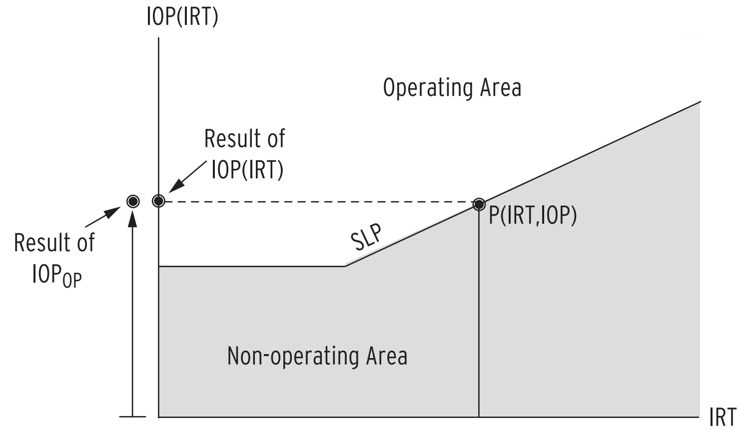


Figure 14.32 Differential Element Characteristic

To simplify *Equation 14.7*, consider a fixed angular relationship of 180 degrees between $\overline{IAS}$ and $\overline{IAT}$, i.e., $\overline{IAS} = IAS\angle 0°$ and $\overline{IAT} = IAT\angle 180°$. With this relationship, both IAS and IAT are real numbers, and *Equation 14.7* becomes:

$$IOP_{OP} = IAS - IAT \quad \textbf{Equation 14.10}$$

or

$$IAS = IOP_{OP} + IAT \quad \textbf{Equation 14.11}$$

Also, from *Equation 14.8*,

$$IAS = IRT - IAT \quad \textbf{Equation 14.12}$$

Equate *Equation 14.11* and *Equation 14.12* to solve for IAT:

$$IAT = \frac{IRT - IOP_{OP}}{2} \quad \textbf{Equation 14.13}$$

With this value, use *Equation 14.12* to calculate IAS:

$$IAS = \frac{IRT + IOP_{OP}}{2} \quad \textbf{Equation 14.14}$$

Testing

Connect a three-phase test set to the SEL-487E as shown in *Figure 14.8*. Change the following settings, as shown in *Table 14.22* and *Figure 14.33*.

Table 14.22 Differential Element Settings (Sheet 1 of 2)

Setting	Setting Category	Comment
VTERMT = 132	Group	Rated line-to-line voltage for Winding S
E87 = S,T	Group	Include Windings S and T for the differential element
E87TS = 1	Group	Winding S is permanently included in the differential element
E87TT = 1	Group	Winding T is permanently included in the differential element
O87P = 0.3	Group	Restraint differential element pickup
SLP1 = 30	Group	Set Slope 1 to 30 percent

Table 14.22 Differential Element Settings (Sheet 2 of 2)

Setting	Setting Category	Comment
SLP2 = 60	Group	Set Slope 2 to 60 percent
MVA = 100	Group	Transformer maximum capacity

```
=>>SET TE <Enter>
Group 1

Relay Configuration

Enable Current Terminals (OFF or combo of S,T,U,W,X)
ECTTERM := "S,T"  ? <Enter>
Enable Voltage Terminals (OFF or combo of V,Z)      EPTTERM := OFF    ? <Enter>
Enable Diff Elem. Prot. Terms (OFF or combo of S,T)
E87     := OFF    ?S, T <Enter>
Enable Restricted Earth Fault Element (N,1-3)       EREF    := N      ? <Enter>
Enable Def. Time Dir. O/C Ele. (OFF or combo of S,T)
E50     := OFF    ? <Enter>
Enable Inverse Time Overcurrent Elements (N, 1-10)  E51     := N      ? <Enter>
Enable Current Unb. Elements (OFF or combo of S,T)  E46     := OFF    ? <Enter>
Enable Breaker Fail. Prot. (OFF or combo of S,T)    EBFL    := OFF    ? <Enter>
Enable Demand Metering (N, 1-10)                    EDEM    := N      ? <Enter>

Current Transformer Data

Current Trans. Ratio Terminal S (1-50000)           CTRS    := 100    ? <Enter>
Current Trans. Connection Terminal S (Y,D)          CTCONS  := Y      ? <Enter>
Current Trans. Ratio Terminal T (1-50000)           CTRT    := 100    ? <Enter>
Current Trans. Connection Terminal T (Y,D)          CTCONT  := Y      ? <Enter>

Differential Element Configuration and Data

Term S included in 87 Element (SELogic Eqn)
E87TS  := 0
? 1 <Enter>
Term T included in 87 Element (SELogic Eqn)
E87TT  := 0
? 1 <Enter>
Internal CT Conn. Compensation Enabled (Y,N)        ICOM    := Y      ? <Enter>
Terminal S CT Conn. Compensation (0 - 12)           TSCTC   := 12     ? <Enter>
Terminal T CT Conn. Compensation (0 - 12)           TTCTC   := 12     ? <Enter>
Transformer Max. Power Capacity (OFF, 1 - 5000MVA)  MVA     := OFF    ?100 <Enter>
Terminal S Line-to-Line Voltage  (1.00-1000 kV)     VTERMS  := 275.00 ? <Enter>
Terminal T Line-to-Line Voltage  (1.00-1000 kV)     VTERMT  := 275.00 ?132 <Enter>
Terminal S Current Tap  (0.50-175 A,sec)            TAPS    := 2.10   ? <Enter>
Terminal T Current Tap  (0.50-175 A,sec)            TAPT    := 4.37   ? <Enter>
Differential Element Oper. Current PU (0.10-4)      O87P    := 1.00   ?0.3 <Enter>
Slope 1 Percentage (5.00-100%)                      SLP1    := 35.00  ?30 <Enter>
Slope 2 Percentage (5.00-100%)                      SLP2    := 75.00  ?60 <Enter>
Unrestrained Element Current PU (1.00-20)           U87P    := 8.00   ? <Enter>
Incr. Operate Current Threshold p.u. (0.10-10)      DIOPR   := 1.20   ? <Enter>
Incr. Restraint Current Threshold p.u. (0.10-10)    DIRTR   := 1.20   ? <Enter>
Enable Harmonic Blocking Diff. Element (Y,N)        E87HB   := N      ? <Enter>
Enable Harmonic Restraint Diff. Element (Y,N)       E87HR   := Y      ? <Enter>
Second-Harmonic Percentage (OFF, 5-100%)            PCT2    := 15     ? <Enter>
Fourth-Harmonic Percentage (OFF, 5-100%)            PCT4    := 15     ? <Enter>
Fifth-Harmonic Percentage (OFF, 5-100%)             PCT5    := 35     ? <Enter>
Fifth-Harmonic Alarm Threshold p.u. (OFF, 0.2-3.2)  TH5P    := OFF    ? <Enter>
Neg. Seq. Differential Op current (0.05-1)          87QP    := 0.10   ? <Enter>
Neg. Seq. Differential Slope (5 - 100%)             SLPQ1   := 10     ?END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.33 Group Settings for the Differential Test

Step 1. With arbitrary values IRT = 3 per unit, SLP1 = 30, and SLP2 = 60 percent, use *Equation 14.9* to calculate IOP(IRT) values for Slope 1 and Slope 2:

$$IOP(IRT) = \frac{30}{100} \bullet 3 = 0.9\text{pu (Slope 1)} \qquad \textbf{Equation 14.15}$$

$$IOP(IRT) = \frac{60}{100} \bullet 3 = 1.8\text{pu (Slope 2)}$$ **Equation 14.16**

Case 1: Internal Fault

Select an IOP_{OP} value greater than 1.8 to ensure that the relay will operate, such as 3 per unit. *Figure 14.34* shows the selected point P(3,3), which is well within the tripping area (shaded area).

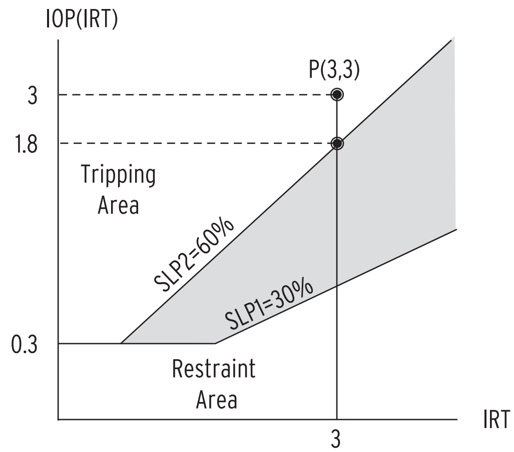


Figure 14.34 Values for Case 1

For this test, you need to inject current into Winding S only, i.e., I*n*T (*n* = A, B, C) = 0, and I*n*S = 3 per unit. Convert per-unit values (pu) to ampere values, by multiplying the per-unit values with the TAPS value (2.1), as shown in *Table 14.23*.

Table 14.23 Calculate the Current Values in Ampere (Case 1)

Current (per unit)	Current (Ampere)
$IAS = 3\angle 0°pu \bullet 2.1$	$IAS = 6.3\angle 0°A$
$IBS = 3\angle -120°pu \bullet 2.1$	$IBS = 6.3\angle -120°A$
$ICS = 3\angle 120°pu \bullet 2.1$	$ICS = 6.3\angle 120°A$

Step 2. Inject balanced 6.3A into Winding S for 100ms, then stop.

Step 3. Verify that LEDs 3, 4, and 5 are illuminated.

Step 4. Press the **{TARGET RESET}** button to reset the LEDs.

Case 2: External Fault With Heavy CT Saturation

This test simulates an external fault that eventually results in extreme CT saturation that would have caused the relay to trip if the relay were still operating on Slope 1. However, because the relay switched to Slope 2, the relay does not operate for this fault for less than one second. This test will be run in two stages, the first stage simulating an external fault without CT saturation and the second stage introducing heavy CT saturation.

Step 1. For Stage 1, select a large IRT value that will simulate an external fault without CT saturation (IOP_{OP} is zero); a good value for IRT is 3 pu. *Figure 14.35* shows the selected point P1(3,0).

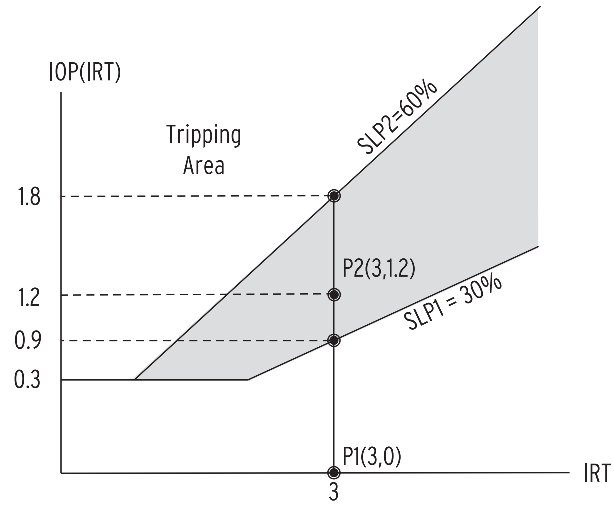


Figure 14.35 Values for Case 2

Step 2. Calculate IAS and IAT for the point P1(3,0):

$$IAS = \frac{IRT + IOP_{OP}}{2} = \frac{3 + 0}{2} = 1.5$$ **Equation 14.17**

$$IAT = \frac{IRT - IOP_{OP}}{2} = \frac{3 - 0}{2} = 1.5$$ **Equation 14.18**

Convert per-unit values (pu) to ampere values by multiplying the per-unit vales with the TAP values, as shown in *Table 14.24*.

Table 14.24 Calculate the Current Values in Ampere (Case 2, Stage 1)

Current (per unit)	Current (Ampere)
IAS = 1.5∠0°pu • 2.1	IAS = 3.15∠0°A
IBS = 1.5∠–120°pu • 2.1	IBS = 3.15∠–120°A
ICS = 1.5∠120°pu • 2.1	ICS = 3.15∠120°A
IAT = 1.5∠180°pu • 4.37	IAT = 6.56∠180°A
IBT = 1.5∠60°pu • 4.37	IBT = 6.56∠60°A
ICT = 1.5∠-60°pu • 4.37	ICT = 6.56∠–60°A

Step 3. For Stage 2, select an IOP_{OP} value between 0.9 pu and 1.8 pu that will simulate CT saturation. Accounting for the relay's group settings, a good choice for IOP_{OP} would be 1.2 pu. *Figure 14.35* shows the selected point P2(3,1.2) and the area between the two slopes (shaded area).

Step 4. Calculate IAS and IAT for the point P2(3,1.2):

$$IAS = \frac{IRT + IOP_{OP}}{2} = \frac{3 + 1.2}{2} = 2.1$$ **Equation 14.19**

$$IAT = \frac{IRT - IOP_{OP}}{2} = \frac{3 - 1.2}{2} = 0.9$$ **Equation 14.20**

As before, convert the pu values to ampere values by multiplying by the appropriate TAP values, as shown in *Table 14.25*.

Table 14.25 Calculate the Current Values in Ampere (Case 2, Stage 2)

Current (per unit)	Current (Ampere)
IAS = 2.1∠0°pu • 2.1	IAS = 4.41∠0°A
IBS = 2.1∠–120°pu • 2.1	IBS = 4.41∠–120°A
ICS = 2.1∠120°pu • 2.1	ICS = 4.41∠120°A
IAT = 0.9∠180°pu • 4.37	IAT = 3.93∠180°A
IBT = 0.9∠60°pu • 4.37	IBT = 3.93∠60°A
ICT = 0.9∠-60°pu • 4.37	ICT = 3.93∠–60°A

Step 5. Inject the currents for Stage 1 shown in *Table 14.24* into Winding S and Winding T for 1.8 cycles, and then inject the currents for Stage 2 shown in *Table 14.25* into Winding S and Winding T for 800 ms.

Step 6. Verify that LEDs 3, 4, and 5 are NOT illuminated, i.e., the relay did not trip.

Case 3: Evolving Fault, Causing the Relay to Trip on Slope 2

This test is for a fault that starts out as an external fault (causing the relay to switch to Slope 2), but then evolves into an in-zone fault. The worst case for this fault is when there is only one source, i.e., when the fault moves to an internal fault, the side where the external fault was, does not contribute any fault current.

This test is in two stages: Stage 1 for the external fault (no saturation) and Stage 2 for the evolved fault.

Table 14.26 Current Values in Ampere (Case 3)

Current (Ampere) Stage 1	Current (Ampere) Stage 2
IAS = 4.2∠0°A	IAS = 4.2∠0°A
IBS = 4.2∠–120°A	IBS = 4.2∠–120°A
ICS = 4.2∠120°A	ICS = 4.2∠120°A
IAT = 8.74∠180°A	IAT = 0
IBT = 8.74∠60°A	IBT = 0
ICT = 8.74∠–60°A	ICT = 0

Step 1. Enable an overcurrent element for Winding T, and set the pickup value to 0.5 A, as shown in *Figure 14.36*.

```
=>>SET E50 TE <Enter>
Group 1

Relay Configuration

Enable Def. Time Dir. O/C Ele. (OFF or combo of S,T)
E50     := OFF     ?T <Enter>
Enable Inverse Time Overcurrent Elements (N, 1-10)   E51     := N       ?1 <Enter>
Enable Current Unb. Elements (OFF or combo of S,T)   E46     := OFF     ?> <Enter>

Current Transformer Data

Current Trans. Ratio Terminal S (1-50000)           CTRS    := 100     ? <Enter>
Current Trans. Connection Terminal S (Y,D)          CTCONS  := Y       ? <Enter>
Current Trans. Ratio Terminal T (1-50000)           CTRT    := 100     ? <Enter>
Current Trans. Connection Terminal T (Y,D)          CTCONT  := Y       ? <Enter>

Winding T
Overcurrent Elements Terminal T

Type of O/C Elements Enabled Term. T (Combo of P,Q,G)
E50T    := "P"     ? <Enter>
Enable Directional elements Terminal T (Y,N)        E67T    := N       ? <Enter>

Terminal T Phase Overcurrent Element Level 1

Phase Inst O/C pickup level 1 (OFF,0.25-100)        50TP1P  := OFF     ?0.5 <Enter>
Phase Inst O/C level 1 Torque Ctrl (SELogic Eqn)
67TP1TC := TF32P
? END <Enter>


Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.36 Enable Overcurrent Element for Winding T

Step 2. Enter the setting in *Figure 14.37* to include the overcurrent element in the SER.

```
=>>SET R TE <Enter>
Report

SER Chatter Criteria

Automatic Removal of Chattering SER Points (Y,N)     ESERDEL := N       ?

SER Points
(Relay Word Bit, Reporting Name, Set State Name, Clear State Name, HMI Alarm)

1:
?  50TP1 <Enter>
2:
?  TRPXFMR <Enter>
3:
?  END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait...........
Settings Saved

=>>
```

Figure 14.37 Enter Overcurrent Element in the SER

Step 3. Inject the current shown in the Stage 1 column of *Table 14.26* into Winding S and Winding T for 200 ms, then inject the Stage 2 currents for 200 ms.

Step 4. Issue the **SER** command and calculate the time difference between the de-assertion of 50TP1 and the assertion of TRPXFMR. This must be less than two cycles.

Negative-Sequence Differential Element

Use the settings shown in *Table 14.27* for the negative-sequence differential element test.

Table 14.27 Settings for the Negative-Sequence Test

Settings	Setting Group	Comment
MVA = 100	Group	Transformer rating
VTERMS = 275	Group	HV rated voltage
VTERMT = 132	Group	LV rated voltage
E87 = S, T	Group	Enable Windings S and T in the differential element
E87TS = 1	Group	
E87TT = 1	Group	

Be sure that the compensation settings (TSCTC = TTCTC = 12) and the negative-sequence elements (87QP = 0.1, SLPQ1 = 10) are at default settings.

Step 1. Inject the currents shown in *Table 14.28* in the relay.

Table 14.28 Currents for Negative-Sequence Differential Test

Winding S	Winding T
IAS = 2.1∠0°	IAT = 4.37∠180°
IBS = 2.1∠–120°	IBT = 4.37∠60°
ICS = 1.8∠120°	ICT = 4.37∠–60°

Step 2. Issue the **TAR 87Q 9999** command as shown below:

```
=>>TAR 87Q 9999 <Enter>

87Q     *       *       *       *       *       *       *
0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0
0       0       0       0       0       0       0       0
```

Step 3. Slowly decrease IAS current in 10 mA steps. 87Q asserts (87Q = 1) when IAS is ± 1.89 A.

Negative-Sequence Directional Element for Phase Faults

Use the phase directional element (represented by Relay Word bits *k*F32P/*k*R32P, *k* = S, T, U, W, X) to convert non-directional phase overcurrent elements to directional phase overcurrent elements. The negative-sequence directional element, *k*F32Q/*k*R32Q, is a part of the phase directional element, and provides directional control for all shunt faults except for bolted, three-phase faults. Because the negative-sequence element is part of the phase element, the phase directional element asserts whenever the negative-sequence directional element asserts.

The SEL-487E calculates the negative-sequence impedance Z2 from the magnitudes and angles of the negative-sequence voltage and current. *Equation 14.21* defines this function (the “c” in Z2c indicates “calculated”).

$$Z2c = \frac{\mathrm{Re}[V_2 \bullet (1\angle Z1ANG \bullet I_2)^*]}{|I_2|^2}$$
$$= \frac{|V_2|}{|I_2|} \bullet \cos(\angle V_2 - \angle Z1ANG - \angle I_2) \quad \textbf{Equation 14.21}$$

where:

V_2 = the negative-sequence voltage
I_2 = the negative-sequence current
Z1ANG = the positive-sequence line impedance angle
Re the real part of the term in brackets, for example, (Re[A + jB] = A)
* = the complex conjugate of the expression in parentheses, (A + jB)* = (A – jB)

The result of *Equation 14.21* is an impedance magnitude that varies with the magnitude and angle of the applied current. Normally, a forward fault results in a negative Z2c relay calculation.

Test Current

Solve *Equation 14.22* to find the test current values that you need to apply to the relay to test the element. For the negative-sequence current I_2, the result is

$$|I_2| = \frac{|V_2|}{Z2c} \quad \textbf{Equation 14.22}$$

when:

$$\angle I_2 = \angle V_2 - \angle Z1ANG \quad \textbf{Equation 14.23}$$

Multiply the quantities in *Equation 14.22* by three to obtain $3I_2$, the negative-sequence current that the relay processes. With a fixed applied negative-sequence voltage VA, the relay negative-sequence voltage is 3V2. Set Z2c = Z2FT to find the test current magnitude at the point where the impedance calculation equals the forward fault impedance threshold as follows:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2FT} \quad \textbf{Equation 14.24}$$

when:

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG \quad \textbf{Equation 14.25}$$

Use *Equation 14.26* for a reverse fault impedance threshold, where Z2c = Z2R:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2c} = \frac{|3V_2|}{Z2R} \quad \textbf{Equation 14.26}$$

when the angle calculation is the same as *Equation 14.25*.

Checking the Negative-Sequence Directional Element (Phase Faults Clear of Ground)

NOTE: As you perform this test, other protection elements can assert. This causes the relay to assert other targets and possibly close control outputs. Be sure to isolate the relay from the power system to avoid unexpected system effects.

This test confirms operation of the TF32Q and the TR32Q negative-sequence directional element for Terminal T, using a 5 A relay; scale values appropriately for a 1 A relay. This example assumes that you have successfully established communication with the relay, and that you are familiar with relay access levels and passwords. *Table 14.29* shows the settings necessary for the test.

Table 14.29 Settings to Test the Negative-Sequence Directional Element for Terminal T

Settings	Description	Category
EPTTERM = V	Enables the PT inputs (V or Z)	Group
E50 = T	Enables the directional element for Terminal T	Group
VREFT = V	Declares which PT to use (V or Z)	Group
E50T = Q	Specifies which overcurrent elements to enable for Terminal T (P, Q, G)	Group
E67T = Y	Enables the directional logic for Terminal T	Group
Z1ANGT = 84 degrees	Positive-sequence line impedance angle	Group
EADVST = Y	Enable advanced settings Terminal T	Group
50FPT = 0.6 A	Forward directional O/C pickup	Group
50RPT = 0.4 A	Reverse directional O/C pickup	Group
Z2FT = 3.9 Ω	Forward directional Z2 Threshold	Group
Z2RT = 4.4 Ω	Reverse directional Z2 Threshold	Group
A2T = 0.10	Positive-sequence Restraint Factor	Group

Step 1. Configure the relay.

Set the Group settings for Terminal T (see *Figure 14.38*).

```
=>>SET <Enter>
Group 1

Relay Configuration

Enable Current Terminals (OFF or combo of S,T,U,W,X)
ECTTERM := "S,T"   ? <Enter>
Enable Voltage Terminals (OFF or combo of V,Z)      EPTTERM := OFF    ?V <Enter>
Enable Diff Elem. Prot. Terms (OFF or combo of S,T)
E87     := OFF     ? <Enter>
Enable Restricted Earth Fault Element (N,1-3)       EREF    := N      ? <Enter>
Enable Def. Time Dir. O/C Ele. (OFF or combo of S,T)
E50     := OFF     ?T <Enter>
Enable Inverse Time Overcurrent Elements (N, 1-10)  E51     := N      ? <Enter>
Enable Current Unb. Elements (OFF or combo of S,T)  E46     := OFF    ? <Enter>
Enable Over Voltage Elements (N,1-5)                E59     := N      ? <Enter>
Enable Under Voltage Elements (N,1-5)               E27     := N      ? <Enter>
Enable Frequency Elements (N,1-6)                   E81     := N      ? <Enter>
Enable Volts per Hertz Element (Y,N)                E24     := N      ? <Enter>
Enable Breaker Fail. Prot. (OFF or combo of S,T)    EBFL    := OFF    ? <Enter>
Enable Power Calc. Term (OFF or combo of S,T)       EPCAL   := OFF    ? <Enter>
Enable Demand Metering (N, 1-10)                    EDEM    := N      ? <Enter>

Current Transformer Data

Current Trans. Ratio Terminal S (1-50000)           CTRS    := 100    ? <Enter>
Current Trans. Connection Terminal S (Y,D)          CTCONS  := Y      ? <Enter>
Current Trans. Ratio Terminal T (1-50000)           CTRT    := 100    ? <Enter>
Current Trans. Connection Terminal T (Y,D)          CTCONT  := Y      ? <Enter>

Potential Transformer Data

Potential Trans. Ratio Terminal V (1-10000)         PTRV    := 2000   ? <Enter>
Potential Trans. Connection Terminal V (Y,D)        PTCONV  := Y      ? <Enter>
PT Comp. Angle Terminal V (-179.99 to +180 deg)     PTCOMPV := 0.00   ? <Enter>
```

```
PT Nominal Voltage (L-L) Term. V (30-300 V,sec)      VNOMV   := 110     ? <Enter>

Voltage Reference Terminal Selection

Voltage Reference For Terminal S (OFF,V)             VREFS   := OFF     ? <Enter>
Voltage Reference For Terminal T (OFF,V)             VREFT   := OFF     ?V <Enter>

Winding T
Overcurrent Elements Terminal T

Type of O/C Elements Enabled Term. T (Combo of P,Q,G)
E50T    := "P"    ?
Enable Directional elements Terminal T (Y,N)         E67T    := N       ?Y <Enter>
Current Transformer Polarity Terminal T (P,N)        CTPT    := P       ? <Enter>
Pos.-Seq. Line Impedance Angle (5.00-90 deg)         Z1ANGT  := 89.00   ?84 <Enter>
Enable Advanced Setting Terminal T (Y,N)             EADVST  := N       ?Y <Enter>
Forward Dir. O/C Pickup (0.25-5 A,sec)               50FPT   := 0.25    ?0.6 <Enter>
Reverse Dir. O/C Pickup (0.25-5 A,sec)               50RPT   := 0.25    ?0.4 <Enter>
Fwd Dir Z2 Threshold (-64.00-64 ohms,sec)            Z2FT    := -0.10   ?3.9 <Enter>
Rev Dir Z2 Threshold (-64.00-64 ohms,sec)            Z2RT    := 0.10    ?4.4 <Enter>
Pos.-Seq. Restraint Factor, I2/I1 (0.02-0.50)        A2T     := 0.10    ?

Terminal T Phase Overcurrent Element Level 1

Phase Inst O/C pickup level 1 (OFF,0.25-100)         50TP1P  := 0.50    ?END <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 14.38 Group Settings for the Directional Test

Step 2. Set test values in the relay.

Step 3. Set the Front Panel LED to show the directional element word bits, as in *Figure 14.39*. With these settings, the LEDs are green when TF32Q and TR32Q are deasserted, and red when TF32Q and TR32Q are asserted.

```
=>>SET F PB8_LED TE <Enter>
Front Panel

Front Panel Settings

Pushbutton LED 8 (SELOGIC Equation)
PB8_LED := NA
?  TF32Q <Enter>
PB8_LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB8_COL := AO     ?RG
Pushbutton LED 9 (SELOGIC Equation)
PB9_LED := NA
?  TR32Q <Enter>
PB9_LED Assert & Deassert Color (Enter 2: R,G,A,O)   PB9_COL := AO     ?RG
Pushbutton LED 10 (SELOGIC Equation)
PB10LED := NA
?  END

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure 14.39 Front-Panel Settings

Step 4. Display the F32Q and R32Q Relay Word bits on the front-panel LCD screen.

a. Access the front-panel LCD MAIN MENU.

b. Highlight RELAY ELEMENTS and press **{ENT}**.

You will see a RELAY ELEMENTS screen with SEARCH highlighted at the bottom of the screen.

c. Press **{ENT}** to go to the ELEMENT SEARCH submenu

d. Enter characters in the text input field using the navigation keys.

e. Highlight `T` and press **{ENT}** to enter the T character
f. Highlight `F` and press **{ENT}** to enter the F character.
g. Enter the `3`, `2`, and `Q` characters in like manner.
h. Highlight `ACCEPT` and press **{ENT}**.

The relay displays the screen containing the TF32Q and TR32Q elements, as shown in *Figure 14.40*.

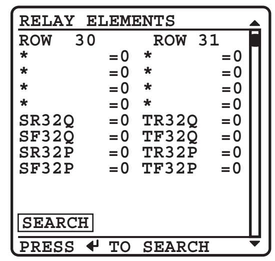


Figure 14.40 RELAY ELEMENTS LCD Screen Containing Elements TF32Q and TR32Q

Step 5. Calculate impedance thresholds.

a. For this test, apply an A-phase voltage of VAV = 3V2 = 18.0 ∠180° V secondary.
b. Use *Equation 14.27* to find the current that is equal to the reverse impedance threshold Z2R:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2RT} = \frac{|18.0\angle 180°V|}{4.4} = 4.1\ A$$

Equation 14.27

Step 6. Use *Equation 14.28* to find the current that is equal to the forward impedance threshold Z2F:

$$|I_{TEST}| = |3I_2| = \frac{|3V_2|}{Z2RFT} = \frac{|18.0\angle 180°V|}{3.90} = 4.62\ A$$

Equation 14.28

Step 7. Use *Equation 14.29* to determine the applied current angle ($\angle I_{TEST}$):

$$\angle I_{TEST} = \angle 3I_2 = \angle 3V_2 - \angle Z1ANG = 180° - 84° = 96°$$

Equation 14.29

Step 8. Apply a test current to confirm operation of TR32Q and TF32Q.

a. Connect a test source as shown in *Figure 14.41*.

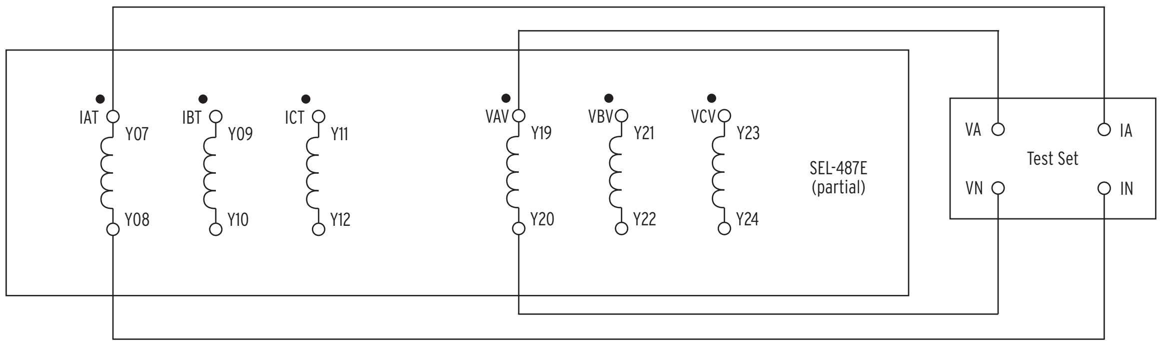


Figure 14.41 Connections for Directional Element Test

b. Apply an A-phase voltage of VA = 18.0∠180° V secondary.

c. Set the current source for IA = 0.0∠96° A.

d. Slowly increase the magnitude of IAT to apply the source test current.

e. Observe the `RELAY ELEMENT` LCD screen. Relay Word bit TR32Q asserts when |IA| = 0.4 A, indicating that the relay negative-sequence current is greater than the 50RPT pickup threshold. TR32Q deasserts when |IA| = 4.1 A, indicating that the relay negative-sequence calculation Z2c is now less than the Z2 reverse threshold Z2RT.

f. Continue to increase the current source while you observe the `RELAY ELEMENT` LCD screen. Relay Word bit TF32Q asserts when |IA| = 4.62 A, indicating that the relay negative-sequence calculation Z2c is less than the Z2 forward threshold Z2FT.

Commissioning Testing

When: When installing a new protection system.

Goal:

- Ensure that all system ac and dc connections are correct.
- Ensure that the relay functions as intended using your settings.
- Ensure that all auxiliary equipment operates as intended.

What to test: All connected or monitored inputs and outputs; polarity and phase rotation of ac current connections; simple check of protection elements.

SEL performs a complete functional check and calibration of each relay before it is shipped. This helps ensure that you receive a relay that operates correctly and accurately. Commissioning tests should verify that the relay is properly connected to the power system and all auxiliary equipment. Verify control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection check to verify that the relay current inputs are of the proper magnitude and phase rotation.

Brief fault tests ensure that the relay settings are correct. It is not necessary to test every relay element, timer, and function in these tests.

Use the SEL-487E Relay Commissioning Test Worksheet, located at the end of this section, to verify correct CT connections and settings when placing the relay in service. The worksheet shows how using software commands or the front-panel display can replace the need for the traditional phase angle meter and ammeter.

At commissioning time, use the relay **METER DIF** command to record the measured operate and restraint values for through-load currents. Use the **PULSE** command to verify relay output contact operation.

Commissioning Assistant

Commissioning Assistant is a software tool that checks for single-contingency wiring errors and then calculates a matching compensation matrix for a test winding with respect to a user-defined reference winding.

Use Commissioning Assistant to further assist you during commissioning. In general, commissioning tools to check the differential element are limited to measuring the differential current. However, use of the operating current as a catchall indicator of all commissioning errors can result in ambiguous conclusions. For example, both incorrect CT polarity and a CT connected to the incorrect CT tap result in the presence of operating current.

Therefore, although the presence of excessive operating current indicates commissioning error(s), the commissioning engineer cannot identify the specific cause of the unbalance by the mere presence of operating current. Clearly, we need to take measurements other than just the differential current to identify the specific cause of the operating current. *Table 14.30* shows the measurement methods we use in the Commissioning Assistant.

Table 14.30 Measurement Methods To Identify Various Causes of Operating Current

Error	Measuring Method
Insufficient load current	Current magnitude measurement
Two crossed phases	Negative-sequence current measurement
CT connected to the incorrect tap	Expected current to measured current magnitude comparison; negative-sequence current measurement
Incorrect CT polarity	Angular comparison between a reference phase and all other phases
Vector-group compensation selection	Operating current and phase angle measurement

Be aware of the following limits:

1. The matrix calculations are reliable when no wiring errors are present and the transformer is on the nominal tap.
2. The error-detection algorithm is designed to identify single errors; it may or may not correctly identify multiple errors.
3. The error-detection algorithm is reliable for a system unbalance as great as 25 percent.
4. The incorrect CT tap that the consistent CT ratio error calculations can detect is inversely proportional to the magnitude of the load current. At the minimum load current (five percent of full-load current), the CT ratio error must exceed 30 percent for the consistent CT ratio error check to detect the error. At 20 percent load, the CT ratio error must

exceed only 10 percent. At full load, this value drops to 4 percent.

Flow Diagram

Figure 14.42 shows the flow diagram of the process.

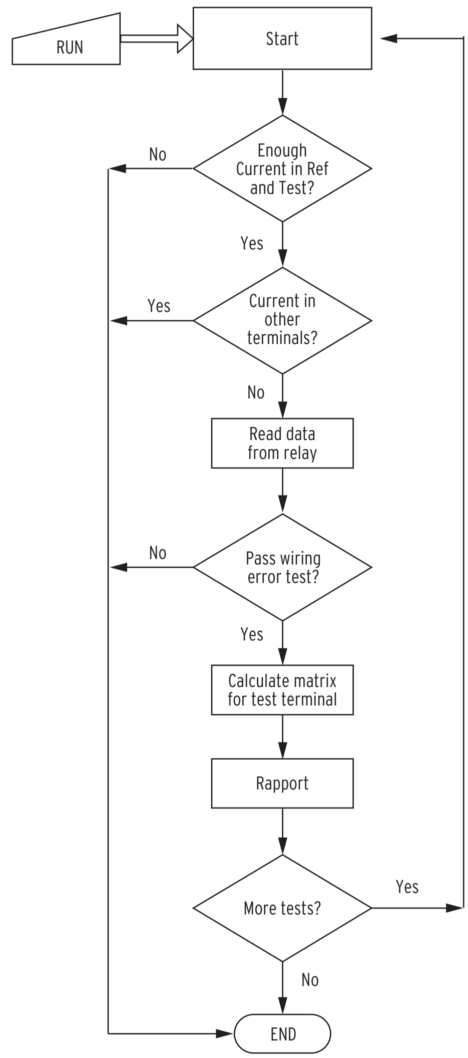


Figure 14.42 Process Flow Diagram

In general, Commissioning Assistant compares quantities from a test terminal against quantities from a reference terminal. To avoid ambiguous results, Commissioning Assistant processes only two terminals in each test. For multi-terminal applications, use one of the terminals from the first test in subsequent tests for the remaining windings.

As an example, consider the station shown in *Figure 14.43*. This station has a breaker-and-a-half busbar on the HV side of the wye/wye (star/star) transformer, and a single busbar on the LV side. All CTs are wye (star) connected.

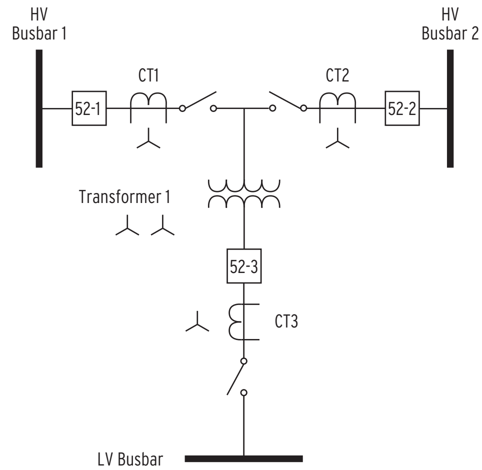


Figure 14.43 Example Substation

Launch Commissioning Assistant from ACSELERATOR QuickSet under the **Tools** menu, as in *Figure 14.44*. Notice the tree on the left side of the figure. Presently, the **Select Transformer Terminals** is highlighted. As you complete a step in the process, the highlight moves to the next step to guide you through the selection process.

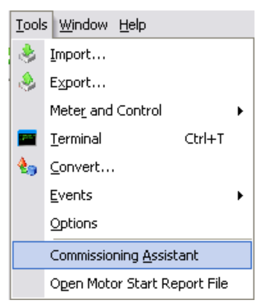


Figure 14.44 Launch Commissioning Assistant

Click on the **I Agree** button of the Disclaimer to continue with the testing (*Figure 14.45*), and click **OK** to select **487E** (*Figure 14.46*).

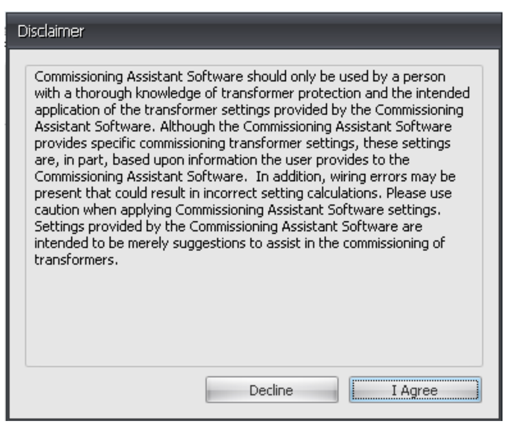


Figure 14.45 Disclaimer

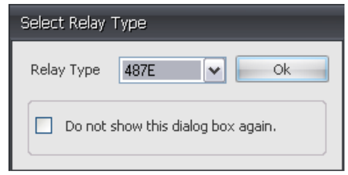


Figure 14.46 SEL-487E Relay Selection

Figure 14.47 shows the configuration screen, consisting of the following four areas:

➤ Control Area—Run tests, reset/start a new diagram, and save the report.

➤ Test Step Area—This area shows all the steps in the testing procedure, and highlights the present step. Presently, the **Select Transformer Terminals** is highlighted. As you complete a step in the process, the highlight moves to the next step to guide you through the selection process.

➤ Configuration Selection Area—Select the HV and LV CT configuration, and the transformer type in this area.

➤ Configuration Reference Area—This area displays the selections from the Configuration Selection Area to give you an overall picture of the bay configuration.

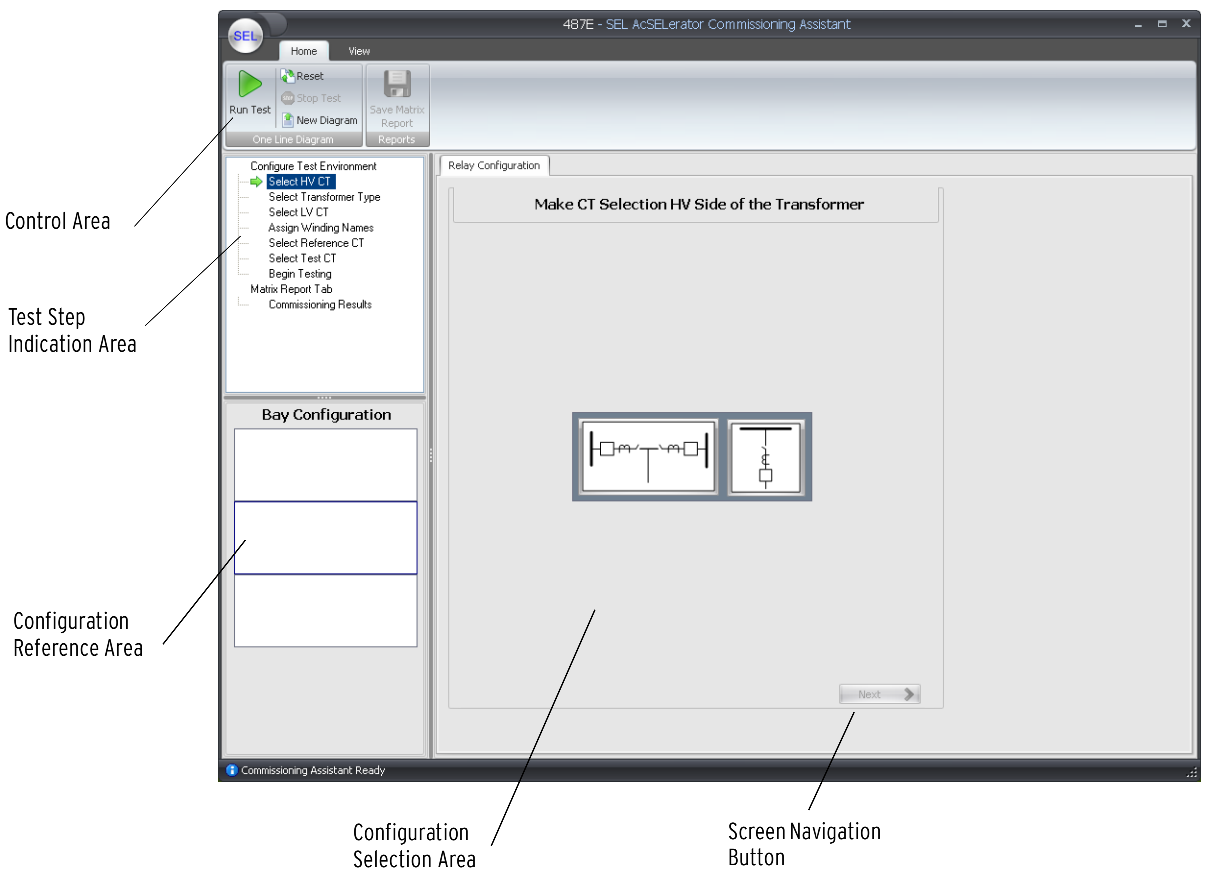


Figure 14.47 Configuration Screen

To configure the HV part of the example substation, select the encircled image (*Figure 14.48*). Notice that the selection appears in the Reference Area.

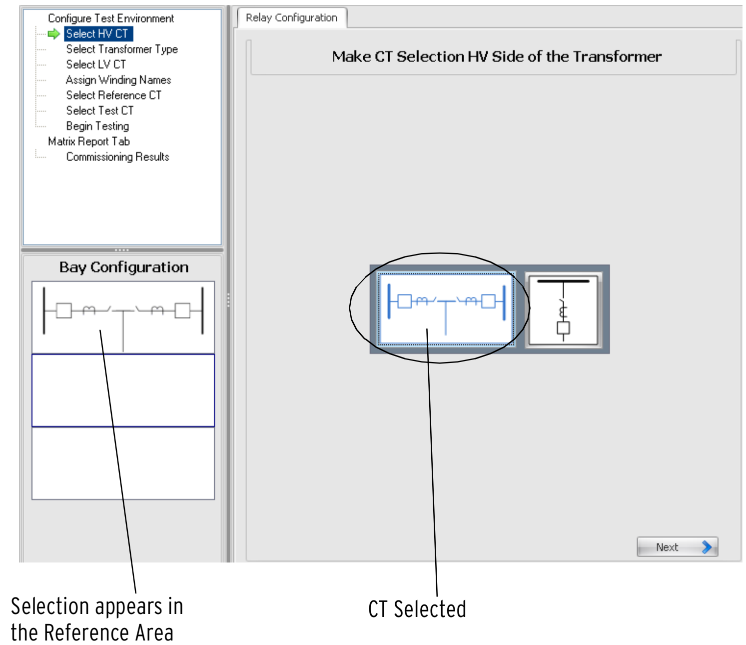


Figure 14.48 HV CT Selection

Click the **Next** button to move to the screen displayed in *Figure 14.49*. Select the appropriate transformer type, and notice that the selection appears in the Reference Area. Also notice that the "Select Transformer Type" is highlighted in the Test Step Area. If you want to select a different HV CT arrangement, click the **Previous** button to go to the previous screen.

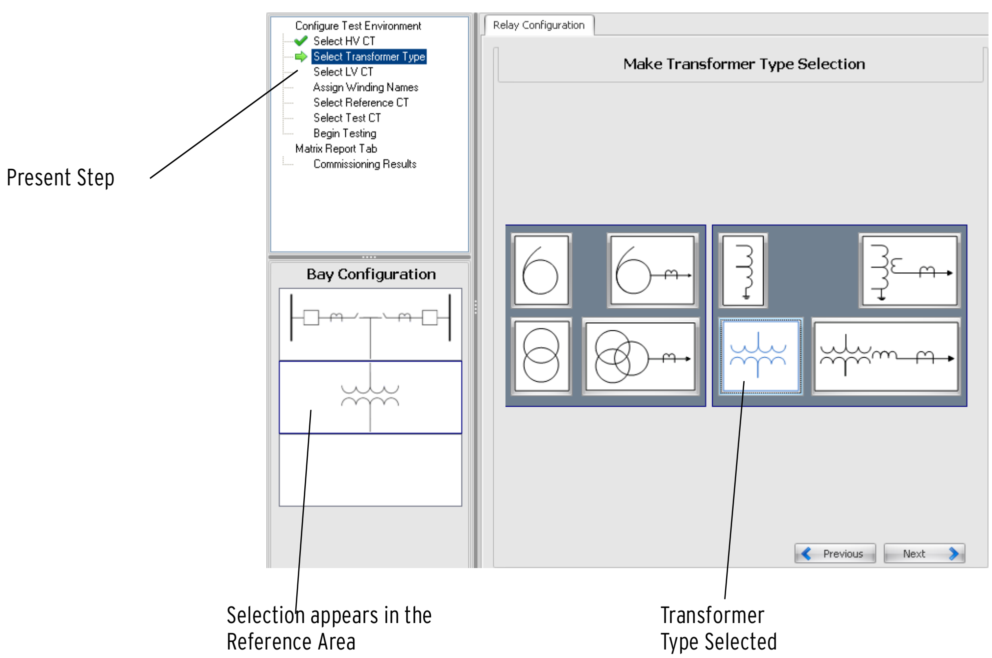


Figure 14.49 Transformer Type Selection

Click the **Next** button, and select the LV CT configuration as in *Figure 14.50*. This completes the configuration of the transformer bay.

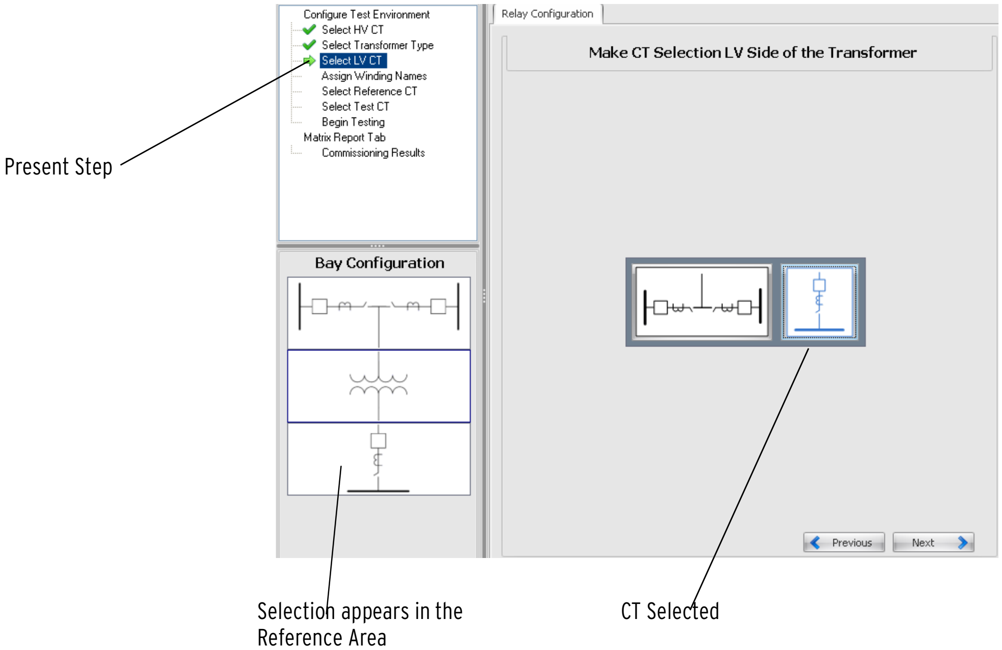


Figure 14.50 LV CT Selection

Click the **Next** button to move to the screen displayed in *Figure 14.50*. Because you can install the SEL-487E in widely varying substation configurations with differing CT allocations, the terminals and CTs are not fixed. Therefore, you must associate a terminal with each CT.

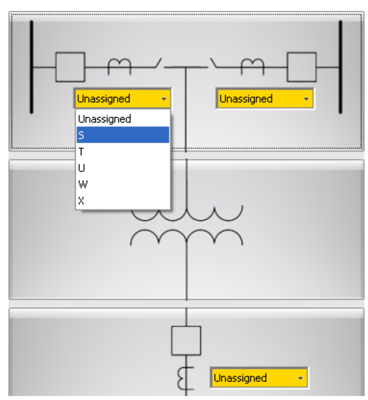


Figure 14.51 CT S Assignment

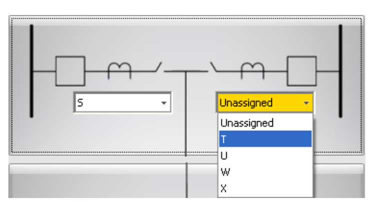


Figure 14.52 CT T Assignment

Make sure you assign the CTs to match the wiring of each terminal. Assume the following for this example:

- ➤ Terminal S: HV left-hand CT (CT1 in *Figure 14.46*)
- ➤ Terminal T: HV right-hand CT (CT2 in *Figure 14.46*)
- ➤ Terminal U: LV CT (CT3 in *Figure 14.46*)

Figure 14.51 shows the screen that appears after you click in the box below CTS. All five windings are available at this point. Move the cursor down to **S** and left-click the mouse.

Click on the box below CTT, as shown in *Figure 14.52*. Notice that, because S is already assigned, only T, U, W, and X are available. Move the cursor down to **T** and left-click the mouse.

If you want to re-assign an already assigned winding, first unassign the winding (*Figure 14.53*), then choose from the available windings.

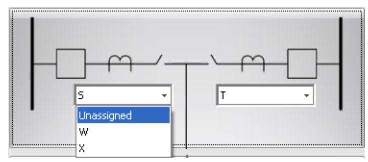


Figure 14.53 Unassign Winding S

In a similar way, assign Terminal U to the LV CT (CTU), as shown in *Figure 14.54*.

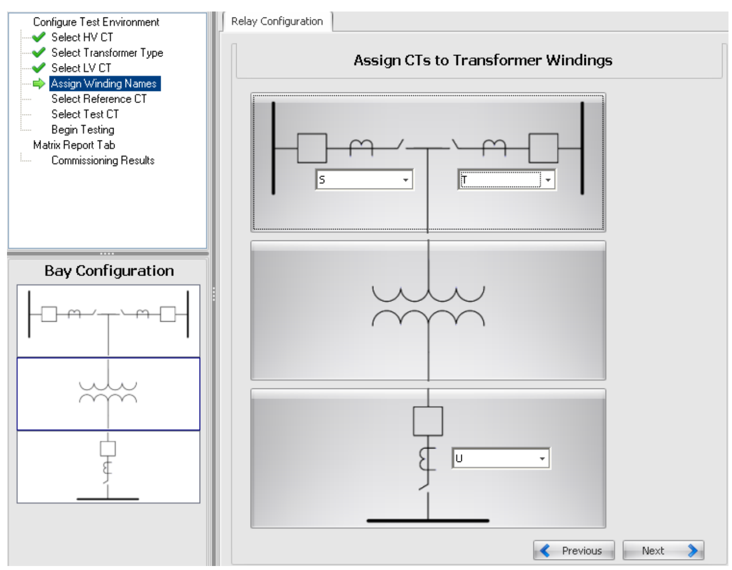


Figure 14.54 Completed CT Assignment

The final step in the configuration process is to choose a reference winding and a test winding. For example, arbitrarily select **Winding S** as reference and **Winding U** as test. *Figure 14.55* shows the selection of S as reference winding. Notice that the text "Reference Winding S" appears below CTS.

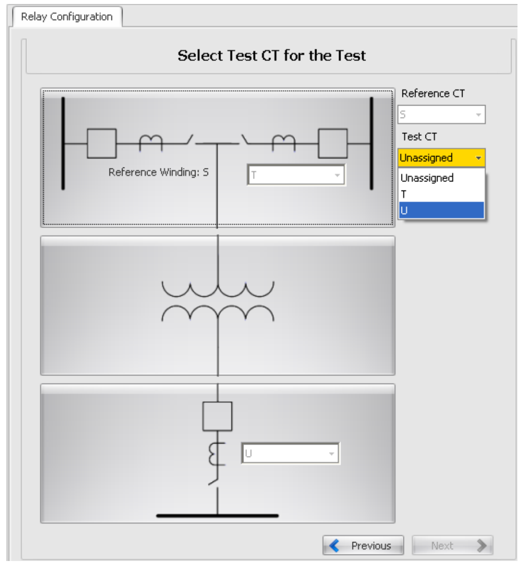


Figure 14.55 Selection of S as Reference Winding

After assigning Winding U as test winding, click **Next** to move to the screen shown in *Figure 14.56*. Notice that the text "Test Winding U" appears next to CT U.

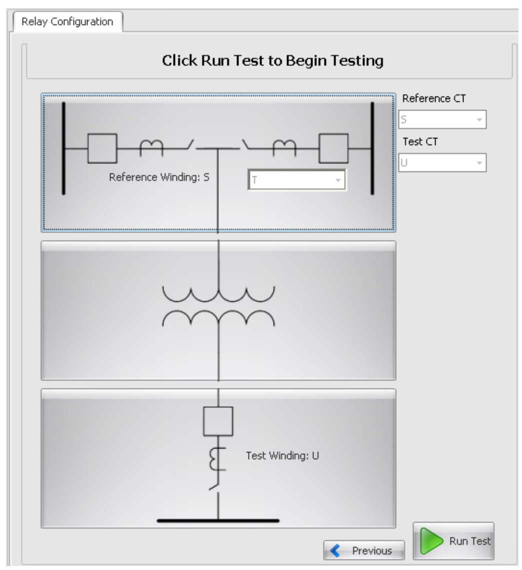


Figure 14.56 Ready to Run the Test

Because Commissioning Assistant allows only two windings per test, open Breaker 52-2 and the disconnect to ensure that no current flows through CTT. *Figure 14.57* shows the correct flow of current for this test.

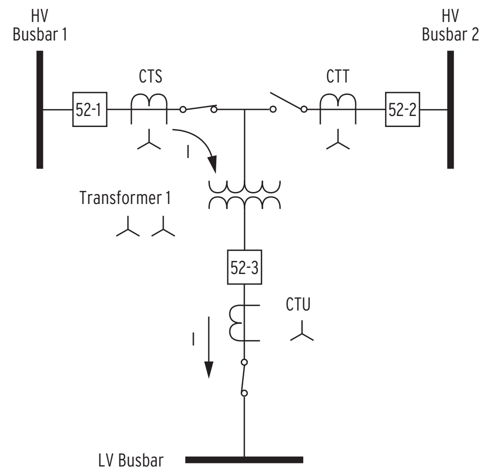


Figure 14.57 Current Flow Through CTS and CTU Only

After clicking the **Run Test** button, the message shown in *Figure 14.58* appears. Commissioning Assistant uses the voltage ratio to calculate certain quantities, so please ensure that the transformer is on the nominal tap. Nominal tap is where the transformer turns ratio equals the system voltage ratio.

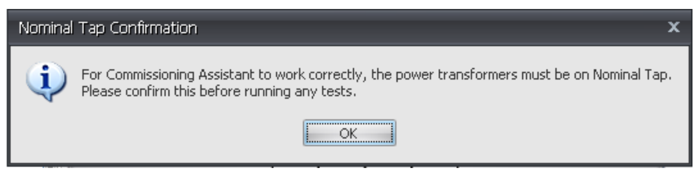


Figure 14.58 Nominal Tap Position Reminder

After clicking on the **OK** button, the screen with communication parameters (*Figure 14.59*) appears. Select the correct values and click **OK**.

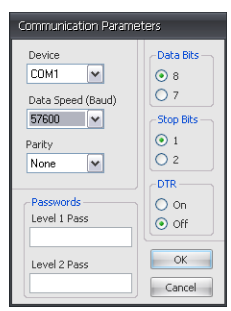


Figure 14.59 Communication Parameters

IMPORTANT: Commissioning Assistant does not report a matrix setting of 0. In all cases, a matrix setting of 0 is reported as 12. This includes reporting a present setting of 0 as 12 in the commissioning report.

Click on **Run Test** to start the matrix calculation process. Commissioning Assistant now reads selected information from the relay using ASCII **MET** commands.

Commissioning Assistant first performs two current checks: Check 1 ensures that more than five percent of the full load current flows in both Terminal S and Terminal U; Check 2 ensures that no current flows in Terminal T. If either check fails, the relay reports the error and aborts the test, as in *Figure 14.60*.

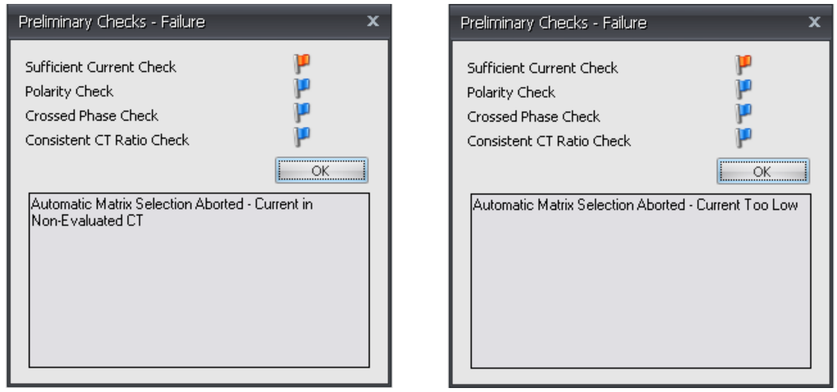


Figure 14.60 Current in Non-Evaluated CT and Current Too Low Error Screens

Commissioning Assistant then tests for the following before calculating the matrix for the test winding (also see *Table 14.1*):

- ➤ Correct polarities
- ➤ Consistent CT ratio
- ➤ Two crossed phases

If the installation fails any of these wiring tests, Commissioning Assistant flags the error and aborts the test. For example, assume that the B-phase HV CT has an incorrect polarity. Commissioning Assistant finds this error and specifies the offending CT. *Figure 14.61* shows the error messages for the three wiring checks.

- ➤ Green—passed
- ➤ Red—failed
- ➤ Blue—not tested yet

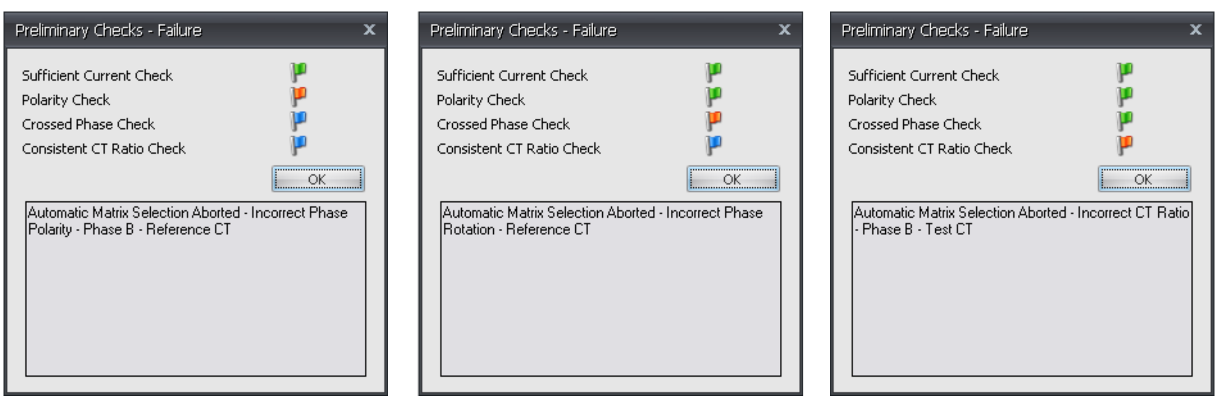


Figure 14.61 Failed Wiring Checks

If the relay passes the wiring tests, Commissioning Assistant calculates the matrix for the test winding. Using the present settings in the relay, Commissioning Assistant assigns the existing matrix setting to the reference winding. Assume that the following are the present compensation settings in the relay:

- ➤ TSCTC = 11
- ➤ TTCTC = 12
- ➤ TUCTC = 10

With a wye/wye connected transformer and all CTs connected in wye, these settings are clearly wrong. For the differential elements to balance, all compensation settings must have the same value: all set to 11, 12, or 10. Because Commissioning Assistant uses the present settings for the reference terminal (11 in this case since Terminal S is the reference), all compensation settings must equal 11. For the first test (testing Terminal S and Terminal U), Commissioning Assistant must therefore calculate a matrix value of 11 for Terminal U. *Figure 14.62* shows the report of the first test, with the expected result.

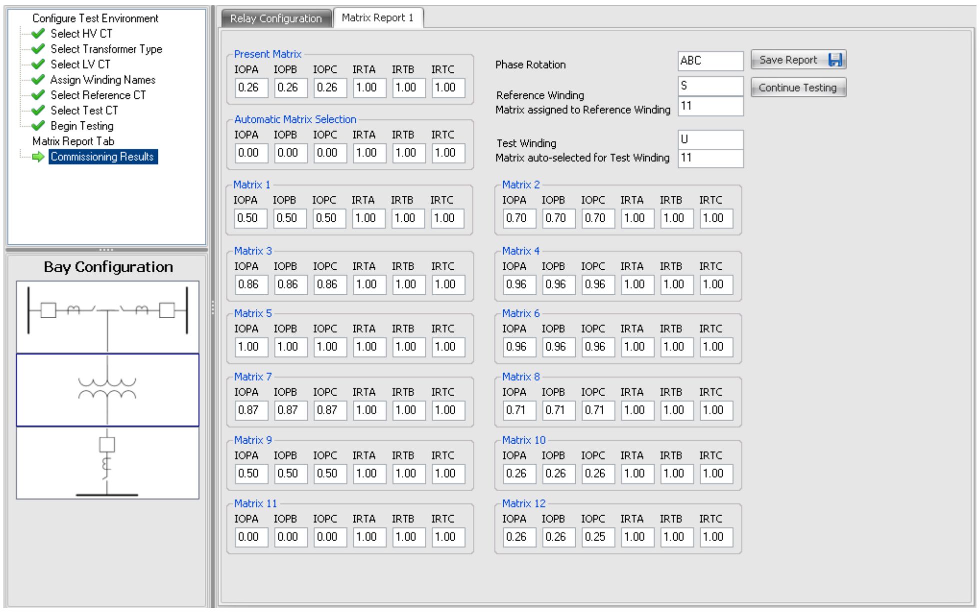


Figure 14.62 Results of Testing Terminal S and Terminal U

The report shows the relevant information for this test:

- Operate and restraint current with the present settings
- Operate and restraint current with the calculated matrix
- Phase rotation
- Matrix number of the reference winding
- Calculated matrix number of the test winding
- Results of all other matrix combinations

Click on **Save Report** to save the report to your hard drive or to any other convenient location, then click on Continue Testing to also test Terminal T. For subsequent tests, any qualified winding can be used as reference. Qualified windings are windings that have already been successfully matched with matrices that produce (almost) zero differential current. In this case, either Winding S or Winding U are qualified windings, but not Winding T. For the next test, assign Terminal U as reference winding and Terminal T as test winding, as shown in *Figure 14.63*.

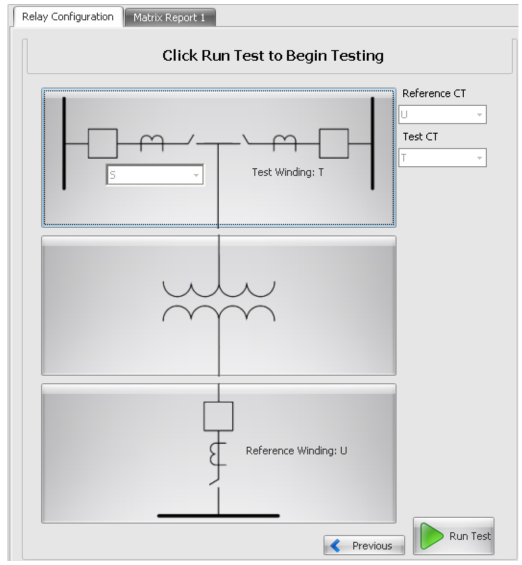


Figure 14.63 Assign Terminal U as Reference Winding and Terminal T as Test Winding

For this test, be sure that current flows only in Terminal T and Terminal U, as shown in *Figure 14.64*.

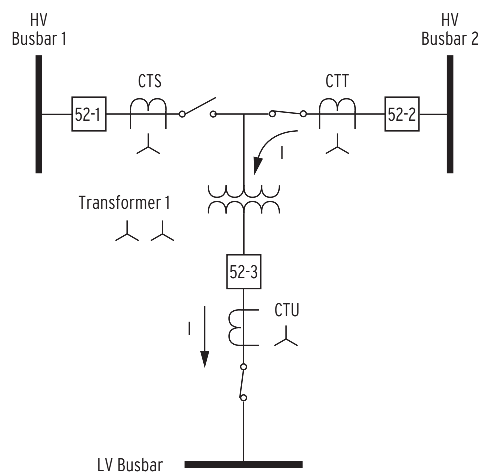


Figure 14.64 Current Flow Through CTT and CTU Only

Follow the steps described in Test 1. As with Test 1, the correct matrix number for Terminal T is 11, as shown in *Figure 14.65*.

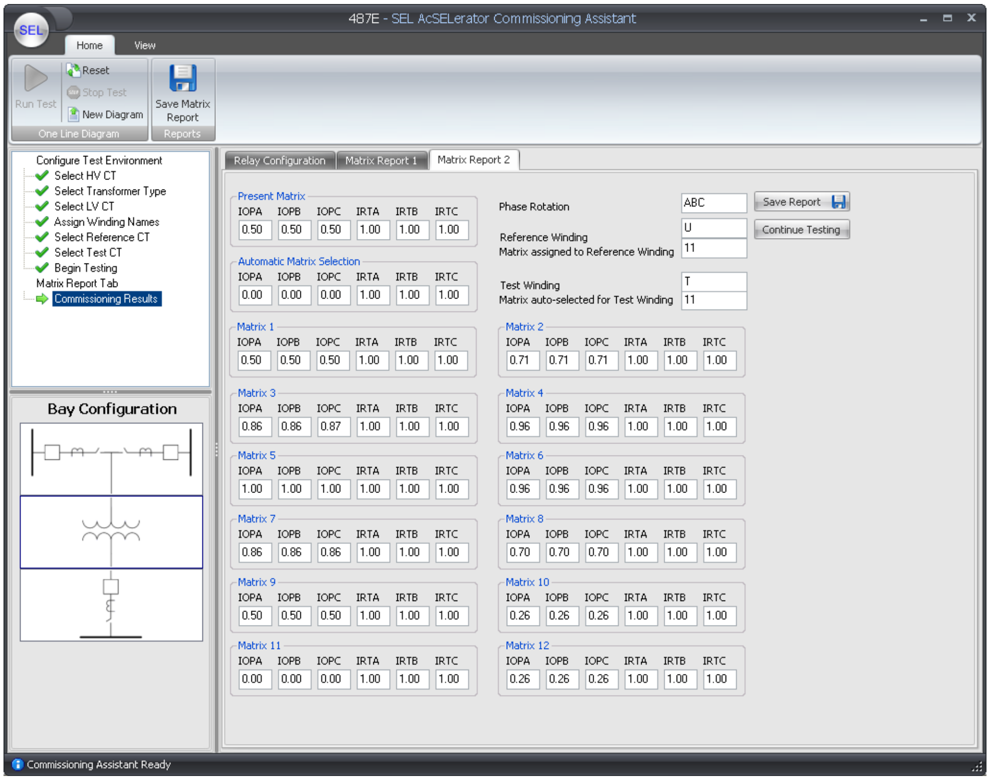


Figure 14.65 Results of Testing Terminal S and Terminal T

Be sure to save all test results. After you save these results, the screen shown in *Figure 14.66* appears. Click on **No** to conclude the tests.

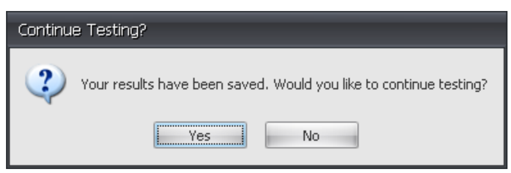


Figure 14.66 Conclusion of the Testing

Relay Self-Tests

The SEL-487E continuously runs many self-tests to detect out-of-tolerance conditions. These tests run simultaneously with relay protection and automation logic without degrading SEL-487E performance.

Status Warning and Status Failure

The relay reports out-of-tolerance conditions as a status warning or status failure. For conditions that do not compromise relay protection, yet are beyond expected limits, the relay issues a status warning and continues to operate. A severe out-of-tolerance condition causes the relay to declare a status failure and enter a protection-disabled state. During a protection disabled state, the relay suspends protection element processing and trip logic processing and de-energizes all control outputs. When disabled, the front-panel **ENABLED** LED is not illuminated. The relay signals a status warning by pulsing the HALARM Relay Word bit (hardware alarm) to logical 1 for five seconds. For a status failure, the relay latches the HALARM Relay Word bit at logical 1.

To provide remote status indication, connect the b contact of OUT108 to your control system remote alarm input and program the output SELOGIC control equation to respond to NOT (SALARM OR HALARM). See *Alarm Output on page 2.26* for information on connecting this alarm output for the SEL-487E.

If you repeatedly receive status warnings, check relay operating conditions as soon as possible. Take preventive action early during the development of potential problems to avoid system failures. For any status failure, contact your Technical Service Center or the SEL factory immediately (see *Factory Assistance on page 14.65*).

The relay generates an automatic status report at the serial ports for a self-test status failure if you set Port setting AUTO := Y. The relay issues a status message with a format identical to the **STATUS** command output, but includes the power supply information from the STA A response. The relay also displays status warning and status failure automatic messages on the front-panel LCD. Use the serial port **STATUS** and **CSTATUS** commands and the front-panel RELAY STATUS menu to display status warnings and status failures. See *STATUS on page 13.46* for more information on automatic status notifications and on viewing relay status.

Status

Figure 14.67 is the **STATUS A** report showing all status information obtained with terminal emulation software.

Firmware Version Number

At the top of each status report, the relay displays the present firmware version number that identifies the software program that controls relay functions. The firmware version is the four-place designator immediately following the relay model number (the first characters in the firmware identification string). The first character in the four-place firmware version number is R (representing Release). For example, in *Figure 14.67*, the firmware version number is R100. SEL numbers subsequent firmware releases sequentially; the next revision following R100 is R101. See *Appendix A: Firmware and Manual Versions* for firmware version information.

```
=>>STA A <Enter>
Relay 1                                    Date: 04/12/2008  Time: 07:36:34.40
Station A                                  Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080328      CID=0x2ac1

Failures
  No Failures

Warnings
  A/D OFFSET WARNING
  CAL BOARD A CHANGED FROM     13 TO absent
  CAL BOARD B CHANGED FROM     13 TO absent


Channel Offsets (mV)   W=Warn    F=Fail
  CH1  CH2  CH3  CH4  CH5  CH6  CH7  CH8  CH9 CH10 CH11 CH12  MOF
   -8   -7   -7   38W  60W  66W  -8   61W  -8   -8   -8   30W  -5
 CH13  CH14  CH15  CH16  CH17  CH18  CH19  CH20  CH21  CH22  CH23  CH24  MOF2
   61W   66W   -8    67W   -6    -6    -9    36W   61W   69W   -7    36W   -7

Power Supply Voltages (V)   W=Warn    F=Fail
  3.3V_PS  5V_PS  N5V_PS  15V_PS   N15V_PS
     3.27   4.98   -5.07   14.95    -15.18

Temperature
   35.3 degrees Celsius

Communication Interfaces

Active High Accuracy Time Synchronization Source: NONE
  IRIG-B Source ABSENT
SELOGIC Relay Programming Environment Errors
 No Errors
Relay Enabled

=>>
```

Figure 14.67 Relay Status Information Obtained With the STATUS A Serial Port Command

CSTATUS

The relay reports status information in Compressed ASCII format when you issue the **CST** command. The Compressed ASCII status message is similar to the following:

```
=>>CSTA <Enter>
"RID","SID","FID","03e2"
"Relay 1","Station A","SEL-487E-R100-V0-Z001001-D20080328","0e5c"
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0ACA"
4,12,2008,7,37,45,886,"0445"
"CPU_RAM","CPU_PROG","SELBOOT","CPU_SET","DSP_RAM","DSP","DSP_CSUM","DSP_T_OUT",
"CPUCRD_RAM","CPUDSP_RAM","FRNT_PNL","CAL_BOARDA","CAL_BOARDB","CCRD_CHG","COMM_
CARD","CCRD_CODE","ANA_CONV","IO_1","IO_2","343D"
"Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok","W","W","Ok"," "," ","Ok"
,"Ok","Ok","1424"
"ATOD_OFFST","MSTR_OFFST","MSTR_OFST2","3.3V_PS","5V_PS","N5V_PS","15V_PS","N15V
_PS","TEMP_STA","TEMP","PRT_O_LOAD","LCD_ERROR","FPGA","22C1"
"W","Ok","Ok","Ok","Ok","Ok","Ok","Ok","Ok",35.3,"Ok","Ok","Ok","0E8A"
"MBA","MBB","ACTTIM_SRC","SELOG_MATH","FM_TEST","CCRD_TEST","DNP_TEST","RLY_STA"
,"PRT_F_TP","PRT_1_TP","PRT_2_TP","PRT_3_TP","PRT_5_TP","23D2"
"Inac","Inac"," ","Ok","Disabled","Disabled","Disabled","Enabled","0","0","0","0
","0","1663"

=>>
```

Figure 14.68 Relay Status Information Obtained With the CSTATUS Serial Port Command

Relay Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the SEL-487E. After you finish the inspection, proceed to *Troubleshooting Procedures*.

Step 1. Confirm that power is on.

Do not turn the relay off

Step 2. Measure and record the ac power supply voltage at the relay **POWER** terminals marked + and - on the rear-panel terminal strip.

Step 3. Measure and record the voltages at all control inputs.

Step 4. Measure and record the state of all control outputs.

Step 5. Inspect the serial communications ports cabling to be sure that a communications device is connected to at least one communications port.

Troubleshooting Procedures

Troubleshooting procedures for common problems are listed in *Table 14.31*. The table lists each symptom, possible causes, and corresponding diagnoses/solutions. Related SEL-487E commands are listed in bold capitals. See *Section 13: ASCII Command Reference* for details on SEL-487E commands and *Section 6: Settings* for details on relay settings.

Table 14.31 Troubleshooting Procedures (Sheet 1 of 3)

Possible Cause	Diagnosis/Solution
Dark Front Panel	
Power is off.	Verify that substation battery power is operational.
Input power is not present.	Verify that power is present at the rear-panel terminal strip.
Blown power supply fuse.	Replace the fuse. See *Power Supply Fuse Replacement on page 2.24*.
Poor contrast adjustment.	Press and hold **{ESC}** for two seconds. Press **{Up Arrow}** and **{Down Arrow}** pushbuttons to adjust contrast.
Status Failure Notice on Front Panel	
Self-test failure.	Contact the SEL factory or your Technical Service Center. The OUT108 relay control output b contacts will be closed if you programmed NOT HALARM to OUT108, see *Alarm Output on page 2.26*.
Alarm Output Asserts	
Power is off.	Restore power.
Blown power supply fuse.	Replace the fuse. See *Power Supply Fuse Replacement on page 2.24*.
Power supply failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
Main board or interface board failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.

Table 14.31 Troubleshooting Procedures (Sheet 2 of 3)

Possible Cause	Diagnosis/Solution
Other self-test failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
System Does Not Respond to Commands	
No communication.	Confirm cable connections and types. If OK, type **<Ctrl+X>**, then **<Enter>**.This resets the terminal program.
Communications device is not connected to the system.	Connect a communications device.
Incorrect data speed (baud rate) or other communications parameters.	Configure your terminal port parameters to the particular relay port settings. Use the front panel to check port settings. See *SET/SHOW on page 8.27*.
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications. See *Communications Ports Connections on page 2.28*.
Communications cabling error.	Check cable connections.
Handshake line conflict; system is attempting to transmit information, but cannot do so.	Check communications cabling. Use SEL communications cables, or cables you build according to SEL specifications. See *Communications Ports Connections on page 2.28*.
System is in the XOFF state, halting communications.	Type **<Ctrl+Q>** to put the system in the XON state.
Terminal Displays Meaningless Characters	
Data speed (baud rate) is set incorrectly.	Check the terminal parameters configuration. See *Communications Ports Connections on page 2.28*.
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Faults	
Relay is set improperly.	Review the relay settings.
Improper test settings.	Restore operating settings.
PT or CT connection wiring error.	Confirm PT and CT wiring.
Input voltages and currents phasing, and rotation errors.	Use relay metering. Use the **TRI** event trigger command and examine the generated event report. See *Examining Metering Quantities*.
The analog input (flat multipin ribbon) cable between the input module board and the main board is loose or defective.	Reseat both ends of the analog input cable, observing proper ESD precautions. See *Installing Optional I/O Interface Boards on page 2.11*.
Check the relay self-test status.	Take preventive action as directed by relay STATUS WARNING and STATUS FAILURE information. See *Relay Self-Tests on page 14.59* and *Checking Relay Status*.

Table 14.31 Troubleshooting Procedures (Sheet 2 of 3)

Possible Cause	Diagnosis/Solution
Other self-test failure.	LCD displays STATUS FAILURE screen. Contact the SEL factory or your Technical Service Center.
System Does Not Respond to Commands	
No communication.	Confirm cable connections and types. If OK, type **<Ctrl+X>**, then **<Enter>**.This resets the terminal program.
Communications device is not connected to the system.	Connect a communications device.
Incorrect data speed (baud rate) or other communications parameters.	Configure your terminal port parameters to the particular relay port settings. Use the front panel to check port settings. See *SET/SHOW on page 8.27*.
Incorrect communications cables.	Use SEL communications cables, or cables you build according to SEL specifications. See *Communications Ports Connections on page 2.28*.
Communications cabling error.	Check cable connections.
Handshake line conflict; system is attempting to transmit information, but cannot do so.	Check communications cabling. Use SEL communications cables, or cables you build according to SEL specifications. See *Communications Ports Connections on page 2.28*.
System is in the XOFF state, halting communications.	Type **<Ctrl+Q>** to put the system in the XON state.
Terminal Displays Meaningless Characters	
Data speed (baud rate) is set incorrectly.	Check the terminal parameters configuration. See *Communications Ports Connections on page 2.28*.
Terminal emulation is not optimal.	Try other terminal types, including VT-100 and VT-52 terminal emulations.
System Does Not Respond to Faults	
Relay is set improperly.	Review the relay settings.
Improper test settings.	Restore operating settings.
PT or CT connection wiring error.	Confirm PT and CT wiring.
Input voltages and currents phasing, and rotation errors.	Use relay metering. Use the **TRI** event trigger command and examine the generated event report. See *Examining Metering Quantities*.
The analog input (flat multipin ribbon) cable between the input module board and the main board is loose or defective.	Reseat both ends of the analog input cable, observing proper ESD precautions. See *Installing Optional I/O Interface Boards on page 2.11*.
Check the relay self-test status.	Take preventive action as directed by relay STATUS WARNING and STATUS FAILURE information. See *Relay Self-Tests on page 14.59* and *Checking Relay Status*.

Table 14.31 Troubleshooting Procedures (Sheet 3 of 3)

Possible Cause	Diagnosis/Solution
Tripping Output Relay Remains Closed Following a Fault	
Auxiliary contact control inputs are improperly wired.	Check circuit breaker auxiliary contacts wiring.
Control output relay contacts have burned closed.	Remove relay power. Remove the control output connection. Check continuity; a contacts will be open and b contacts will be closed. Contact the SEL factory or your Technical Service Center if continuity checks fail.
I/O interface board failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Warning	
Power supply voltage(s) are out-of-tolerance.	Log the `STATUS WARNING`. If repeated warnings occur, take preventive action.
A/D converter failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
Power Supply Voltage Status Failure	
Power supply voltage(s) are out-of-tolerance.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
A/D converter failure.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.
A/D OFFSET WARN Status Warning	
Loose ribbon cable between the input module board and the main board.	Reseat both ends of the analog input cable.
A/D converter drift.	Log the `STATUS WARNING`. If repeated warnings occur, contact the SEL factory or your Technical Service Center.
Master offset drift.	LCD displays `STATUS FAILURE` screen. Contact the SEL factory or your Technical Service Center.

Maintenance Testing

When: At regularly scheduled intervals, or when there is an indication of a problem with the relay or system.

Goals:

- ➤ Ensure that the relay is measuring ac quantities accurately.
- ➤ Ensure that scheme logic and protection elements are functioning correctly.
- ➤ Ensure that auxiliary equipment is functioning correctly.

What to test: Anything not shown to have operated during an actual fault within the past maintenance interval. SEL relays use extensive self-testing capabilities and feature detailed metering and event reporting functions that lower utility dependence on routine maintenance testing.

Use the SEL relay reporting functions as maintenance tools. Periodically verify that the relay is making correct and accurate current and voltage measurements by comparing the relay METER output to other meter readings on that line. Review relay event reports in detail after each fault.

Using the event report current, voltage, and relay element data, you can determine that the relay protection elements are operating properly. Using the event report input and output data, you can determine that the relay is asserting outputs at the correct instants and that auxiliary equipment is operating properly. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

The basis of this testing philosophy is simple: If the relay is correctly set and connected, is measuring properly, and no self-test has failed, there is no reason to test it further. Each time a fault occurs, the protection system is tested. Use event report data to determine areas requiring attention. Slow breaker auxiliary contact operations and increasing or varying breaker operating time can be detected through detailed analysis of relay event reports.

Because SEL relays are microprocessor based, their operating characteristics do not change over time. Time-overcurrent and current differential element operating times are affected only by the relay settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

At SEL, we recommend that maintenance tests on SEL relays be limited under the guidelines provided above. The time saved may be spent analyzing event data and thoroughly testing those systems that require more attention.

Factory Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 USA
Telephone: +1.509.332.1890
Fax: +1.509.332.7990
Internet: www.selinc.com
Email: info@selinc.com

SEL-487E Relay Commissioning Test Worksheet

System Information

System Settings

RID (Relay identification) =										
TID (Terminal identification) =										
MVA (Maximum transformer Rating) =										
	Winding S		**Winding T**		**Winding U**		**Winding W**		**Winding X**	
Current transformer connection:	CTCONS =		CTCONT =		CTCONU =		CTCONW =		CTCONX =	
Current transformer ratio:	CTRS =		CTRT =		CTRU =		CTRW =		CTRX =	
Connection compensation:	TSCTC =		TTCTC =		TUCTC =		TWCTC =		TXCTC =	
Nominal line-to-line voltage (kV):	VTERMS=		VTERMT=		VTERMU=		VTERMW=		VTERMX=	
TAP calculation:	TAPS =		TAPT =		TAPU =		TAPW =		TAPX =	

Differential Settings

087P =		SLP1 =		SLP2 =		U87P =	

Metered Load (Data taken from substation panel meters, not the SEL-487E)

± Readings from meters	**Winding S**		**Winding T**		**Winding U**		**Winding W**		**Winding X**	
Megawatts:	MWS =		MWT =		MWU =		MWW =		MWX =	
Megavars:	MVARS =		MVART =		MVARU =		MVARW =		MVARX =	
MVA calculation:	MVAS =		MVAT =		MVAU =		MVAW =		MVAX =	

MVA calculation:

$$\mathrm{MVAn} = \sqrt{\mathrm{MWn}^2 + \mathrm{MVARn}^2}$$

Calculated Relay Load

	Winding S		Winding T		Winding U		Winding W		Winding X	
Primary Amperes calculation:	ISpri =		ITpri =		IUpri =		IWpri =		IXpri =	
Secondary Amperes calculation:	ISsec =		ITsec =		IUsec =		IWsec =		IXsec =	

Primary Amperes calculation:

$$\mathrm{Inpri} = \frac{\mathrm{MVAn} \bullet 1000}{\sqrt{3} \bullet \mathrm{VTERMn}}$$

Secondary Amperes calculation:

$$\mathrm{CTCONn} = \mathrm{Y}, \mathrm{In\ sec} = \frac{\mathrm{Inpri}}{\mathrm{CTRn}}$$

$$\mathrm{CTCONn} = \mathrm{D}, \mathrm{In\ sec} = \frac{\mathrm{Inpri} \bullet \sqrt{3}}{\mathrm{CTRn}}$$

Connection Check

System load conditions should be higher than 0.1 A secondary. 0.5 A secondary is recommended for the best results.

Differential Connection (issue MET DIF <Enter> to serial port or front panel)

Operate Current:	IOPA =		IOPB =		IOPC =	
Restraint Current:	IRTA =		IRTB =		IRTC =	
Mismatch Calculation:	MMA =		MMB =		MMC =	

Check individual current magnitudes, phase angles, and operate and restraint currents in an event report if mismatch is not less than 0.10.

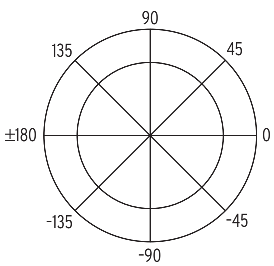
Mismatch Calculation:

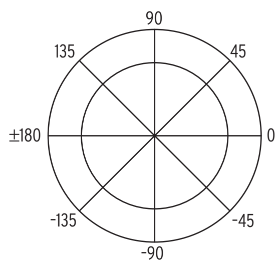
$$\mathrm{MMn} = \frac{\mathrm{IOPn}}{\mathrm{IRTn}}$$

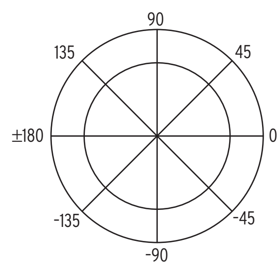
Magnitude, Angle, and Phase Rotation Check

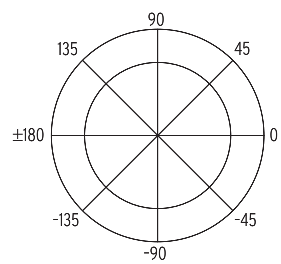
Issue **MET SEC <Enter>** to the serial port or front panel.

	Winding S		Winding T		Winding U		Winding W		Winding X	
A-Phase Secondary Amperes:	IAWS =		IAWT =		IAWU =		IAWW =		IAWX =	
A-Phase Angle:										
B-Phase Secondary Amperes:	IBWS =		IBWT =		IBWU =		IBWW =		IBWX =	
B-Phase Angle:										
C-Phase Secondary Amperes:	ICWS =		ICWT =		ICWU =		ICWW =		ICWX =	
C-Phase Angle:										









1. Calculated relay amperes match MET SEC amperes?

2. Phase rotation is as expected for each winding?

3. Do angular relationships among windings correspond to expected results? (Remember that secondary current values for load current flowing out of a winding will be 180° out of phase with the reference phase position for that winding. The reason is that CT polarity marks normally face away from the transformer on all windings.)

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Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

To find the firmware revision number in your relay, view the status report using the serial port **STATUS** command. The status report displays the Firmware Identification (FID) label:

FID=SEL-487E-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx, or

FID=SEL-487E-x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

You can also view the FID label from the front panel. From the ROTATING DISPLAY front-panel screen, press the **{ENT}** pushbutton to advance to the MAIN MENU screen. Use the **{Down Arrow}** pushbutton to highlight the RELAY STATUS option, and press the **{ENT}** pushbutton. The FID label displays on the screen:

SEL-487E-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx, or

SEL-487E-x-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

In the FID label, the firmware revision number follows the R and the release date follows the D.

For example,

FID=SEL-487E-R102-V0-Z001001-D20080820

is firmware revision number 102, release date August 20, 2008.

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487E-R108-V0-Z003002-D20100118	➤ Added line CT normalization factors in the REF bypass initiate circuit (see *Figure 4.14: Logic Diagram* and *Figure 4.15: Algorithm That Performs the Directional Calculations).*	20100118
SEL-487E-R107-V0-Z003002-D20091216	➤ Changed the initializing values of the dc offset IIR filter from zero to calibrated values to avoid the 51 elements from asserting at power up when the RMS values are selected as the operating quantities.	20091216
SEL-487E-R106-V0-Z003002-D20090626	➤ Manual update only (see *Table A.4*).	20090915
SEL-487E-R106-V0-Z003002-D20090626	➤ Added ability to act as a client for up to two remote synchrophasor units. Time-align collected data with local data to permit control operations using this data. ➤ Corrected handling of DNP fault summary records when EVELOCK = 0.	20090626

Table A.1 Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-487E-R105-V0-Z002001-D20090617	➤ Improved power supply self-test accuracy to avoid false power supply warnings.	20090617
SEL-487E-R104-V0-Z002001-D20090205	➤ Added EPORT port setting so user can disable ports. ➤ Added MAXACC port setting so user can restrict maximum privileges on a port. ➤ Extended password length from 6 to 12 characters.	20090205
SEL-487E-R103-V0-Z001001-D20081008	➤ Ethernet card firmware (see *Table A.2*) and manual update only (see *Table A.4*).	20081022
SEL-487E-R103-V0-Z001001-D20081008	➤ Manufacturability improvement.	20081008
SEL-487E-R102-V0-Z001001-D20080820	➤ Initial version.	20080820

Table A.2 lists the Ethernet card firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.2 Ethernet Card Firmware Revision History

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2702-R110-V0-Z001001-D20090205 SLBT-2701-R103-V0-Z000000-D20080820	➤ Corrected issue that could cause the Ethernet card to fail under heavy DNP traffic. ➤ Improved security (see www.selinc.com/privacy.htm for details).	20090205
SEL-2702-R109-V0-Z001001-D20081022 SLBT-2701-R103-V0-Z000000-D20080820	➤ Updated IEC 61850 firmware to streamline MMS processing and improve TCP/IP connections. ➤ Improved security (see www.selinc.com/privacy.htm for details).	20081022
SEL-2702-R108-V0-Z001001-D20080729 SLBT-2701-R103-V0-Z000000-D20080820	➤ Initial version.	20080820

The optional Ethernet card must be paired with a compatible SEL-487E version. You may need to upgrade your SEL-487E firmware to access features in new versions of the Ethernet cards. *Table A.1* includes notes on SEL-487E modifications that support new features of the Ethernet cards.

To find the firmware revision number in your Ethernet card, first connect to the SEL-487E with the **ACC** command. View the FIDs with the **VERSION** command. Look for the Ethernet card Firmware Identification (FID) label in the response under Communications Card:

FID=SEL-2702-Rxxx-Vx-Zxxxxxx-Dxxxxxxxx

In the FID label, the 4 digits after "SEL" indicate which Ethernet card is installed. The firmware revision number follows the R and the release date follows the D.

For example,

SEL-2702-R108-V0-Z001001-D20080729

is for an SEL-2702 Ethernet card, firmware revision number 108, release date July 29, 2008.

Table A.3 lists current Ethernet card firmware versions with compatible SEL-487E versions.

Table A.3 Compatible SEL-487E and Ethernet Card Firmware Versions

SEL-487E Firmware	Ethernet Card Firmware
R102 or higher	R109 or higher

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.4 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.4 Instruction Manual Revision History (Sheet 1 of 2)

Revision Date	Summary of Revisions
20100118	Section 4 ➤ Modified *Figure 4.14: Logic Diagram*. Appendix A ➤ Updated for firmware version R108.
20091216	Appendix A ➤ Updated for firmware version R107.
20090915	Section 1 ➤ Added information regarding the SEL-487E-2 relay version in *Overview*. Section 4 ➤ Corrected equation in *Figure 4.85: A-Phase Open-Phase Detection Logic*.
20090626	Section 1 ➤ Modified accuracy descriptions of some elements in *Specifications*. Section 2 ➤ Removed references to 10BASE-FL card port option. Section 4 ➤ Modified defaults on settings in *Differential Element Operating Characteristics*. ➤ Expanded *SLP1, SLP2 (Restraint Slope Percentage)*. Section 8 ➤ Modified *Figure 8.40: Alarm Point Data Loss Screen*. Section 11 ➤ Added synchrophasor real-time control description throughout the section. Section 13 ➤ Added **COM RTC** command. ➤ Added **MET RTC** command. ➤ Added **RTC** command. Appendix A ➤ Updated for firmware version R106. Appendix G ➤ Added Relay Word bits related to synchrophasor real-time control. Appendix H ➤ Added analog quantities related to synchrophasor real-time control.
20090617	Appendix A Updated for firmware version R105.

Table A.4 Instruction Manual Revision History (Sheet 2 of 2)

Revision Date	Summary of Revisions
20090205	Section 7 ➤ Added EPORT and MAXACC port settings in table under PROTO. Section 13 ➤ Modified *Password* to reflect the extended password length from 6 to 12 characters. Section 14 ➤ Updated *Communications Ports Access Levels* to reflect added Access Level C. ➤ Updated *Table 14.5: SEL-487E Access Levels and Operator Functions* and *Table 14.6: SEL-487E Access Level Commands and Passwords*. ➤ Updated steps under *Passwords*. Appendix A ➤ Updated for firmware version R104. ➤ Updated Ethernet card firmware version R110.
20081022	Appendix A ➤ Updated Ethernet card firmware version R109.
20081008	Appendix A ➤ Updated for firmware version R103.
20080820	➤ Initial version.

Appendix B
Firmware Upgrade Instructions

Overview

This instruction accompanies the SEL-400 series firmware upgrade kit and will guide you through the process of upgrading the relay's firmware.

The following procedure steps will guide you through the upgrade process.

A. *Load the Upgrade Firmware on Your PC*

B. *Prepare the Relay*

C. *Save Settings and Other Data*

D. *Start SELBOOT*

E. *Download Existing Firmware to Your Computer*

F. *Upload New SELBOOT Firmware to the Relay*

G. *Upload New Firmware to the Relay*

H. *Download Existing Ethernet Card Firmware to the Host Computer*

I. *Upload New SELBOOT Firmware to the Ethernet Card*

J. *Upload New Firmware to the Ethernet Card*

K. *Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT*

L. *Check Relay Self-Tests*

M. *Verify Relay Settings*

N. *Verify IEC 61850 Operation (Optional)*

O. *Return the Relay to Service*

Required Equipment

You will need the following items before beginning the firmware upgrade process:

- ➤ Personal computer (PC)
- ➤ Terminal emulation software that supports Xmodem/CRC protocol
- ➤ SEL Cable C234A or equivalent
- ➤ Disk containing the firmware upgrade file(s) (included)
- ➤ Relay Firmware Upgrade Instructions (included)

Optional Equipment

These items help you manage relay settings and understand procedures in the relay upgrade process:

- ACSELERATOR QuickSet® SEL-5030 software program
- Appropriate SEL-400 series relay manual

Upgrade Procedure

These instructions assume you have a working knowledge of your PC terminal emulation software. In particular, you must be able to modify the serial communications parameters (data speed or baud rate, data bits, parity, and similar parameters), disable any hardware or software flow control in the computer terminal emulation software, select a transfer protocol (1K XMODEM, for example), and transfer files (send and receive binary files).

The programs (firmware) that run in the SEL-400 series relays and Ethernet cards reside in Flash memory. To load new firmware versions, follow these instructions. The SEL-400 series relays and Ethernet cards have two programs that you may need to upgrade: the regular, or "executable" program and the SELBOOT program.

The first step in the upgrade process is the upgrade of the firmware within the relay. The upgrade kit you received contains the firmware needed to upgrade the SEL-400 series relay. The kit may also contain firmware needed to upgrade the Ethernet card and SELBOOT program. See *Table B.1* to identify which firmware files you received in the upgrade kit.

Table B.1 Firmware Upgrade Files

Product	File Name	File Type
SEL-400 series relays SELBOOT	S*nnn*4*xx*.s19	SEL-400 series SELBOOT firmware (can be downloaded to an SEL-400 series relay).
SEL-400 series relays	R*nnn*4*xx*.s19	SEL-400 series relay firmware (can be downloaded to an SEL-400 series relay).
SEL-2702 Ethernet Processor	R*nnn*27*xx*.s19	SEL-2702 firmware (can be downloaded to an Ethernet card).
SEL-2702 SELBOOT	S*vvv*27*xx*.s19	SEL-2702 SELBOOT firmware (can be downloaded to an Ethernet card).

A Load the Upgrade Firmware on Your PC

Obtain the firmware from the Firmware Upgrade CD-ROM included in the firmware upgrade kit using either method described below.

a. Follow the instructions that appear after inserting the Firmware Upgrade CD-ROM into the computer's CD-ROM drive.

Or,

b. Copy the .s19 file from the Firmware Upgrade CD-ROM.

You can place the firmware on the Windows Desktop or put the upgrade firmware in a specific folder (e.g., C:\Firmware).

B Prepare the Relay

If the relay is in service, follow your company practices for removing a relay from service. Typically, these practices include disabling input and output control functions.

C Save Settings and Other Data

Enter Access Level 2

Step 1. Using the communications terminal, at Access Level 0 type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**, and then type the correct password to go to Access Level 2.

You will see the Access Level 2 =>> prompt.

For more information, see *Making an EIA-232 Serial Port Connection on page 14.6*.

View Passwords and FID

Step 1. Type **PAS <Enter>** at Access Level 2 to view relay passwords.

Note the original password settings in case you need these passwords later.

Step 2. Type **STA A <Enter>** to view the SEL-400 series relay and Ethernet card status and firmware identifier (FID). The results of a typical **STA A** command are shown in *Figure B.1*.

Note the FID identifier number(s) for use in *Step E on page B.5* and *Step M on page B.11* of this document.

```
=>>STA A <Enter>

Relay 1                                     Date: 05/08/2008  Time: 07:59:59.092
Station A                                   Serial Number: 2008030645

FID=SEL-487E-R100-V0-Z001001-D20080506      CID=0xe47c

Failures
  No Failures

Warnings
  No Warnings

Channel Offsets (mV)   W=Warn    F=Fail
  CH1  CH2  CH3  CH4  CH5  CH6  CH7  CH8  CH9 CH10 CH11 CH12  MOF
   -7   -7   -8   -7   -8   -7   -6   -6   -8   -7   -7   -8   -3
 CH13  CH14  CH15  CH16  CH17  CH18  CH19  CH20  CH21  CH22  CH23  CH24  MOF2
  -18   -17   -18   -17   -19   -17   -17   -17   -18   -17   -18   -18   -14

Power Supply Voltages (V)   W=Warn    F=Fail
  3.3V_PS  5V_PS  N5V_PS  15V_PS   N15V_PS
     3.31   4.95   -5.04   15.05    -15.17

Temperature
   37.9 degrees Celsius

Communication Interfaces
  Communications Card 1
   SEL-2702-R100-V2-Z001001-D20080409  Enet All
   Normal 0x0000
   Active virtual terminal sessions: 0

Active High Accuracy Time Synchronization Source: NONE
  IRIG-B Source ABSENT

SELogic Relay Programming Environment Errors
  No Errors

Relay Enabled


Relay Enabled
```

Figure B.1 Example Relay STA A Command Results

Backup Relay Settings

The relay preserves the settings and passwords during the firmware upgrade process. However, if relay power is interrupted during the firmware upgrade process, the relay can lose the settings. Make a copy of the original relay settings in case you need to reenter settings.

Use one of the following methods to backup relay settings.

➤ If you have not already saved copies of the relay settings, use ACSELERATOR QuickSet to read and save the relay settings.

  See *Create and Manage Relay Settings on page 3.10*.

➤ Alternatively, you can use the terminal to download all the relay settings.

  See the **FILE READ** command in *Section 13: ASCII Command Reference*.

  For file retrieval procedures see *Oscillography on page 10.7*, *Event Reports, Event Summaries, and Event Histories on page 10.11*, and *SER (Sequential Events Recorder) on page 10.30*.

D Start SELBOOT

Step 1. Establish/confirm binary transfer terminal communication.

Use a terminal program that supports 1K XMODEM transfer protocol to communicate with the relay (ACSELERATOR QuickSet does not provide binary transfer protocols).

Step 2. Prepare to control the relay at Access Level 2. If the relay is not already at Access Level 2, use the procedure in *Enter Access Level 2 on page B.3*.

Step 3. Start the relay SELBOOT program.

a. Type **L_D <Enter>**.

The relay responds with the following message:

`Disable relay to send or receive firmware (Y/N)?`

b. Type **Y <Enter>**.

The relay responds with the following message:

`Are you sure (Y/N)?`

c. Type **Y <Enter>**.

The relay responds with the following message:

`Relay Disabled`

Step 4. Wait for the SELBOOT program to load.

The front-panel LCD screen displays the SELBOOT R*xxx* firmware number (e.g., `SELBOOT R100`); R*xxx* is the SELBOOT revision number and is a different revision number from the relay firmware revision number. The LCD also displays the present relay firmware (e.g., `SEL-487E-R100`), and `INITIALIZING`.

When finished loading the SELBOOT program, the relay responds to the terminal with the SELBOOT `!>` prompt; the LCD shows the SELBOOT and relay firmware revision numbers.

Step 5. Press **<Enter>** to confirm that the relay is in SELBOOT; you will see another SELBOOT `!>` prompt.

Establish a High-Speed Serial Connection

Step 1. At the SELBOOT prompt, type **BAU 115200 <Enter>** (see *Figure B.2*).

Step 2. Set your terminal program for a data speed of 115200 bps.

Step 3. Press **<Enter>** to check for the SELBOOT `!>` prompt indicating that serial communication at 115200 bps is successful.

E Download Existing Firmware to Your Computer

Only follow this step if you want to save a backup copy of the existing relay firmware on your computer. If you do not need to perform this step, proceed to *Step G on page B.7*.

The PC needs approximately 10 MB of free disk space to store the relay firmware.

Step 1. Type **SEN <Enter>** to initiate the firmware transfer from the relay to the PC.

The relay responds as shown in *Figure B.2*.

Step 2. Select the **Receive File** function with **1K XMODEM** protocol in your terminal emulation software.

Step 3. Name the file with the R-number from the FID from *View Passwords and FID on page B.3* to clearly identify the firmware version (e.g., 487E_R100.s19).

Be sure to add the .s19 suffix.

Step 4. Start the terminal emulation software receive program.

Receiving firmware takes approximately 25 minutes at 115200 bps. The front-panel LCD shows `SENDING CODE`. After the transfer, the relay responds with the following message:

```
Transfer completed successfully
```

F Upload New SELBOOT Firmware to the Relay

NOTE: Loading the incorrect SELBOOT firmware to either the relay or Ethernet card may cause the relay to malfunction, requiring factory repair.

Upgrading SELBOOT firmware in SEL-400 series relays is typically not required as part of a normal relay firmware upgrade process. However, occasionally core functions of the relay are enhanced, and the SELBOOT firmware must be upgraded to enable the enhanced functions. If a SELBOOT upgrade for the relay is not indicated in your upgrade kit, skip this step, and continue on to *Step G*. Please note that there may also be SELBOOT upgrades for the Ethernet card of the relay. The Ethernet card uses a separate SELBOOT firmware file. See *Table B.1* for file names.

NOTE: Do not cycle power to the relay during the SELBOOT firmware upgrade process. Doing so may cause the relay to malfunction, requiring factory repair.

To begin the relay SELBOOT upgrade, start at the SELBOOT prompt `!>`.

Step 1. Type **REC BOOT** command at the SELBOOT prompt, and answer **Y** when prompted to erase the existing SELBOOT firmware.

```
!>REC BOOT

Caution! -  This command erases the SELboot firmware.
Are you sure you want to erase the existing firmware? (Y/N)
```

Step 2. After erasing the existing SELBOOT firmware, the relay will prompt to begin file transfer. Press any key to begin the file transfer to the relay.

Step 3. Using an Xmodem file transfer protocol, point the sending software tool to the relay SELBOOT file (S*nnn*4*xx*.s19) that is to be uploaded to the relay.

Upon successful negotiation of the new SELBOOT firmware file, the old SELBOOT software will be erased, and the new SELBOOT firmware will be written to the relay's Flash memory. SELBOOT will then automatically restart using the new SELBOOT firmware.

```
Erasing old SELboot

Writing new SELboot to flash

Press any key to begin transfer, then start transfer at the PCC
Restarting SELboot
```

Step 4. Once the relay has restarted in SELBOOT, the SELBOOT !> prompt will appear in the terminal window. Remain in SELBOOT and continue to *Step G* of this procedure.

G Upload New Firmware to the Relay

Step 1. From the SELBOOT !> prompt, type **REC <Enter>**.

The relay responds with the prompt shown in *Figure B.2*. The end of the relay response is

`Are you sure you want to erase the existing firmware? (Y/N)`

Step 2. Type **Y <Enter>**.

The relay responds, `Erasing`, and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay responds, `Erase successful`, and prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

```
!> BAU 115200 <Enter>
!> <Enter>
!>SEN <Enter>

Program is ready to be transmitted.
Begin transfer at PC.
Transfer completed successfully.

!>REC <Enter>
Caution! - This command erases the device firmware.
If you erase the firmware, new firmware must be loaded into the device
before it can be put back into service.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing

Erase successful
Press any key to begin transfer, then start transfer at the PCCC <Enter>
```

Figure B.2 Transferring New Firmware

NOTE: The relay displays one or more "C" characters while waiting for your PC terminal emulation program to send the new firmware. If you do not start the transfer quickly (within about 18 seconds), the relay times out and responds `Remote system is not responding`. If this happens, begin again at Step G on page B.7.

Step 3. Press **<Enter>** to begin uploading the new firmware.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K XMODEM for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19).

Step 6. Begin the file transfer.

The usual transfer time at 115200 bps with 1K XMODEM is about 25 minutes. The LCD screen shows `SELBOOT Rxxx LOADING CODE` while the relay loads the new firmware.

NOTE: The relay restarts in SELBOOT if relay power fails while receiving new firmware after the old firmware is erased. At power-up, the relay defaults to a data speed of 9600 bps. Continue the upgrade procedure beginning at Establish a High-Speed Serial Connection on page B.5 to increase the serial connection data speed. Then continue the firmware upgrade process again at Step G on page B.7.

Step 7. Wait for firmware load completion.

When finished loading the new firmware, the relay responds, `Transfer completed successfully` and displays the SELBOOT `!>` prompt. The LCD screen displays `SELBOOT Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELBOOT revision number, *xx* is the particular model of the SEL-400 series relays being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-487E-R105.

H Download Existing Ethernet Card Firmware to the Host Computer

Only follow this step if you want to save a backup copy of the existing SEL-2702 Ethernet Processor firmware on your computer. If you do not need to perform this step, proceed to *Step J on page B.10*.

The PC needs approximately 4 MB of free disk space to store the Ethernet card firmware.

Step 1. From the relay SELBOOT prompt `!>` type **SEN 5 <Enter>** to initiate the firmware transfer from the Ethernet card to the PC.

The relay responds as shown in *Figure B.3*.

Step 2. Select the **Receive File** function with **1K XMODEM** protocol in your terminal emulation software.

Step 3. Name the file with the R-number of the FID from *View Passwords and FID on page B.3* to clearly identify the firmware version (e.g., 2702_R100.s19).

Be sure to add the .s19 suffix.

Step 4. Start the terminal emulation software receive program.

Receiving firmware takes approximately 10 minutes at 115200 bps. The front-panel LCD shows `SENDING CODE`. After the transfer, the relay responds with the following message:

`Transfer completed successfully`

IMPORTANT: When the Ethernet card is part of a relay upgrade, you **must** stay in SELBOOT for the entire upgrade process (relay and Ethernet card). Exiting SELBOOT at any point other than Step K (Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT) during the upgrade process may cause the relay to reset to an incorrect part number.

```
!>SEN 5 <Enter>
Program is ready to be transmitted.
Begin transfer at PC from card.
```

Figure B.3 Sending Ethernet Card Firmware to the Host Computer

I Upload New SELBOOT Firmware to the Ethernet Card

Some upgrades of the Ethernet card require an upload of a new version of the SEL-2701 or SEL-2702 SELBOOT firmware. Refer to the SEL-400 Series Relays Upgrade and Conversion Paths document found on the upgrade CD-ROM to determine if your relay needs new SELBOOT firmware. If your relay does not need new SELBOOT firmware, proceed to *Step J on page B.10*. The following steps describe how to complete this operation. Note that it is important that power be maintained continuously to the relay during this process.

Upgrade Warning

SEL-2701 firmware releases prior to R108 are not compatible with the SEL-2701 SELBOOT version R102. A `SLBT FAIL` (Hex 0x0004) message will appear if a **STA <Enter>** command is issued as shown in *Step M on page B.11*. If the `SLBT FAIL` message is shown after the **STA** command is issued, contact SEL for assistance.

Step 1. While still in SELBOOT, type **REC BOOT 5 <Enter>** at the SELBOOT `!>` prompt. This will prompt the Ethernet card to begin receiving new SELBOOT firmware.

The Ethernet card responds with the prompt shown in *Figure B.4*.

Step 2. Type **Y <Enter>** when the relay responds `Are you sure you want to erase the existing firmware? (Y/N)`.

The relay responds `Erasing` and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

```
!>REC BOOT 5 <Enter>
Caution! - This transfer erases the card's SELboot firmware.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing

Press any key to begin transfer, PCC <Enter>
```

Figure B.4 Transferring New SELBOOT Firmware to the Ethernet Card

Step 3. Press **<Enter>** to begin uploading the new firmware to the Ethernet card.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K Xmodem for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19).

Step 6. Begin the file transfer.

The usual transfer time at 115200 bps with 1K Xmodem is about five minutes. The LCD screen shows `SELBOOT Rxxx LOADING CODE` while the relay loads the new firmware.

Step 7. Wait for firmware load completion.

When finishing loading the new firmware, the relay responds `File Successfully Transferred to Card` after which the relay will respond `Card will now attempt to restart`. Once the Ethernet card re-initializes, the relay will respond with `Card has successfully restarted`, and displays the SELBOOT `!>` prompt. The LCD screen displays `SELBOOT, Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELboot revision number, *xx* is the particular model of SEL-400 series relay being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-487E-R105.

J Upload New Firmware to the Ethernet Card

If your relay has an Ethernet card, read the SEL-400 Series Relays Upgrade and Conversion Paths document found on the upgrade CD-ROM to determine if new Ethernet card firmware is needed as part of the upgrade process. If your relay does not need new Ethernet card firmware, proceed directly to *Step M on page B.11*.

Step 1. While the relay is still in SELBOOT, type **REC 5 <Enter>** at the SELBOOT prompt `!>`. This will prompt the Ethernet card to begin receiving new firmware.

Step 2. Type **Y <Enter>** when the relay responds `Are you sure you want to erase the existing firmware? (Y/N)`, as shown in *Figure B.5*.

The relay responds `Erasing`, and erases the existing firmware. The front-panel LCD shows `ERASING MEMORY`.

When finished erasing, the relay prompts you to press any key to begin transferring the new firmware. The front-panel LCD shows only the SELBOOT program revision number.

```
!>REC 5 <Enter>
Caution! - This transfer erases the card's firmware.
Are you sure you want to erase the existing firmware? (Y/N) Y <Enter>
Erasing

Press any key to begin transfer, PCC <Enter>
```

Figure B.5 Transferring New Firmware to the Ethernet Card

Step 3. Press **<Enter>** to begin uploading the new firmware to the Ethernet card.

Step 4. Start the **Transfer** or **Send** process in your terminal emulation program.

Use 1K XMODEM for fast transfer of the new firmware to the relay.

Step 5. Point the terminal program to the location of the new firmware file (the file that ends in .s19).

Step 6. Begin the file transfer.

The usual transfer time at 115200 bps with 1K XMODEM is about 5 minutes. The LCD screen shows `SELBOOT Rxxx LOADING CODE` while the relay loads the new firmware.

Step 7. Wait for firmware load completion.

When finished loading the new firmware, the relay responds `File Successfully Transferred to Card.` and displays the SELBOOT `!>` prompt. The LCD screen displays `SELBOOT, Ryyy SEL-4xx-Rnnn`, where *yyy* is the SELBOOT revision number, *xx* is the particular model of SEL-400 series relay being upgraded, and *nnn* is the firmware revision number of the relay, e.g., R100 SEL-487E-R105.

IMPORTANT: When the Ethernet card is part of a relay upgrade, you **must** stay in SELBOOT for the entire upgrade process (relay and Ethernet card). Exiting SELBOOT at any point other than Step K (Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT) during the upgrade process may cause the relay to reset to an incorrect part number.

K Return Serial Data Speed to Nominal Operating Speed and Exit SELBOOT

Step 1. Type **<Enter>** to confirm relay communication.

The terminal displays the SELBOOT `!>` prompt.

Step 2. Type **BAU 9600 <Enter>** to reduce the data speed to your nominal serial communications speed (9600 bps in this example).

Step 3. Set your terminal emulation program to match the nominal data speed.

Step 4. Type **<Enter>** to confirm that you have reestablished communication with the relay.

The relay responds with the SELBOOT `!>` prompt.

L Exit SELBOOT

Step 1. Type **EXI <Enter>** to exit the SELBOOT program.

After a slight delay, the relay responds with the following message:

```
CAUTION: Initial relay restart. DO NOT cycle power
during this time. Please wait 3 minutes for restart
completion.
```

M Check Relay Self-Tests

Step 1. Press **<Enter>** and confirm that the `Access Level 0 =` prompt appears on your terminal screen.

Step 2. Remove input power to the relay.

a. Allow at least 10 seconds during the removal of relay power to ensure that the power supply has shut down.

b. Reapply input power to the relay.

c. Wait 5 minutes after power-up of the relay to allow the relay to detect any hardware changes made during the upgrade process.

Step 3. Enter Access Level 1 using the **ACC** command and Access Level 1 password.

Step 4. Enter Access Level 2 using the **2AC** command and Access Level 2 password.

Step 5. Type **STA <Enter>** to check the relay status and accept new hardware changes if needed.

Step 6. Verify that all relay self-test parameters are within tolerance.

Step 7. View the front-panel **ENABLED** LED and confirm that the LED is illuminated.

Unless there is a serious problem, the **ENABLED** LED illuminates without any intervention, and the relay retains all settings.

If the relay does not enable within five minutes of the `Initial relay restart` message, contact your Technical Service Center or the SEL factory for assistance (see *Factory Assistance on page 14.65*).

N Verify Relay Settings

Step 1. Prepare to control the relay at Access Level 2; use the procedure in *Enter Access Level 2 on page B.3*.

Step 2. Type **VER <Enter>** to confirm the new firmware.

Step 3. Match the firmware revision number from the firmware diskette label with the FID number on the screen.

Step 4. Use one of the following methods to review your settings.

- Use the ACSELERATOR QuickSet **Read** menu.

  If the settings do not match the settings that you recorded in *Backup Relay Settings on page B.4*, use ACSELERATOR QuickSet to restore relay settings.

- Type **SHOW <Enter>**.

  You can reissue the settings with the **SET** commands (see *Section 13: ASCII Command Reference* for information on the **SHOW** and **SET** commands).

Step 5. Type **STA <Enter>** to check relay status.

Step 6. Verify that all relay self-test parameters are within tolerance.

O Verify IEC 61850 Operation (Optional)

SEL-400 series relays with optional IEC 61850 protocol require the presence of one valid CID file to enable the protocol. You should only transfer a CID file to the relay if you want to implement a change in the IEC 61850 configuration or if new Ethernet card firmware does not support the current CID file version. If you transfer an invalid CID file, the relay will disable the IEC 61850 protocol, as it no longer has a valid configuration. To restart IEC 61850 protocol operation, you must transfer a valid CID file to the relay.

Perform the following steps to verify that the IEC 61850 protocol is still operational after an Ethernet port firmware upgrade and if not, re-enable it. This procedure assumes that IEC 61850 was operational with a valid CID file immediately before initiating the Ethernet port firmware upgrade. If the IEC 61850 protocol was not configured prior to the upgrade, skip to *Step P on page B.13*. Refer to *Appendix F: IEC 61850* for help with IEC 61850 configuration.

Step 1. Establish a Telnet connection to the Ethernet card.

   a. From a command line prompt, type **Telnet [IP address] port** (e.g., **Telnet 192.168.0.213 1024**).

   b. Press **<Enter>** until you see the = prompt.

Step 2. Issue the **STA**, **ID**, and **GOO** commands.

Step 3. Verify that there are no error messages regarding IEC 61850 or CID file parsing.

If the responses to the **STA**, **ID**, or **GOO** commands contain IEC 61850 or CID error messages, continue with the following steps to re-enable the IEC 61850 protocol. Otherwise, skip to *Step P*.

If the IEC 61850 protocol has been disabled due to an upgrade-induced CID file incompatibility, you can use ACSELERATOR Architect® SEL-5032 Software to convert the existing CID file and make it compatible again.

a. Install the ACSELERATOR Architect software upgrade that supports your required CID file version.

b. Run ACSELERATOR Architect and open the project that contains the existing CID file for the relay.

c. Download the CID file to the relay.

Upon connecting to the relay, ACSELERATOR Architect will detect the upgraded Ethernet port firmware and prompt you before converting the existing CID file to a supported version. Once converted, downloaded, and processed, the valid CID file allows the relay to re-enable the IEC 61850 protocol.

Step 4. In the Telnet session, issue the **STA**, **ID**, and **GOO** commands.

Step 5. Verify that no IEC 61850 error messages are in the **STA** or **ID** command responses.

Step 6. Verify the GOOSE transmitted and received messages are as expected.

P Return the Relay to Service

Step 1. Follow your company procedures for returning a relay to service.

Step 2. Type **MET <Enter>** to view power system metering.

Step 3. Verify that the current and voltage signals are correct.

Step 4. Type **TRI <Enter>** and then type **EVE <Enter>** to view the event report for the event just triggered.

Step 5. Verify that the current and voltage signals are correct in the event report.

Step 6. Autoconfigure the communications processor port if an SEL-2032, SEL-2030, or SEL-2020 Communications Processor is connected to the relay.

This step reestablishes automatic data collection between the SEL communications processor and the SEL-400 series relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

The relay is now ready for your commissioning procedure.

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Appendix C
SEL Communications Processors

Overview

This section describes applications where the SEL-487E Relay is applied in a system integration architecture that includes the SEL-2032, SEL-2030, and SEL-2020 Communications Processors. This section contains the following topics:

- ➤ Introduction to the SEL communications processor family
- ➤ SEL-487E and SEL communications processor architecture
- ➤ Example SEL-487E with SEL communications processor Application

For detailed application examples using the SEL Communications Processors, see the SEL library of Application Guides on our website at www.selinc.com.

SEL Communications Processor

NOTE: The IRIG-B signal available from SEL communications processors is not suitable for high-accuracy IRIG (HIRIG) timekeeping mode, which is required for synchrophasor functions.

SEL offers the SEL-2020, SEL-2030, and SEL-2032 Communications Processors, powerful tools for system integration and automation.

The SEL-2020, SEL-2030, and SEL-2032 hardware are similar, except that the SEL-2020 does not support network protocol cards. Both the SEL-2030 and SEL-2032 support as many as two network protocol cards. The SEL-2032 supports relay SER time tagging of data used for DNP; the SEL-2020 and the SEL-2030 do not. The SEL-20xx family provides a single point of contact for integration networks with a star topology as shown in *Figure C.1*.

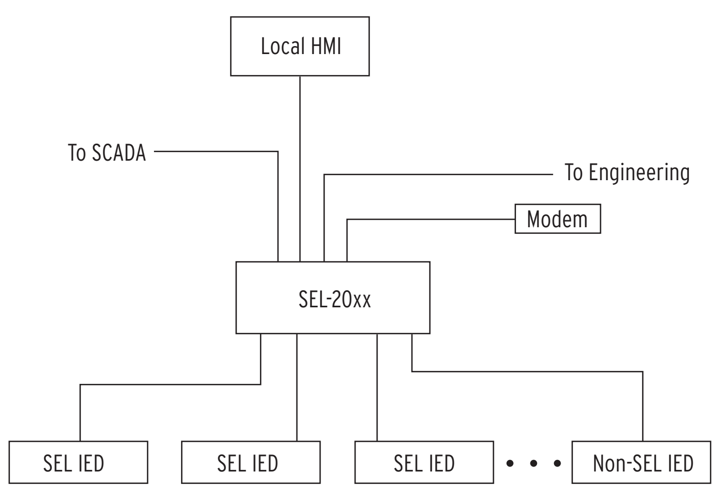

Figure C.1 SEL-20xx Star Integration Network

In the star topology network in *Figure C.1* the SEL communications processors offer the following substation integration functions:

- Collection of real-time data from SEL and non-SEL IEDs
- Calculation, concentration, and aggregation of real-time IED data into databases for SCADA, HMI, and other data consumers
- Access to the IEDs for engineering functions including configuration, report data retrieval, and control through local serial, remote dial-in, and Ethernet network connections
- Simultaneous collection of SCADA data and engineering connection to SEL IEDs over a single cable
- Distribution of IRIG-B time synchronization signal to IEDs based on external IRIG-B input, internal clock, or protocol interface
- Automated dial-out on alarms

The SEL communications processors have 16 serial ports plus a front port. This port configuration does not limit the size of a substation integration project, because you can create a multitiered solution as shown in *Figure C.2*. In this multitiered system, the lower-tier SEL communications processors forward data to the upper-tier SEL communications processor that serves as the central point of access to substation data and station IEDs.

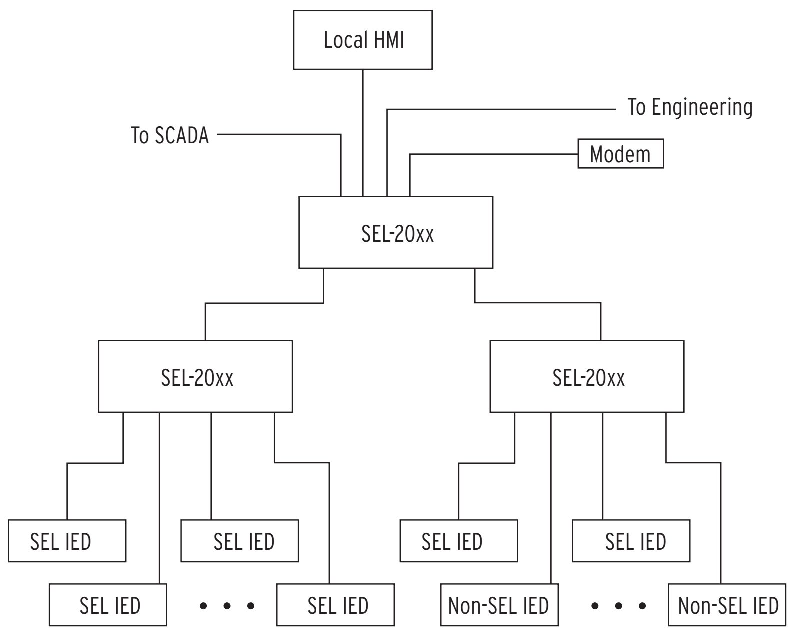

Figure C.2 Multitiered SEL-20xx Architecture

You can add additional communications processors to provide redundancy and eliminate possible single points of failure. The SEL-20xx family of communications processors provides an integration solution with MTBF (mean time between failures) that is 100 to 1000 times more reliable than computer-based and industrial technology-based solutions.

Configuration of an SEL communications processor is different from other general-purpose integration platforms. You can configure the SEL-20xx family with a system of communication-specific keywords and data movement commands rather than programming in C or another general-purpose computer language. The SEL communications processors offer the protocol interfaces listed in *Table C.1*.

Table C.1 SEL-2020, SEL-2030, and SEL-2032 Communications Processor Protocol Interfaces

Protocol	Connect to
DNP3 Level 2 Slave	DNP3 masters (serial)
Modbus® RTU Protocol	Modbus masters
SEL ASCII/Fast Message Slave	SEL protocol masters
SEL ASCII/Fast Message Master	SEL protocol slaves including other communications processors and SEL relays
ASCII and Binary auto messaging	SEL and non-SEL IED master and slave devices
Modbus Plus®[a]	Modbus Plus peers with global data and Modbus Plus masters
DNP3 Level 2 Slave (Ethernet)[b]	DNP3 masters (Ethernet)
FTP (File Transfer Protocol)[b]	FTP clients
Telnet[b]	Telnet servers and clients
UCA2 GOMSFE[b]	UCA2 protocol masters
UCA2 GOOSE[b]	UCA2 protocol peers

[a] SEL-2030 and SEL-2032 only, requires SEL-2711 Modbus Plus protocol card.
[b] SEL-2030 and SEL-2032 only, requires SEL-2701 Ethernet Processor.

SEL Communications Processors and SEL-487E Architecture

You can apply the SEL Communications Processors and the SEL-487E in a limitless variety of applications that integrate, automate, and improve station operation. Most of the system integration architectures utilizing the SEL communications processors involve either developing a star network or enhancing a multidrop network.

Developing Star Networks

The simplest architecture using both the SEL-487E and an SEL-20xx is shown in *Figure C.1*. In this architecture, the SEL communications processor collects data from the SEL-487E and other station IEDs. The SEL-20xx acts as a single point of access for local and remote data consumers (local HMI, SCADA, engineers). The SEL communications processor also provides a single point of access for engineering operations including configuration and the collection of report-based information.

By configuring a data set optimized to each data consumer, you can significantly increase the utilization efficiency on each link. A system that uses the SEL communications processor to provide a protocol interface to an RTU will have a shorter lag time (data latency); communication overhead is much less for a single data exchange conversation to collect all substation data (from a communications processor) than for many conversations required to collect data directly from each individual IED. You can further reduce data latency by connecting the SEL communications processor directly to the SCADA master and eliminating redundant communication processing in the RTU.

The SEL communications processor is responsible for the protocol interface; so you can install, test, and even upgrade the system in the future without disturbing protective relays and other station IEDs. This insulation of the protective devices from the communications interface assists greatly in situations where different departments are responsible for SCADA operation, communication, and protection.

NOTE: The communications processor Ethernet card supports components of UCA2 as a subset of IEC 61850.

The SEL communications processor equipped with an SEL-2701 can provide a UCA2 interface to SEL-487E relays and other serial IEDs. The SEL-2701 and SEL communications processor offer a significant cost savings because you can use existing IEDs or purchase less expensive IEDs. For full details on applying the SEL-2701 and SEL communications processor see the SEL*-2701 Ethernet Processor Instruction Manual*.

The engineering connection can use either an Ethernet network connection through the SEL-2701 or a serial port connection. This versatility will accommodate the channel that is available between the station and the engineering center. SEL software, including the ACSELERATOR QUICKSET® SEL-5030 Software program, can use either a serial port connection or an Ethernet network connection from an engineering workstation to the relays in the field.

Enhancing Multidrop Networks

You can also use the SEL communications processor to enhance a multidrop architecture similar to the one shown in *Figure C.3*. In this example, the SEL communications processor enhances a system that uses the SEL-2701 with an Ethernet HMI multidrop network. In the example, there are two Ethernet networks, the SCADA LAN and the Engineering LAN. The SCADA LAN provides real-time data directly to the SCADA Control Center via a protocol gateway and to the HMI (Human Machine Interface).

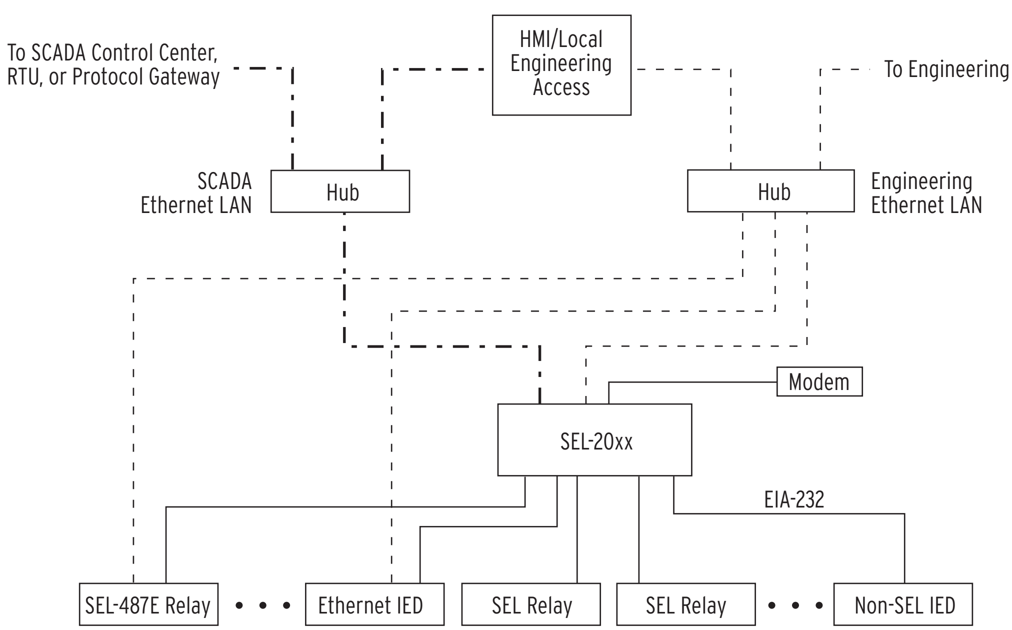

Figure C.3 Enhancing Multidrop Networks With the SEL-20xx

In this example, the SEL-20xx provides the following enhancements when compared to a system that employs only the multidrop network:

- Ethernet access for IEDs with serial ports
- Backup engineering access through the dial-in modem
- IRIG-B time signal distribution to all station IEDs

- ➤ Integration of IEDs without Ethernet
- ➤ Single point of access for real-time data for SCADA, HMI, and other uses
- ➤ Significant cost savings by use of existing IEDs with serial ports
- ➤ Cost savings by installing Ethernet network interfaces in the SEL communications processor rather than in each relay

Relay and Communications Card Data Collection

Table C.2 shows the data available within the SEL-487E relay and communications card (see *Appendix I: Communications Card*). Messages with a “2” appended (top ten values) are only available to the SEL-2032. These values correspond to the data made available to the SEL-2032 within the SEL-487E and are read using Fast Message Data Access. Be sure to enable these values (see *Fast Message Read Data Access*) in the SEL-487E to be available to the SEL-2032.

Table C.2 SEL Communications Processor Data Collection Automessages

Message	Collection Mode	Data Collected
20LOCAL2	Binary	LOCAL database region
20METER2	Binary	METER database region
20DEMAND2	Binary	DEMAND database region
20TARGET2	Binary	TARGET database region
20HISTORY2	Binary	HISTORY database region
20BREAKER2	Binary	BREAKER database region
20STATUS2	Binary	STATUS database region
20ANALOGS2	Binary	ANALOGS database region
20STATE2	Binary	SER database region
20D12	Binary	D1 270x DNP database region
20METER	Binary	Set of 21 AMVs (Automation Math Variables)
20DEMAND	Binary	Demand metering data
20TARGET	Binary	Selected Relay Word bit elements
20HISTORY	ACSII	Relay event history
20STATUS	ACSII	Relay diagnostics
20BREAKER	ACSII	Circuit breaker monitor data
20EVENTL	ACSII	Long (16 samples/cycle) event report stored in a literal format (see the SEL-2030 Instruction Manual)

Fast Message Read Data Access

When the port protocol setting is SEL (**PROTO *n* = SEL**), you can disable Fast Message Read messages from the communications card on a per-region basis with the FMRxxx settings. Note that these settings apply only to the Fast Message Read messages; Fast Message Write messages are unaffected. *Table C.3* shows Fast Message Read messages settings.

After setting the port protocol to SEL, enable the entire Fast Message Read messages function by settings **FMRENAB = Y**. If FMRENAB = N, then no FMR settings are available. Default settings enable the Meter Region, Demand Region, Target Region, and Analog Region. Enable other regions by setting the appropriate region to Yes (Y).

Table C.3 Fast Message Read Message Settings

Label	Prompt	Default Value
FMRENAB	Enable Fast Message Read Data Access (Y/N)	Y
FMRLCL	Enable Local Region for Fast Message Access (Y/N)	N
FMRMTR	Enable Meter Region for Fast Message Access (Y/N)	Y
FMRDMND	Enable Demand Region for Fast Message Access (Y/N)	Y
FMRTAR	Enable Target Region for Fast Message Access (Y/N)	Y
FMRHIS	Enable History Region for Fast Message Access (Y/N)	N
FMRBRKR	Enable Breaker Region for Fast Message Access (Y/N)	N
FMRSTAT	Enable Status Region for Fast Message Access (Y/N)	N
FMRANA	Enable Analog Region for Fast Message Access (Y/N)	Y
FMRSER	Enable State Region for Fast Message Access (Y/N)	N
FMRD1	Enable D1 Region for Fast Message Access (Y/N)	N

SEL Communications Processor Example

This example demonstrates the data and control points available in the SEL communications processor when you connect an SEL-487E. The physical configuration used in this example is shown in *Figure C.4*.

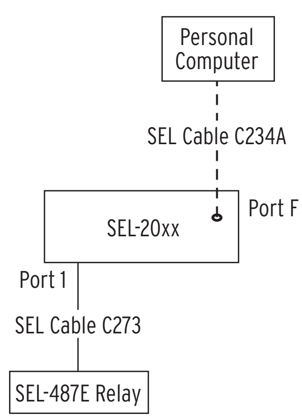

Figure C.4 Example SEL-487E and SEL-20xx Configuration

Table C.4 shows the port settings for Port 1 of the SEL communications processor.

Table C.4 SEL Communications Processor Port 1 Settings

Setting Name	Setting	Description
DEVICE	S	Connected device is an SEL device
CONFIG	Y	Allow autoconfiguration for this device
PORTID	Relay 1	Name of connected relay[a]
BAUD	19200	Channel speed of 19200 bits per second[a]
DATABIT	8	Eight data bits[a]
STOPBIT	1	One stop bit
PARITY	N	No parity
RTS_CTS	Y	Hardware flow control enabled
TIMEOUT	5	Idle timeout that terminates transparent connections of 5 minutes

[a] Automatically collected by the SEL Communications Processor during autoconfiguration.

In this example, we only consider the 20METER and 20TARGET functions. *Table C.5* shows the automessage (SET A) settings for the SEL communications processor.

Table C.5 SEL Communications Processor Port 1 Automatic Messaging Settings

Setting Name	Setting	Description
AUTOBUF	Y	Save unsolicited messages
STARTUP	ACC*n*OTTER*n*	Automatically log on at Access Level 1
SEND_OPER	Y	Send Fast Operate messages for remote bit and breaker bit control
REC_SER	N	Automatic Sequential Event Recorder data collection disabled
NOCONN	NA	No SELOGIC control equation entered to selectively block connections to this port
MSG_CNT	2	Two automessages
ISSUE1	P00:00:01.0	Issue Message 1 every second
MESG1	20METER	Collect metering data
ISSUE2	P00:00:01.0	Issue Message 2 every second
MESG2	20TARGET	Collect Relay Word bit data
ARCH_EN	N	Archive memory disabled
USER	0	No USER region registers reserved

Table C.6 shows the map of regions in the SEL communications processor for data collected from the SEL-487E.

Table C.6 SEL Communications Processor Port 1 Region Map

Region	Data Collection Message Type	Region Name	Description
D1	Binary	METER	Relay metering data
D2	Binary	TARGET	Relay Word bit data
D3–D8	n/a	n/a	Unused
A1–A3	n/a	n/a	Unused
USER	n/a	n/a	Unused

Table C.7 shows the list of meter data available in the SEL-20xx and the location and data type for the memory areas within D1 (Data Region 1). The type field indicates the data type and size. The type "int" is a 16-bit integer. The type "float" is a 32-bit IEEE® floating point number. Because the number of terminals differs from substation to substation, the SEL-487E provides 21 automation math variables (AMV001 through AMV021) instead of dedicated meter values. This flexibility makes it possible to assign meter values to suit the substation. The communications processor treats these as vector quantities.

Table C.7 SEL Communications Processor METER Region Map

Item	Starting Address	Type
_YEAR	2000h	int
DAY_OF_YEAR	2001h	int
TIME(ms)	2002h	int
MONTH	2003h	char
DATE	2004h	char
YEAR	2005h	char
HOUR	2006h	char
MIN	2007h	char
SECONDS	2008h	char
MSEC	2009h	int
AMV001	200Ah	float
AMV002	200Ch	float
AMV003	200Eh	float
AMV004	2010h	float
AMV005	2012h	float
AMV006	2014h	float
AMV007	2016h	float
AMV008	2018h	float
AMV009	201Ah	float
AMV010	201Ch	float
AMV011	201Eh	float
AMV012	2020h	float
AMV013	2022h	float
AMV014	2024h	float
AMV015	2026h	float
AMV016	2028h	float
AMV017	202Ah	float
AMV018	202Ch	float
AMV019	202Eh	float
AMV020	2030h	float
AMV021	2032h	float

Table C.8 lists the Relay Word bit data available in the SEL-20xx TARGET region.

Table C.8 SEL-487E Object 1, 2 Relay Word Bit Mapping (Sheet 1 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
7-0	EN	TRIPLED	*	*	*	*	*	*
15-8	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
23-16	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
31-24	TLED_17	TLED_18	TLED_19	TLED_20	TLED_21	TLED_22	TLED_23	TLED_24
39-32	52CLS	52ALS	52CLT	52ALT	52CLU	52ALU	52CLW	52ALW
47-40	52CLX	52ALX	*	*	*	*	*	*
55-48	89CL1	89CL2	89CL3	89CL4	89CL5	89CL6	89CL7	89CL8
63-56	89OPN1	89OPN2	89OPN3	89OPN4	89OPN5	89OPN6	89OPN7	89OPN8
71-64	89AL1	89AL2	89AL3	89AL4	89AL5	89AL6	89AL7	89AL8
79-72	89OIP	89AL	*	*	*	*	*	*
87-80	EBSMON	BSBCWAL	BSESOAL	BSBITAL	BSKAIAL	BSMSOAL	BSMRTAL	*
95-88	EBTMON	BTBCWAL	BTESOAL	BTBITAL	BTKAIAL	BTM-SOAL	BTMRTAL	*
103-96	EBUMON	BUBCWAL	BUESOAL	BUBITAL	BUKAIAL	BUM-SOAL	BUMRTAL	*
111-104	EBWMON	BWB-CWAL	BWESOAL	BWBITAL	BWKAIAL	BWM-SOAL	BWMRTAL	*
119-112	EBXMON	BXBCWAL	BXESOAL	BXBITAL	BXKAIAL	BXM-SOAL	BXMRTAL	*
127-120	TO1_1	TO2_1	TO3_1	TO1	TO1_2	TO2_2	TO3_2	TO2
135-128	HS1_1	HS2_1	HS3_1	HS1	HS1_2	HS2_2	HS3_2	HS2
143-136	FAA1_1	FAA2_1	FAA3_1	FAA1	FAA1_2	FAA2_2	FAA3_2	FAA2
151-144	RLL_1	RLL_2	RLL_3	RLL	TLL_1	TLL_2	TLL_3	TLL
159-152	CSE_1	CSE_2	CSE_3	CSE	CSCM_1	CSCM_2	CSCM_3	CSCM
167-160	CSALRM	*	*	*	MAMB_OK	MTO1_OK	MTO2_OK	MTO3_OK
175-168	RTD08OK	RTD07OK	RTD06OK	RTD05OK	RTD04OK	RTD03OK	RTD02OK	RTD01OK
183-176	*	*	*	*	RTD09OK	RTD10OK	RTD11OK	RTD12OK
191-184	*	*	*	*	*	*	RTDCOMF	RTDFL
199-192	DC1F	DC1W	DC1G	DC1R	*	*	*	*
207-200	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
215-208	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
223-216	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
231-224	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
239-232	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
247-240	*	IN107	1N106	IN105	IN104	IN103	IN102	IN101
255-248	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
263-256	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
271-264	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
279-272	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
287-280	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
295-288	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317

Table C.8 SEL-487E Object 1, 2 Relay Word Bit Mapping (Sheet 2 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
303-296	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
311-304	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09
319-312	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
327-320	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
335-328	PLT08	PLT07	PLT0	PLT05	PLT04	PLT03	PLT02	PLT01
343-336	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
351-344	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
359-352	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
367-360	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
375-368	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
383-376	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
391-384	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
399-392	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV001
407-400	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
415-408	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
423-416	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
431-424	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
439-432	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
447-440	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
455-448	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
463-456	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
471-464	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
479-472	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
487-480	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
495-488	SALARM	HALARM	BADPASS	CCALARM	*	*	*	*
503-496	TIRIG	TUPDH	TSYNCA	TSOK	PMDOK	*	*	*
511-504	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
519-512	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
527-520	OUT216	OUT215	OUT214	OUT213	OUT212	OUT211	OUT210	OUT209
535-528	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
543-536	OUT316	OUT315	OUT314	OUT313	OUT312	OUT311	OUT310	OUT309
551-544	PB1	PB2	PB3	PB4	PB5	PB6	PB7	PB8
559-552	PB9	PB10	PB11	PB12	*	*	*	*
567-560	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
575-568	PB9_LED	PB10LED	PB11LED	PB12LED	*	*	*	*
583-576	RST_DEM	RST_PDM	RST_ENE	RST_BKS	RST_BKT	RST_BKU	RST_BKW	RST_BKX
591-584	RST_BAT	RSTTRGT	RSTDNPE	*	*	*	*	*
599-592	TRGTR	PHASE_A	PHASE_B	PHASE_C	*	*	ER	FAULT
607-600	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
615-608	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A

Table C.8 SEL-487E Object 1, 2 Relay Word Bit Mapping (Sheet 3 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
623-616	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
631-624	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
639-632	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*
647-640	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
655-648	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
663-656	CCIN025	CCIN026	CCIN027	CCIN028	CCIN029	CCIN030	CCIN031	CCIN032
671-664	CCIN017	CCIN018	CCIN019	CCIN020	CCIN021	CCIN022	CCIN023	CCIN024
679-672	CCIN009	CCIN010	CCIN011	CCIN012	CCIN013	CCIN014	CCIN015	CCIN016
687-680	CCIN001	CCIN002	CCIN003	CCIN004	CCIN005	CCIN006	CCIN007	CCIN008
695-688	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
703-696	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
711-704	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
719-712	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
719-712	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
727-720	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
735-728	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
742-736	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
750-743	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*

[a] An * denotes reserved for future use.

Control Points

The SEL communications processor can automatically pass control messages, called Fast Operate messages, to the SEL-487E. You must enable Fast Operate messages using the FASTOP setting in the SEL-487E port settings for the port connected to the communications processor. You must also enable Fast Operate messages in the SEL communications processor by setting the automessage setting SEND_OPER equal to Y.

When you enable Fast Operate functions, the SEL communications processor automatically sends messages to the relay for changes in remote bits RB1–RB16 or breaker bits BR1 through BR13 on the corresponding communications processor port. In this example, if you set RB1 on Port 1 in the SEL communications processor, it automatically sets RB01 in the SEL-487E.

Breaker bits BR1 through BR5 operate differently than remote bits. There are no breaker bits in the SEL-487E. For Circuit Breaker S, when you set BR1, the SEL communications processor sends a message to the SEL-487E that asserts the manual open command bit OCS for one processing interval. If you clear BRS, the SEL communications processor sends a message to the SEL-487E that asserts the close command bit CCS for one processing interval. If you are using the default settings, OCS will open the circuit breaker and CCS will close the circuit breaker. You can control and condition the effect of OCS and CCS by changing the manual trip and close settings (BK1MTR, BK2MTR, BK1MCL, BK2MCL) in the SEL-487E. Operation for Circuit Breaker T, U, W, and X with OCT, OCU, OCW, OCX, CCT, CCU, CCW, and CCX is similar.

To control the eight disconnects, the communications processor uses breaker bits BR6 through BR13. Setting the BR6 bit in the communications processor sends a message to the SEL-487E relay that asserts Relay Word bit 89OC1 for one processing interval. If the LOCAL Relay Word bit is deasserted in the

SEL-487E relay, Relay Word bit 89OPEN1 asserts. Clearing the BR6 bit in the communications processor sends a message to the SEL-487E relay that asserts 89CC1 for one processing interval. If the

LOCAL Relay Word bit is deasserted, Relay Word bit 89CLS1 asserts. *Table C.9* shows the communications processor bits and the corresponding relay bits for the breaker and disconnect control.

Table C.9 Communications Processor and Relay Control Bit Correlation

Communications Processor bits	SEL-487E bits
BR1	Set BR1: asserts OCS Clear BR1: asserts CCS
BR2	Set BR2: asserts OCT Clear BR2: asserts CCT
BR3	Set BR3: asserts OCU Clear BR3: asserts CCU
BR4	Set BR4: asserts OCW Clear BR4: asserts CCW
BR5	Set BR5: asserts OCX Clear BR5: asserts CCX
BR6	Set BR6: asserts 89OC1 Clear BR6: asserts 89CC1
BR7	Set BR7: asserts 89OC2 Clear BR7: asserts 89CC2
BR8	Set BR8: asserts 89OC3 Clear BR8: asserts 89CC3
BR9	Set BR9: asserts 89OC4 Clear BR9: asserts 89CC4
BR10	Set BR10: asserts 89OC5 Clear BR10: asserts 89CC5
BR11	Set BR11: asserts 89OC6 Clear BR11: asserts 89CC6
BR12	Set BR12: asserts 89OC7 Clear BR12: asserts 89CC7
BR13	Set BR13: asserts 89OC8 Clear BR13: asserts 89CC8

Appendix D

High-Accuracy Timekeeping

Overview

The SEL-487E provides high-accuracy timekeeping when supplied with an IRIG-B signal. You can use the high-accuracy timekeeping to time stamp COMTRADE event report data. Furthermore, synchrophasors operate only when high-accuracy timekeeping is available.

IRIG-B

The SEL-487E has two input connectors that accept IRIG-B (Inter-Range Instrumentation Group-B) demodulated time-code format: the IRIG-B pins of Serial Port 1, and the IRIG-B BNC connector.

NOTE: The SEL-2407 Satellite Synchronized Clock meets both the SEL-487E accuracy and IEEE C37.118 requirements for a high-accuracy time source.

The IRIG-B BNC connector can be used for high-accuracy timekeeping purposes, with up to 1 µs accuracy with an appropriate time source. Either input can be used for general-purpose timekeeping, and the relay will have up to 500 µs accuracy. See *Table D.1* for SEL-487E timekeeping mode details.

Table D.1 SEL-487E Timekeeping Modes

Item	Internal Clock	IRIG	HIRIG (or High-Accuracy IRIG)
Best accuracy (condition)	Depends on last method of setting, or synchronization[a]	500 µs (when time source jitter is less than 3 ms)	1 µs (when time source jitter is less than 500 ns, and time-error is less than 1 µs)[b]
IRIG-B Connection Required	None	BNC connector (preferred), or Serial Port 1	BNC connector
Relay Word bits	TIRIG = logical 0 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 0	TIRIG = logical 1 TSOK = logical 1

[a] The SEL-487E internal clock can be synchronized via DNP3, Ethernet card, SEL-2030 Communications Processor, or MIRRORED BITS communications.
[b] The time source must include the IEEE C37.118 IRIG-B control bit assignments to provide the Time Error estimate for the clock.

NOTE: If the time-code signal connected to the BNC connector degrades in quality, the SEL-487E will **not** switch-over to the IRIG-B pins of serial port 1. The SEL-487E will only switch to Serial Port 1 if the signal on the BNC connector completely fails (e.g., the cable is unplugged).

Only one IRIG-B time source can be used by the SEL-487E, and the signal connected to the IRIG-B BNC connector takes priority over the Serial Port 1 IRIG-B pins. If a signal is detected on the IRIG-B BNC input, the IRIG-B pins of Serial Port 1 will be ignored.

The SEL-487E determines the suitability of the IRIG-B signal connected to the BNC connector for high-accuracy timekeeping by applying two tests:

- ➤ Measuring whether the jitter between positive-transitions (rising edges) of the clock signal is less than 500 ns.
- ➤ Decoding the time-error information contained in the IRIG-B control field and determining that Analog Quantity TQUAL is less than 1 microsecond.

When these two tests are met, Relay Word bit TSOK asserts, indicating HIRIG mode. The TQUAL Analog Quantity can be viewed with the **MET PM** command, and is shown beside the label

```
Time Quality   Maximum time synchronization error:
```

The IRIG-B control field is defined in the IEEE C37.118 standard. The SEL-487E places the raw time quality information in Relay Word bits TQUAL1, TQUAL2, TQUAL4, and TQUAL8; and the decoded maximum clock error in Analog Quantity TQUAL, in seconds.

If the clock signal is determined to be of low quality, with more than 500 ns of jitter, the SEL-487E will not assert the TIRIG Relay Word bit.

Connecting High-Accuracy Timekeeping

The procedure in the following steps assumes that you have a modern high-accuracy GPS receiver with a BNC connector output for an IRIG-B signal. Use a communications terminal to send commands and receive data from the relay.

This example assumes that you have successfully established communication with the relay. In addition, you must be familiar with relay access levels and passwords to change the default access level passwords.

Step 1. Confirm that the relay is operating.

Step 2. Prepare to control the relay at Access Level 2.

a. Using a communications terminal, type **ACC <Enter>**.

b. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

NOTE: Consult the specific GPS Clock (IRIG-B time source) instruction manual for the IRIG-B cable requirements, termination resistor requirements, antenna installation, and clock configuration details.

Step 3. Connect the cable.

Attach the IRIG-B signal with a BNC-to-BNC coaxial jumper cable from the GPS receiver IRIG-B output to the SEL-487E **TIME IRIG-B** BNC connector (see *Figure D.1*).

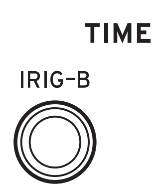

Figure D.1 TIME BNC Connector, New Hardware

Step 4. Confirm/Enable automatic detection of high-accuracy timekeeping.

a. Wait at least 20 seconds for the SEL-487E to acquire the clock signal, and then, at a communications terminal, type **TAR TIRIG <Enter>.**

The relay will return one row from the Relay Word, as shown in *Figure D.2*. Only the state of the TIRIG and TSOK Relay Word bits are discussed in the troubleshooting steps below. The other Relay Word bits of interest to this discussion are TUPDH, which indicates that the SEL-487E internal clock is presently being updated by the HIRIG source, and TSYNCA, which acts as an alarm bit that asserts when the SEL-487E is not synchronized to either an internal or an external source. TSYNCA will only assert briefly when the HIRIG time source is connected or disconnected.

```
=>TAR TIRIG <Enter>

*       *       TIRIG   TUPDH   TSYNCA  TSOK    PMDOK   FREQOK
0       0       1       1       0       1       1       0
=>
```

Figure D.2 Confirming the High-Accuracy Timekeeping Relay Word Bits

b. The TIRIG and TSOK Relay Word bits should be asserted (logical 1), indicating that the relay is in the High-Accuracy IRIG timekeeping mode (HIRIG).

If TSOK is not asserted, but TIRIG is asserted, the relay is in regular IRIG timekeeping mode. Here is a list of possible reasons for not entering HIRIG mode:

➢ The termination resistor, required by some IRIG clocks, is not installed.

➢ If the time-source clock is reporting that its time error is greater than 1 µs.

➢ The IRIG-B clock source is connected via Serial Port 1 instead of the IRIG-B BNC connector.

➢ The IRIG-B clock source is connected to the unlabeled BNC connector on older relay hardware (the previous location of the IRIG-B BNC connector).

NOTE: If the firmware in an already installed SEL-487E is upgraded to version R112 or later, and the previous IRIG-B BNC cable is not moved to the new location (see Figure D.1), the SEL-487E cannot enter High-Accuracy mode.

If neither TSOK nor TIRIG are asserted, the relay is not in an IRIG time-source mode. Here is a list of possible reasons for not entering IRIG mode:

➢ The IRIG-B clock signal is not of sufficient accuracy or is improperly configured.

➢ The termination resistor, required by some IRIG clocks, is not installed.

➢ The time source clock is not connected to an antenna.

Step 5. Type **TIME Q <Enter>** to confirm that the relay is operating in the high-accuracy IRIG (HIRIG) mode.

The relay displays information similar to *Figure D.3*.

The Time Source will be HIRIG, indicating that the relay internal clock is locked to the high-accuracy IRIG input signal.

```
=>TIME Q <Enter>
Relay 1                                           Date: 10/06/2004  Time: 15:44:30.840
Station A                                         Serial Number: 2008030645

Time Source: HIRIG
Last Update Source: HIRIG

IRIG Time Mark Period:  1000.000000 ms
Internal Clock Period:  24.999995 ns

=>
```

Figure D.3 Results of the TIME Q Command

TIME Q Descriptions

The **TIME Q** command provides details about relay timekeeping (see *Figure D.3*). The SEL-487E internal clock is initially calibrated at the SEL factory. An external IRIG source is required to eliminate clock drift. For high-accuracy timekeeping functions such as synchrophasor measurement, the connected clock must support IEEE C37.118—Annex F, IRIG-B Control Bit assignments. The Time Source field provides the present high-accuracy timing input source; entries for this line are HIRIG and OTHER. The Last Update Source reports the source from which the relay referenced the last time value measurement. Entries for this line can be high-priority or low-priority sources. *Table D.2* lists the possible Last Update Source values for the SEL-487E.

Table D.2 Date/Time Last Update Sources

Time Input Source Mode (QQQQQ)	Priority	Time Source
HIRIG	High	Time/date from the high-accuracy IRIG-B input.
IRIG	High	Time/date from the IRIG-B format time base signal
DNP	Low	Time/date from the DNP communications port
MIRRORED BITS	Low	Time/date from the MIRRORED BIT port
ASCII TIME	Low	Time from the relay serial ports
ASCII DATE	Low	Date from the relay serial ports
NONV CLK	Low	Time/date from the nonvolatile memory clock
FRONT PANEL TIME	Low	Time from the front-panel TIME entry screen
FRONT PANEL DATE	Low	Time from the front-panel DATE entry screen

NOTE: For the year to be updated automatically, be sure to set IRIGC = C37.118, i.e., the year is not updated when IRIGC = NONE.

⚠CAUTION
When setting IRIGC = C37.118, make sure that the input control bits are compliant with the C37.118 format.

The IRIG Time Mark Period value indicates the instantaneous period in which the relay measures the time-source inputs. The relay displays the time mark periods showing the present time precision derived from the applied time-source signals.

The **TIME Q** command is also helpful for troubleshooting IRIG problems. If the IRIG Time Mark Period value changes significantly between successive **TIME Q** commands, there may be too much noise in the signal for the relay timekeeping function.

Adaptive Internal Clock Period Adjustment

The Internal Clock Period is the internal relay timekeeping period. The relay adjusts this master internal clock when you apply HIRIG mode timekeeping, adapting the internal relay clock for your installation temperature conditions. If you lose the HIRIG timing lock, the relay internal clock operates at this precisely adapted clock period until HIRIG mode is restored. Time tags for event reports during a loss of HIRIG mode timekeeping remain very accurate. Lower accuracy time sources do not adaptively adjust the internal relay clock period.

Monitoring High-Accuracy Time Source Status

The purpose of the procedure in the following steps is to show one method for deriving the TIME Q Time Source information from Relay Word bits TSOK and TIRIG. The TSOK Relay Word bit is at logical 1 when the relay is in HIRIG time mode. For this application example, use a PSV (Protection SELOGIC Variable) to monitor time keeping status.

PSV01 asserts when the relay is synchronized to the HIRIG source. A departure from this condition asserts the relay alarm output (OUT108 for this application example).

This example assumes that you have successfully established communication with the relay. In addition, you must be familiar with relay access levels and passwords to change the default access level passwords. Also, you should be familiar with ACSELERATOR QuickSet® SEL-5030 Software.

Step 1. Configure the communications port.

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, open the **Communication** menu, and then click **Port Parameters**.

You will see the **Port Parameters** dialog box similar to *Figure D.8*.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings.

The defaults are **9600**, **8**, **1**, **None**, and **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Confirm that the **Communications Status** bar at the bottom of the ACSELERATOR QuickSet window says **Connected**.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords.

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box, and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK** to accept changes and close the dialog box.

Step 3. Read the present configuration in the SEL-487E. Click **Settings > Read**.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Access the protection free-form SELOGIC settings.

a. Click the **+** mark next to **Group 1** in the **Settings** tree view.

b. Click the **Protection Logic 1** settings (see *Figure D.4*).

Step 5. Enter the two lines of SELOGIC control equation programming in the **Protection Free-Form Logic Settings** shown in *Figure D.4*.

Comments begin with the # character.

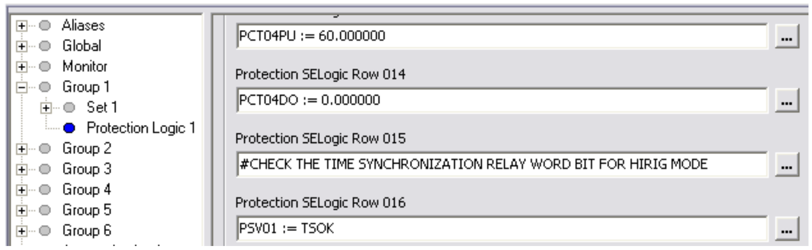

Figure D.4 Programming a PSV in ACSELERATOR QuickSet

Step 6. Configure a control output to alarm a loss of HIRIG mode.

a. In the **Settings** tree view, double-click **Outputs** and then click **Main Board** (see *Figure D.5*).

b. In the **OUT108 Main Board Outputs** text box, enter the OR NOT PSV01 condition to the preexisting OUT108 := NOT (SALARM OR HALARM) equation, as shown in *Figure D.5*.

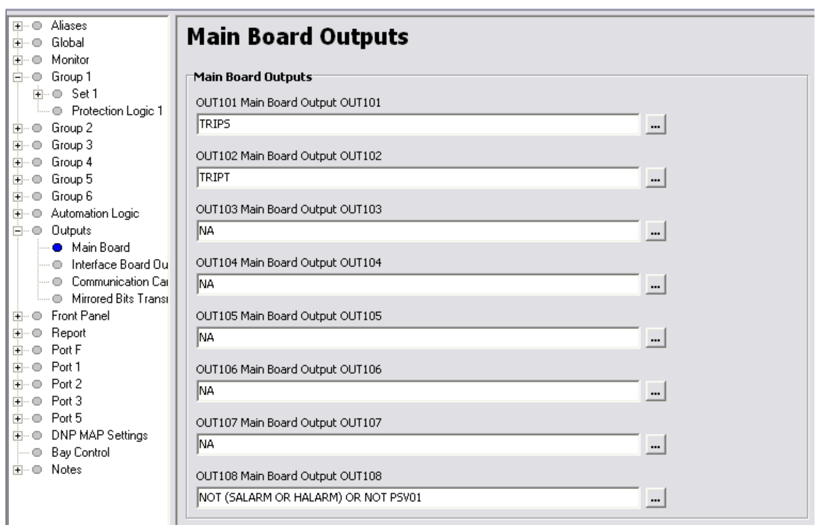

Figure D.5 Setting OUT108 in ACSELERATOR QuickSet

Step 7. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 8. Upload the new settings to the SEL-487E.

a. Click **File > Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay.

b. Click the check box for **Group 1** check box and the **Output** check box, as shown in the first dialog box of *Figure D.6*.

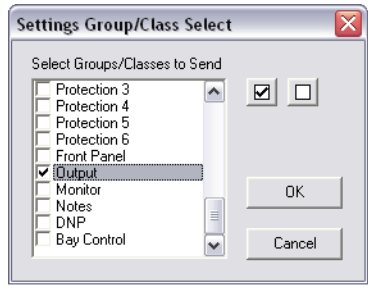

Figure D.6 Uploading Output Settings to the SEL-487E

c. Click **OK**.

ACSELERATOR QuickSet responds with a display similar to the second dialog box of *Figure D.6*.

If you see no error message, the new settings are loaded in the relay.

To confirm that you have prepared an out-of synchronization/loss of HIRIG mode alarm, disconnect the IRIG-B input. The relay alarm will activate.

Relay Configuration for High-Accuracy Timekeeping

The SEL-487E features two IRIG-B timekeeping modes, IRIG and high-accuracy IRIG, called HIRIG. Relay Word bit TSOK asserts when the SEL-487E is in HIRIG mode. *Figure D.7* shows a GPS connected to the SEL-487E relay.

The SEL-487E must be in the HIRIG mode in order for the synchrophasor features to operate (see *Section 11: Synchrophasors*).

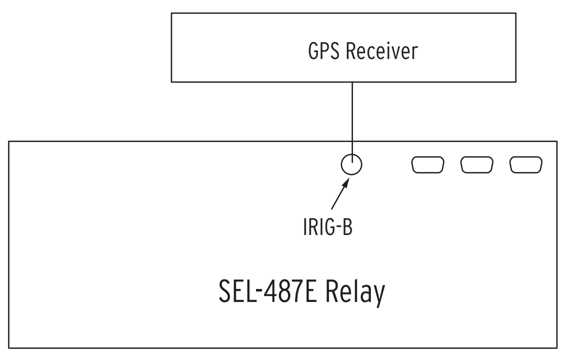

Figure D.7 High-Accuracy Timekeeping Connections

Time-Synchronized Triggers

Program the SEL-487E to perform data captures at *specific* times. Relays that are time-locked using HIRIG mode provide high-accuracy time-synchronized data captures. When you use this method on multiple relays, the actual trigger times can differ by as much as 5 ms, but the information in the binary COMTRADE file outputs from each relay is time-stamped at very high accuracy. Do not assume that the relay triggers are locked with high accuracy; rather, compare corresponding time-stamped data points from each COMTRADE file.

Time Triggering the SEL-487E

NOTE: The **MET PM time** command can be used to capture synchrophasor data at a specific time, if synchrophasors are enabled with Global setting EPMU := Y. See View Synchrophasors by Using the MET PM Command on page 11.25.

Perform the following steps to trigger an event data capture in the SEL-487E at a specific time. These settings cause the relay to initiate a data capture at 12:00:30 p.m. Use other SELOGIC® control equations in a similar manner to trigger relay event recordings.

You should be familiar with ACSELERATOR QuickSet. See *Section 3: PC Software* for ACSELERATOR QuickSet operational information.

This example assumes that you have successfully established communication with the relay. In addition, you should be familiar with relay access levels and passwords.

Step 1. Configure the communications port:

a. Start ACSELERATOR QuickSet.

b. On the top toolbar, click **Communication > Parameters**.

You will see the **Communication Parameters** dialog box.

c. Select the **Data Speed**, **Data Bits**, **Stop Bits**, **Parity**, and **RTS/CTS** that match the relay settings. The defaults are **9600**, **8**, **1**, **None**, **Off**, respectively.

d. Click **OK** to update the ACSELERATOR QuickSet communications parameters.

e. Type **<Ctrl+T>** to use the serial communications terminal.

f. Type **<Enter>** to see whether the communications link is active between ACSELERATOR QuickSet and the relay.

You will see the Access Level 0 = prompt in the terminal window.

g. Exit the terminal window.

Step 2. Confirm the correct ACSELERATOR QuickSet passwords:

a. Reopen the **Communication** menu and click **Port Parameters**.

b. Enter your Access Level 1 password in the **Level One Password** text box and your Access Level 2 password in the **Level Two Password** text box.

c. Click **OK**.

Step 3. Click **Settings > Read** to read the present configuration in the SEL-487E.

The relay sends all configuration and settings data to ACSELERATOR QuickSet.

Step 4. Click the **+** mark next to the **Group** you want to program on the **Settings** tree view.

This example uses **Group 1**.

You will see the **Protection Free-Form Logic Settings** dialog box.

Step 5. Enter time trigger settings:

a. Click the ... button beside the first unused Protection SELOGIC row entry field to start the **Expression Builder**.

b. On the left side of the SELOGIC control equation, select **Math Variables** and double-click **PMV64**.

c. On the right side of the equation, select **Analog Quantities > Date and Time**.

d. Double click **THR** (Time in Hours).

e. Use the **#** character to add a comment to the line.

f. When finished, click **Accept**.

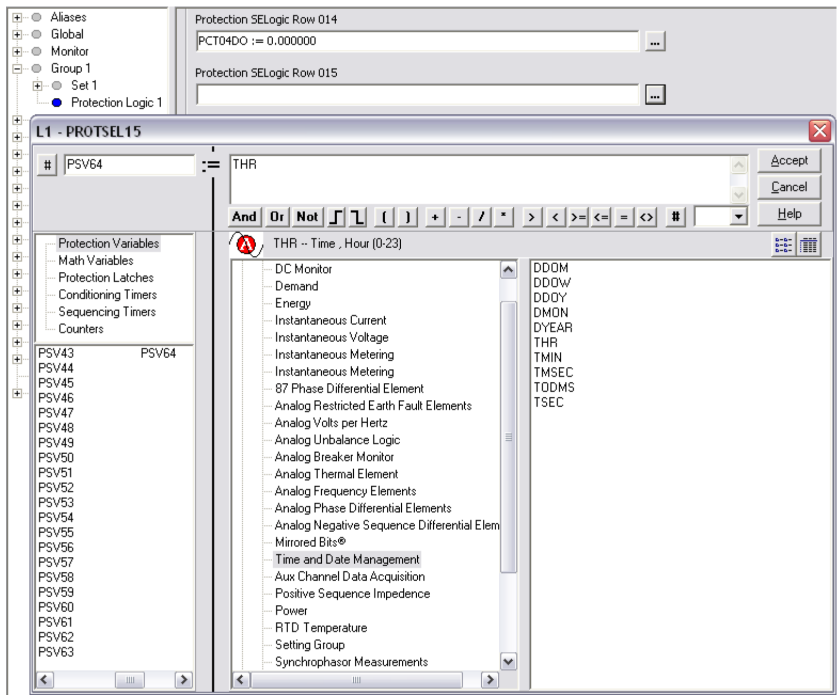

Figure D.8 Setting PMV64 with the Expression Builder Dialog Box

Step 6. In a similar manner, build a free-form SELOGIC program in Protection Logic that causes protection free-form SELOGIC control equation variable PSV02 to assert to logical 1 at 12:00:30.005 p.m. Use the following expressions:

> **NOTE:** In this example, the event report trigger will occur between 12:00:30.002 and 12:00:30.005 because of the method of SEL-487E protection logic processing.

```
PSV02 := (THR=12) AND (TMIN=00) AND (TSEC=30) # Set PSV02 at
12:00:30
```

Step 7. Select settings:

a. Click the **+** mark next to **Relay Configuration** as shown in *Figure D.9*.

b. Click the **Trip Logic** and **ER Trigger** branch.

You will see the **Trip Logic** and **ER Trigger Settings** dialog box (see *Figure D.9*).

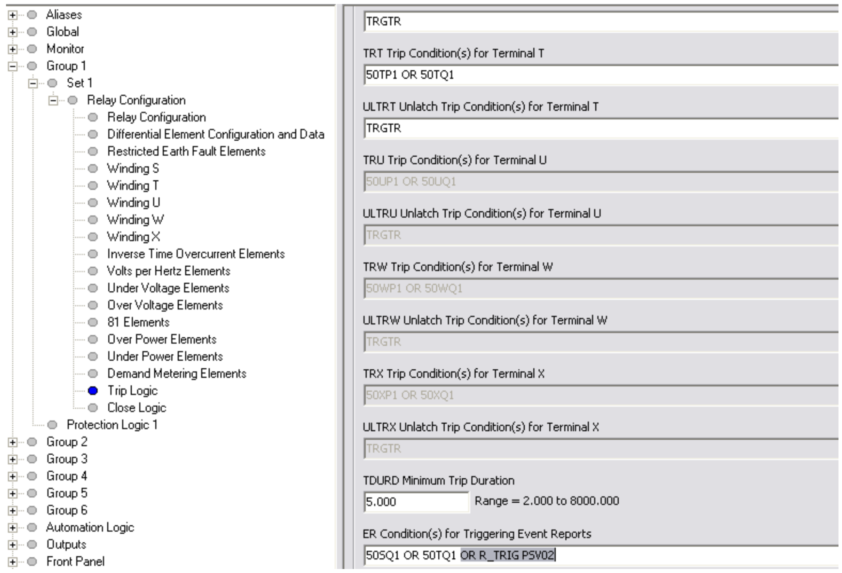

Figure D.9 Selecting Trip Logic and ER Trigger Settings in ACSELERATOR QuickSet

Step 8. Click in the **ER Event Report Trigger Equation** (SELOGIC) text box and add **OR R_TRIG PSV02** to the end of elements already in this SELOGIC control equation.

Step 9. Click **File > Save** to save the new settings in ACSELERATOR QuickSet.

Step 10. Upload the new settings to the SEL-487E:

a. Click **File > Send**.

ACSELERATOR QuickSet prompts you for the settings class or instance you want to send to the relay, as shown in the first dialog box in *Figure D.10*.

b. Click the check box for **Group 1** (or the settings group that you are programming).

c. Click **OK**.

The relay responds with the second dialog box shown in *Figure D.10*.

If you see no error message, the new settings are loaded in the relay.

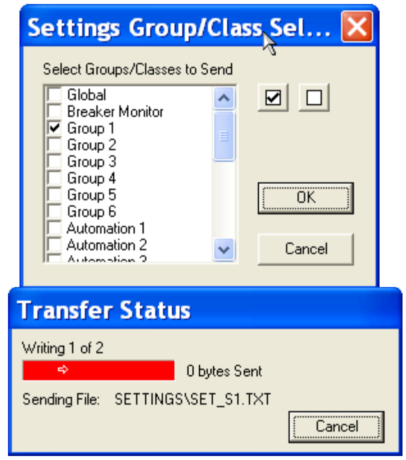

Figure D.10 Uploading Group Settings to the SEL-487E

COMTRADE File Information

Retrieve the COMTRADE files for the time-triggered data captures from each relay with the **FILE READ EVENTS** command. Parse the binary COMTRADE data for the power system currents and voltages you need to calculate system quantities.

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Appendix E
DNP3 Communications Protocol

Overview

The SEL-487E Relay provides a DNP3 (Distributed Network Protocol 3) Level 2 Outstation interface for direct network connections to the relay. This section covers the following topics:

Introduction to DNP3

A SCADA (Supervisory Control and Data Acquisition) manufacturer developed DNP3 from the lower layers of IEC 60870-5. DNP3 was designed for use in telecontrol applications. The protocol has become popular for both local substation data collection and telecontrol. DNP3 is one of the protocols included in the IEEE Recommended Practice for Data Communication between Remote Terminal Units and Intelligent Electronic Devices in a Substation.

Rather than individual input and output points wired from the station RTU (remote terminal unit) to the station IEDs (intelligent electronic devices), many stations use DNP3 to convey measurement and control data to and from the RTU. The RTU then forwards data to the off-site master station. By using data communications rather than hard wiring, designers have reduced installation, commissioning, and maintenance costs while increasing remote control and monitoring flexibility.

The DNP User's Group maintains and publishes DNP3 standards. See the DNP User's Group web site (www.dnp.org) for more information on DNP3 standards, implementers of DNP3, and tools for working with DNP3.

NOTE: In order to use DNP3 features, including virtual terminal connections, your DNP3 master device must support the required standard DNP3 objects and operations.

This section describes the serial networking features of DNP3. The DNP3 interface has the capabilities summarized in *Table E.1*.

Table E.1 DNP3 Serial Feature Summary

Feature	Application
DNP3 event data reporting	More efficient polling through event collection or unsolicited data
Time-tagged events	Time-stamped SER data
Control output relay blocks	Operator-initiated control through remote bits
Write analog setpoint	Change the active protection settings group
Time synchronization	Set the relay time from the master station or automatically request time synchronization from the master
Custom mapping	Increase communication efficiency by organizing data and reducing available data to what you need for your application
Modem support	Reduce the cost of the communications channel by either master dialing to relay or relay dialing to master
Virtual terminal	Establish an engineering connection across a DNP3 network
TEST DNP command	Test DNP3 interface without disturbing protection

You can build a DNP3 network using either a multidrop or star topology. Each DNP3 network has a DNP3 master and DNP3 outstations. *Figure E.1* shows the DNP3 multidrop network topology.

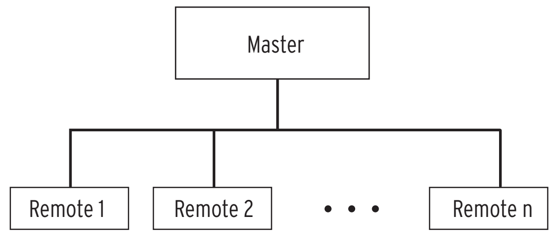


Figure E.1 DNP3 Multidrop Network Topology

Figure E.2 shows the DNP3 star network topology.

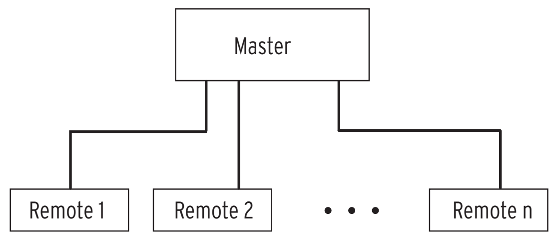


Figure E.2 DNP3 Star Network Topology

DNP3 multidrop networks that are used within substations often use an EIA-485 physical layer. The multidrop network is vulnerable to the failure of a single transmitter. If any one transmitter fails in a state that disrupts signals on the network, the network will fail. The DNP3 star network topology eliminates the network transmitters and other single points of failure related to the physical medium.

If you are planning either a DNP3 star or network topology, you should consider the benefits of including an SEL communications processor in your design. A network with a communications processor is shown in *Figure E.3*. A DNP3 network that includes a communications processor has a lower data latency and shorter scan time than comparable networks through two primary mechanisms. First, the communications processor collects data from all remotes in parallel rather than one-by-one. Second, the master can collect all data with one message and response, drastically reducing message overhead.

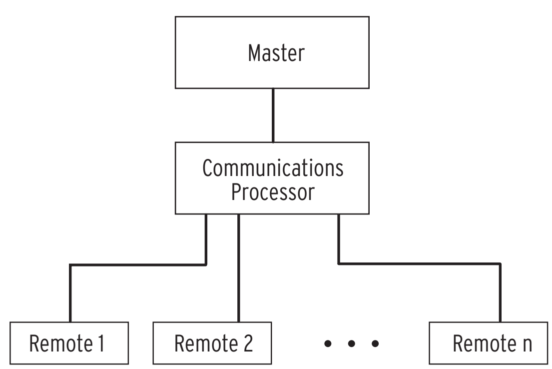


Figure E.3 DNP3 Network with Communications Processor

In the communications processor DNP3 network you can also collect data from devices that do not have DNP3 protocol. The communications processor can collect data and present it to the master as DNP3 data regardless of the protocol between the communications processor and the remote device.

DNP3 LAN/WAN

Installation of the Ethernet card in an SEL-487E relay provides a high performance DNP3 Level 2 outstation network interface designed for operation in a substation environment. See *Section 7: Communications, Interfaces, and Protocols*.

The DNP3 Ethernet interface has the capabilities summarized in *Table E.2*.

Table E.2 Ethernet DNP3 Feature Summary

Feature	Key Features
DNP3 Event data reporting	More efficient polling through event collection or unsolicited data
Time tagged events	Time-stamped SER data directly from the SEL-487E, not an intermediate device
Control output relay blocks	Operator-initiated control through remote bits
Custom mapping	Increase communication efficiency by organizing and/or reducing available data to what is needed with 5 custom data maps for up to 10 different sessions
Analog deadband settings per session	Deadbands may be set to different values per session depending on desired application

Customized DNP3 data within the SEL-487E relay is available to any of ten DNP3 master sessions configured in the Ethernet card. Configuration and implementation of DNP3 over the Ethernet interface is entirely independent of any serial DNP3 settings that might exist in the SEL-487E.

See *DNP3 LAN/WAN in the SEL-487E* for information on configuring and using DNP3 LAN/WAN for the SEL-487E.

DNP3 Specifications

DNP3 is a protocol with many features and many ways to accomplish tasks. DNP3 is defined in the 8 Volume DNP3 specification (including subset information). This specification defines four levels of subsets to help improve interoperability. The levels are listed in *Table E.3*.

Table E.3 DNP3 Implementation Levels

Level	Description	Equipment Types
1	Simple: limited communication requirements	Meters, simple IEDs
2	Moderately complex: monitoring and metering devices and multifunction devices that contain more data	Protective relays, RTUs
3	Sophisticated: devices with great amounts of data or complex communication requirements	Large RTUs, SCADA masters
4	Sophisticated and complex, similar to Level 3, but also includes XML device description, double bit inputs, and event objects for binary and analog outputs	Large RTUs, SCADA masters

Each level is a proper superset of the next lower-numbered level. A higher subset level device can act as a master to a lower subset level device. For example, a typical SCADA master is a Level 3 device and can poll a Level 2 or Level 1 device by using only the data types and functions that the lower-level device uses. A lower-level device can also poll a higher-level device. For example, a Level 1 device can poll a Level 3 device, but the Level 1 device can only access the features and data available in Level 1.

Data Handling

Objects

DNP3 uses a system of data references called objects, which the DNP3 standard object library defines. Each subset level specification requires a minimum implementation of object types and also recommends several optional object types. Object types are commonly referred to as objects. DNP3 objects are specifications for the type of data the object carries. An object can include a single value or more complex data. Some objects serve as shorthand references for collections of data or even all data within the DNP3 device.

If there can be more than one instance of a type of object, then each instance of the object includes an index that makes it unique. For example, each binary status point (Object 1) has an index. If there are 16 binary status points, these points are Object 1, Index 0 through Object 1, Index 15.

Each object also includes multiple versions called variations. For example, Object 1 has three variations: 0, 1, and 2. Variation 0 is used to request the default variation of the object. Variation 0 is only used in requests and not in responses. Variation 1 is used to specify binary input values only and Variation 2 is used to specify binary input values with status information.

Each DNP3 device has both a list of objects and a map of object indices. The list of objects defines the available objects, variations, and qualifier codes. The map defines the indices for objects that have multiple instances and defines what data or control points correspond with each index.

A master initiates all DNP3 message exchanges except unsolicited data. DNP3 terminology describes all points from the perspective of the master. Binary points for control that move from the master to the remote are called Binary Outputs, while binary status points within the remote are called Binary Inputs.

Function Codes

Each DNP3 message includes a function code. Each object has a limited set of function codes that a master may use to manipulate the object. The object listing for the device shows the permitted function codes for each type of object. The most common DNP3 function codes are listed in *Table E.4*.

Table E.4 Selected DNP3 Function Codes

Function Code	Function	Description
1	Read	Request data from the remote
2	Write	Send data to the remote
3	Select	First part of a select-before-execute operation
4	Execute	Second part of a select-before-execute operation
5	Direct operate	One-step operation with reply
6	Direct operate, no reply	One-step operation with no reply

Qualifier Codes and Ranges

DNP3 masters use qualifier codes and ranges to make requests for specific objects by index. Qualifier codes specify the style of range, and the range specifies the indices of the objects of interest. DNP3 masters use qualifier codes to compose the shortest, most concise message possible when requesting points from a DNP3 remote.

For example, the qualifier code 01 specifies that the request for points will include a start address and a stop address. Each of these two addresses uses two bytes. An example request using qualifier code 01 might have the four hexadecimal byte range field, 00h 04h 00h 10h, that specifies points in the range 4 to 16.

Access Methods

The access methods listed in *Table E.5* are in order of increasing communication efficiency. With various tradeoffs, each method is less demanding of communication bandwidth than the previous one. For example, unsolicited report-by-exception consumes less communication bandwidth because of the elimination of polling messages from the master required by polled report-by-exception. You must also consider overall system size and the volume of data communication expected in order to properly evaluate which access method provides optimum performance for your application.

Table E.5 DNP3 Access Methods

Access Method	Description
Polled static	Master polls for present value (Class 0) data only.
Polled report-by-exception	Master polls frequently for event data and occasionally for Class 0 data.
Unsolicited report-by-exception	Remote devices send unsolicited event data to the master, and the master occasionally polls for Class 0 data.
Quiescent	Master never polls and relies on unsolicited reports only.

Binary Control Operations

DNP3 masters use Object 12 control relay output block to perform DNP3 binary control operations. The control relay output block has both a trip/close selection and a code selection. The trip/close selection allows a single DNP3 index to operate two related control points, such as trip and close or raise and lower. Trip/close pair operation is not recommended for new DNP3 devices, but is often included for interoperability with older DNP3 master implementations.

The control relay output block code selection specifies either a latch or pulse operation on the point. In many cases, DNP3 remotes have only a limited subset of the possible combinations of the code field. Sometimes, DNP3 remotes assign special operation characteristics to the latch and pulse selections. *Table E.17* and *Table E.18* describe control point operation for the SEL-487E.

Conformance Testing

In addition to the protocol specifications, the DNP User's Group has approved conformance testing requirements for Level 1 and Level 2 remote devices. Some implementers perform their own conformance specification testing, while some contract with independent companies to perform conformance testing.

Conformance testing does not always guarantee that a master and remote will be fully interoperable (work together properly for all implemented features). Conformance testing does help to standardize the testing procedure and move the DNP3 implementers toward a higher level of interoperability.

Data Link Layer Operation

DNP3 employs a three-layer version of the seven-layer OSI (Open Systems Interconnect) model called the enhanced performance architecture. The layer definition helps to categorize functions and duties of various software components that make up the protocol. The middle layer, the Data Link Layer, includes several functions for error checking and media access control. A feature called data link confirmation is a mechanism that provides positive confirmation of message receipt by the receiving DNP3 device. While this feature helps you recognize a failed device or failed communications link quickly, it also adds significant overhead to the DNP3 conversation. Consider for your individual application whether you require this link integrity function at the expense of overall system speed and performance.

The DNP3 standard recommends against using data link confirmations because these processes can add to traffic in situations where communications are marginal. The increased traffic will reduce connection throughput further, possibly preventing the system from operating properly.

Network Medium Contention

When more than one device requires access to a single network medium, you must provide a mechanism to resolve the resulting network medium contention. For example, unsolicited reporting results in network medium contention if you do not design your network as a star topology of point-to-point connections or use carrier detection on a multidrop network.

To avoid collisions among devices trying to send messages, DNP3 includes a collision avoidance feature. Before sending a message, a DNP3 device listens for a carrier signal to verify that no other node is transmitting data. The device transmits if there is no carrier or waits for a random time before rechecking for a carrier signal. However, if two nodes both detect a lack of carrier at the same instant, these two nodes could begin simultaneous transmission of data and cause a data collision. If your network allows for spontaneous data transmission including unsolicited event data transmissions, you also must use application confirmation to provide a retry mechanism for messages lost due to data collisions.

DNP3 in the SEL-487E

The SEL-487E is a DNP3 Level 2 outstation device. Additional implementation documentation describing DNP3 in the relay is in *DNP3 Documentation on page E.14*.

Data Access

NOTE: Because unsolicited messaging only operates properly in some situations, for maximum performance and minimum risk of configuration problems, SEL recommends the polled report-by-exception access method. Configure the master to perform at least 10 event polls for every integrity poll.

You can use any of the data access methods listed in *Table E.6*. *Table E.6* also lists the SEL-487E DNP3 settings. You must configure the DNP3 master for the data access method you select.

Table E.6 DNP3 Access Methods

Access Method	Master Polling	SEL-487E Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA, ECLASSV to Off, UNSOL to No.
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLSSC, ECLASSA, ECLASSV to the desired event class, UNSOL to No.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLSSC, ECLASSA, ECLASSV to the desired event class, set UNSOL to Yes and PUNSOL to Yes or No.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLSSC, ECLASSA to the desired event class, set UNSOL and PUNSOL to Yes.

In both the unsolicited report-by-exception and quiescent polling methods shown in *Table E.6*, you must make a selection for the PUNSOL setting. This setting enables or disables unsolicited data reporting at power up. If your master can send the DNP3 message to enable unsolicited reporting from the SEL-487E, you should set PUNSOL to No.

While automatic unsolicited data transmission on power up is convenient, problems can result if your master is not prepared to start receiving data immediately on power up. If the master does not acknowledge the unsolicited data with an Application Confirm, the relay will resend the data until it is acknowledged. On a large system, or in systems where the processing power of the master is limited, you may have problems when several relays simultaneously begin sending data and waiting for acknowledgement messages.

Collision Avoidance

If your application uses unsolicited reporting, you must select a polled mode (polled static or polled report-by-exception) or a medium that includes carrier detection to avoid data collisions. EIA-485 two-wire networks are half duplex.

EIA-485 four-wire networks do not provide carrier detection, while EIA-232 systems can support carrier detection. The relay uses Application Confirmation messages to guarantee delivery of unsolicited event data before erasing the local event data buffer. Data collisions are typically resolved when messages are repeated until confirmed.

The SEL-487E pauses for a random delay between the settings MAXDLY and MINDLY when it detects a carrier through data on the receive line or the CTS pin. If you use the settings of 0.10 seconds for MAXDLY and 0.05 seconds for MINDLY, the SEL-487E will insert a random delay of 50 to 100 ms (milliseconds) between the end of carrier detection and the start of data transmission.

Transmission Control

If you use a media transceiver (for example, EIA-232 to EIA-485) or a radio system for your DNP3 network, you may need to adjust data transmission properties. Use the PREDLY and POSTDLY settings to provide a delay between RTS signal control and data transmission. For example, an EIA-485 transceiver typically requires 10 to 20 ms to change from receive to transmit. If you set the pre-delay to 30 ms, you will avoid data loss resulting from data transmission beginning at the same time as RTS signal assertion.

Event Data

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. Confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-487E.

DNP3 event data objects contain change-of-state and time-stamp information that the SEL-487E collects and stores in a buffer. You can configure the SEL-487E to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB, ECLASSC, ECLASSA, and ECLASSV you can set the event class for binary, counter, analog, and virtual terminal information. You can use the classes as a simple priority system for collecting event data. The relay does not treat data of different classes differently with respect to unsolicited messages, but the relay does allow the master to perform independent class polls.

For event data collection you must also consider and enter appropriate settings for dead band and scaling operation on analog points shown in *Table E.8*. You can either set and use default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Configurable Data Mapping* for a discussion of how to set scaling and dead-band operation on a point-by-point basis.

The settings ANADBA, ANADBV, and ANADBM control default dead-band operation for the specified data type. Because DNP3 Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value.

With no scaling, the value of 12.632 would be sent as 13. With a scaling setting of 1, the value transmitted is 126. With a scaling setting of 3, the value transmitted is 12632. You must make certain that the maximum value does not exceed 32767 if you are polling the default 16-bit variations for Objects 30 and 32, but you can send some decimal values using this technique. You must also configure the master to perform the appropriate division on the incoming value to display it properly.

Set the default analog value scaling with the DECPLA, DECPLV, and DECPLM settings. Application of event reporting dead bands occurs after scaling in the DECPLA, DECPLV, and DECPLM. For example, if you set DECPLA to 2 and ANADBA to 10, a measured current of 10.14 amps would be scaled to the value 1014 and would have to increase to more than 1024 or decrease to less than 1004 (a dead band of 0.2 amps) for the relay to report a new event value.

The relay uses the NUMEVE and AGEEVE settings to decide when to send unsolicited data to the master. The relay sends an unsolicited report when the total number of events accumulated in the event buffer reaches NUMEVE. The relay also sends an unsolicited report if the age of the oldest event in the buffer exceeds AGEEVE. The SEL-487E has the buffer capacities listed in *Table E.7*.

Table E.7 SEL-487E Event Buffer Capacity

Type	Maximum Number of Events
Binary	1024
Analog	256
Counters	128

Binary Controls

The SEL-487E provides more than one way to control individual points within the relay. The relay maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations. *Table E.17* and *Table E.18* list control points and control methods available in the SEL-487E.

A DNP3 standard recommends that you use one point per Object 12, control block output relay. You can use this method to perform Pulse On, Pulse Off, Latch On, and Latch Off operations on selected remote bits.

If your master does not support the single-point-per-index messages or single operation database points, you can use the trip/close operation or use the code field in the DNP3 message to specify operation of the points shown in *Control Point Operation on page E.30*.

Time Synchronization

The accuracy of DNP3 time synchronization is insufficient for most protection and oscillography needs. DNP3 time synchronization provides backup time synchronization in the event the relay loses primary synchronization through the IRIG-B TIME input or some other high-accuracy source. Enable time synchronization with the TIMERQ setting and use Object 50, Variation 1, and Object 52, Variation 2, to set the time via a DNP3 master. TIMERQ can be set in one of three ways:

➤ A numeric setting of 1 through 32767 minutes specifies the rate at which the SEL-487E shall request a time synchronization.

➤ A setting of M disables the SEL-487E from requesting a time synchronization, but still allows the SEL-487E to accept and apply time synchronization messages from the master.

➤ A setting of 1 disables the SEL-487E from requesting a time synchronization, and sets the SEL-487E to ignore time synchronization messages from the master.

Modem Support

The SEL-487E DNP3 implementation includes modem support. Your DNP3 master can dial-in to the SEL-487E and establish a DNP3 connection. The SEL-487E can automatically dial out and deliver unsolicited DNP3 event data. When the relay dials out, it waits for the CONNECT message from the local modem and for assertion of the relay CTS line before continuing the DNP3 transaction. This requires a connection from the modem DCD to the relay CTS line.

NOTE: Contact SEL for information on serial cable configurations and requirements for connecting your SEL-487E to other devices.

NOTE: RTS/CTS hardware flow control is not available for a DNP3 modem connection. You must set the port data speed slower than the effective data rate of the modem.

Either connect the modem to a computer and configure it before connecting it to the relay, or program the appropriate modem setup string in the modem startup string setting MSTR. Use the PH_NUM setting to set the phone number that you want the relay to dial. The relay will automatically send the ATDT modem dial command and then the contents of the PH_NUM setting when dialing the modem. PH_NUM is a text setting that must conform to the AT modem command set dialing string standard. Use a comma (,) for a pause of four seconds. You may need to include a nine to reach an outside line or a one if the number requires long distance access. You can also insert other special codes your telephone service provider designates for block call waiting and other telephone line features.

DNP3 Settings

NOTE: You can set the data format when PROTO := DNP.

The DNP3 protocol settings that become available when you select DNP3 on a serial port are shown in *Table E.8*. The DNP3 protocol settings are in the port settings for the port that you select for the DNP3 protocol. You can use DNP3 on any of the serial ports, **PORT F** and **PORT 1** through **PORT 3**, but you can only enable DNP3 on one serial port at a time.

Table E.8 SEL-487E Port DNP3 Protocol Settings (Sheet 1 of 2)

Name	Description	Range	Default
DNPADR	DNP3 address	0–65519	0
ECLASSB	Class for binary event data	OFF, 1–3	1
ECLASSC	Class for counter event data	OFF, 1–3	OFF
ECLASSA	Class for analog event data	OFF, 1–3	2
ECLASSV	Class for virtual terminal data	OFF, 1–3	OFF
TIMERQ	Time-set request interval (I, M, 1–32767 minutes)	I, M, 1–32767	I
DECPLA	Current value scaling	0–3	1
DECPLV	Voltage value scaling	0–3	1
DECPLM	Miscellaneous data scaling	0–3	1
STIMEO	Select/operate time-out	0.0–60.0 seconds	1.0
DRETRY	Data link retries	OFF, 1–15	OFF
DTIMEO	Data link time-out; hidden if DRETRY set to Off	0.0–30.0 seconds	1.0
MINDLY	Minimum delay from DCD to TX	0.00–1.00 seconds	0.05
MAXDLY	Maximum delay from DCD to TX	0.00–1.00 seconds	0.10
PREDLY	Settle time from RTS on to TX; Off disables PSTDLY	OFF, 0.00–30.00 seconds	0.00
PSTDLY	Settle time from TX to RTS off; hidden if PREDLY set to Off	0.00–30.00 seconds	0.00
ANADBA	Analog reporting dead band for current; hidden if ECLASSA set to Off	0–32767	100
ANADBV	Analog reporting dead band for voltages; hidden if ECLASSA set to Off	0–32767	100
ANADBM	Analog reporting dead band; hidden if ECLASSC and ECLASSA set to Off	0–32767	100
EVELOCK	Event summary lock period	0–1,000 seconds	0
ETIMEO	Event data confirmation time-out	0.1–100.0 seconds	10.0
UNSOL	Enable unsolicited reporting; hidden and set to N if ECLASSB, ECLASSC, ECLASSA, and ECLASSV set to Off	Y, N	N
PUNSOL	Enable unsolicited reporting at power up; hidden if UNSOL set to N	Y, N	N
REPADR	DNP3 address to which the relay reports unsolicited data; hidden if UNSOL set to N	0–65519	1
NUMEVE	Number of events on which the relay transmits unsolicited data; hidden if UNSOL set to N	1–200	10
AGEEVE	Age of oldest event on which the relay transmits unsolicited data; hidden if UNSOL set to N	0.0–60.0 seconds	2.0
MODEM	Modem connected to port	Y, N	N
MSTR	Modem startup string; hidden if MODEM set to N	Up to 30 characters	"E0X0&D0S0=4"

Table E.8 SEL-487E Port DNP3 Protocol Settings (Sheet 2 of 2)

Name	Description	Range	Default
PH_NUM	Phone number for unsolicited reporting dial-out; hidden if MODEM set to N or UNSOL set to N	Up to 30 characters	“”
MDTIME	Time to attempt dial	5–300 seconds	60
MDRET	Time between dial-out attempts	5–3600 seconds	120

Configurable Data Mapping

One of the most powerful features of the SEL-487E DNP3 implementation is the ability to remap DNP3 data. Remapping is the process of selecting data from the default map and organizing it into a smaller data set optimized for your application.

Use the settings Class D to access the SEL-487E DNP3 Map settings shown in *Table E.9*. The SEL-487E provides binary input information with one of two reference maps: binary or extended. When you are remapping points, the new index will be the row number minus one. For example, if you want to remap the power in MW, Object 30 Index 87, to the first, Index 0, set DNPAID to N and enter 87 in the setting for Row 1 of the custom analog map.

Table E.9 SEL-487E DNP3 Map Settings (Sheet 1 of 2)

Name	Description	Range	Default
MAPSEL	Reference Map Selection	B, E	B
DNPBID	Default binary input map enable	Y, N	Y
DNPBOD	Default binary output map enable	Y, N	Y
DNPCOD	Default counters map enable	Y, N	Y
DNPAID	Default analog input map enable	Y, N	Y
DNPAOD	Default analog output map enable	Y, N	Y
Row 1[a]	Custom binary input map	Index number from default map	
•			
•			
•			
Row 400[a]	Maximum custom binary input map		
Row 1[a]	Custom binary output map	Index number from default map	
•			
•			
•			
Row 70[a]	Maximum custom binary output map		
Row 1[a]	Custom counter map, custom counter dead band[b] (Example: 3, 6)	Index number from default map; 1–32767	
•			
•			
•			
Row 10[a]	Last custom counter map; custom counter dead band[b] (Example: 3, 6)	Index number from default map; 1–32767	

Table E.9 SEL-487E DNP3 Map Settings (Sheet 2 of 2)

Name	Description	Range	Default
Row 1[a]	Custom analog input map; custom analog input scaling[b], custom analog input dead band[b] (Example: 3, 10, 6)	Index number from default map; 0.001–1000.000: 1–32767	
• • •			
Row 200[a]	Last custom analog input map; custom analog input scaling[b] custom analog input dead band	Index number from default map; 0.001–1000.000: 1–32767	
Row 1[a]	Custom analog output map	Index number from default map	
Row 2[a]	Custom analog output map	Index number from default map	

[a] Free-form setting row hidden if corresponding default map is enabled.
[b] Optional. If not specified, defaults to value associated with point in default map.

The settings shown in *Table E.9* that follow DNPAOD are entered in a line-based free-form format. An example of these settings is shown in the *Application Example on page E.34*. You can program a custom scaling and dead band for each point where indicated. If you do not specify a custom scaling or dead band, the relay will use the default for the type of value you are mapping. For example, if you enter 87 in Row 1 of the custom analog map with no other parameters, the power in MW will be available as Object 30 and 32, Index 0 and the relay will use the default scaling DECPLM and default dead band of ANADBM (*Table E.9*). Scaling factors allow you to overcome the limitations imposed by the integer nature of Objects 30 and 32. For example, the relay rounds a value of 11.4 amps to 11 amps. Use the scaling to include decimal point values by multiplying by a number larger than one. If you use 10 as a scaling factor, 11.4 amps will be transmitted as 114. You must divide the value by 10 in the master device to see the original value including one decimal place.

You can also use scaling to avoid overflowing the 16-bit maximum integer value of 32767. If you have a value that can reach 157834 you cannot send it using DNP3 16-bit analog object variations. Use a scaling factor of 0.1 so that the maximum value reported is 15783. You must multiply the value by 10 in the master to see a value of 157830. You will lose some precision as the last digit is rounded in the scaling process, but you can transmit the scaled value using standard DNP3 Objects 30 and 32.

Warm Start and Cold Start

The DNP3 function codes for warm start and cold start reset the SEL-487E serial port. These function codes do not interrupt protection processes within the relay.

Testing

Use the **TEST DNP** command to test the data mapping from the relay to your DNP3 master. You can use the **TEST DNP** command to force DNP3 values by object and index number. Although the relay reports forced values to the DNP3 host, these values do not affect protection processing or other protocol interfaces on the SEL-487E. The **TEST DNP** command operates by object and index number, so it works equally well with custom mapping and the default DNP3 map.

When you are using the **TEST DNP** command to test DNP3 operation, the Relay Word bit TESTDNP will be asserted to indicate that test mode is active. The DNP3 status bit will also show forced status for any object variations that include status.

DNP3 Documentation

Device Profile

Table E.10 contains the standard DNP3 device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table E.10 SEL-487E DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-487E Relay
Highest DNP3 request level	Level 2
Highest DNP3 response level	Level 2
Device function	Outstation
Notable objects, functions, and/or qualifiers supported	Virtual terminal
Maximum data link frame size transmitted/received (octets)	292
Maximum data link retries	Configurable, range 0 to 15
Requires data link layer confirmation	Configurable by setting
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch Off	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged

Table E.10 SEL-487E DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
Reports time-tagged binary input change events when no specific variation requested	Binary Input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	16 bits
Sends multifragment responses	No

Object List

Table E.11 lists the objects and variations with supported function codes and qualifier codes available in the SEL-487E. The list of supported objects conforms to the format laid out in the DNP3 specifications and includes both supported and unsupported objects. Those that are supported include the function and qualifier codes. The objects that are not supported are shown without any corresponding function and qualifier codes.

Table E.11 SEL-487E DNP3 Object List (Sheet 1 of 4)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8		
1	1	Binary Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
1	2[e]	Binary Input With Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
2	0	Binary Input Change—All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3[f]	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1	0, 1, 6, 7, 8		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
20	6[e]	16-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				

Table E.11 SEL-487E DNP3 Object List (Sheet 2 of 4)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
21	0	Frozen Counter—All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Frozen Delta Counter Event With Time				
23	8	16-Bit Frozen Delta Counter Event With Time				
30	0	Analog Input—All Variations	1	0, 1, 6, 7, 8		
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				

Table E.11 SEL-487E DNP3 Object List (Sheet 3 of 4)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28
32	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
40	0	Analog Output Status—All Variations	1	0, 1, 6, 7, 8		
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 7, 8
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date—All Variations				
50	1	Time and Date	1, 2	7, 8 index=0	129	07, quanity=1
50	2	Time and Date With Interval				
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO	07, quanity=1			
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine	129	07, quantity=1		
60	0	All Classes of Data	1, 20, 21	6		
60	1	Class 0 Data	1	6		
60	2	Class 1 Data	1, 20, 21	6, 7, 8		
60	3	Class 2 Data	1, 20, 21	6, 7, 8		
60	4	Class 3 Data	1, 20, 21	6, 7, 8		
70	1	File Identifier				
80	1	Internal Indications	2	0, 1 index=7		

Table E.11 SEL-487E DNP3 Object List (Sheet 4 of 4)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary—Coded Decimal				
101	2	Medium Packed Binary—Coded Decimal				
101	3	Large Packed Binary—Coded Decimal				
112	All	Virtual Terminal Output Block	2	6		
113	All	Virtual Terminal Event Data	1, 20, 21	6	129, 130	17, 28
N/A		No object required for the following function codes: 13 cold start 14 warm start 23 delay measurement	13, 14, 23			

[a] Supported in requests from master.
[b] May generate in response to master.
[c] Decimal
[d] Hexadecimal
[e] Default variation
[f] Supports request, but response contains no data.

Default Data Map

Table E.12 shows the SEL-487E default DNP3 data map. The default data map makes a wide range of data in the relay available. If your DNP3 master does Class 0 polls (polls of all present value points) the response will be quite large. Use the custom DNP3 mapping functions of the SEL-487E to reduce the data map to the points that your application requires.

The SEL-487E provides binary input information with one of two reference maps: base or extended. The default map selection is base (MAPSEL := B). With the base reference map, Object 1 and 2 Indices 0 through 799 and 800 through 1599 contain the same data but provide different levels of time-stamp accuracy for associated Object 2 DNP3 events. The SER (sequential events recorder) in the relay controls events for indices 800 through 1599. The time stamps for these indices have the same accuracy and resolution that the SER provides. The only points available within indices 800 through 1599 are those that you configure for tracking by the relay SER. Use indices 800 through 1599 and corresponding SER settings to track each change of bits in the Relay Word and provide SER quality time stamps via DNP3. Event report for indices 0 through 799 uses a slower, less accurate time stamping mechanism, but this reporting operates for all points within the range without additional configuration.

With the extended reference map, Object 1 and 2 Indices 16 through 265 contain the points available for tracking by the relay SER. SER quality time stamps are available for these points and only the SER settings are needed in order to configure the points available. The entire visible Relay Word is available starting at Index 272.

The relay scales analog values by the indicated settings or fixed scaling indicated in the description. Analog dead bands for event reporting use the indicated settings, or ANADBM if you have specified no setting.

Table E.12 SEL-487E DNP3 Default Data Map (Sheet 1 of 7)

Object	Indices	Description
		MAPSEL = B
01,02	000–799	Relay Word bits
01,02	800–1599	SER Points add 800 to indices
01,02	1600–1615	Relay front panel target rows 1 and 2
01,02	1616	Relay Disabled
01,02	1617	Relay diagnostic failure
01,02	1618	Relay diagnostic warning
01,02	1619	New relay event available
01,02	1620	Settings change or relay restart
01,02	1621–1623	Reserved for future status points
01,02	1624–1631	Relay front panel target row 3
		MAPSEL = E
01,02	0	Relay Disabled
01,02	1	Relay diagnostic failure
01,02	2	Relay diagnostic warning
01,02	3	New relay event available
01,02	4	Settings change or relay restart
01,02	5–15	Reserved
01,02	16–265	SER points 1–250
01,02	266–271	Reserved
01,02	272-	Entire visible relay word, starting from bit 0
		MAPSEL = B, MAPSEL = E
10,12	00–31	Remote bits RB01–RB32
10,12	32–47	Remote bit pairs RB01–RB32
10,12	48	Pulse Open breaker S command (OCS)
10,12	49	Pulse Close breaker S command (CCS)
10,12	50	Pulse Open breaker T command (OCT)
10,12	51	Pulse Close breaker T command (CCT)
10,12	52	Pulse Open breaker U command (OCU)
10,12	53	Pulse Close breaker U command (CCU)
10,12	54	Pulse Open breaker W command (OCW)
10,12	55	Pulse Close breaker W command (CCW)
10,12	56	Pulse Open Breaker X command (OCX)
10,12	57	Pulse Close Breaker X command (CCX)

Table E.12 SEL-487E DNP3 Default Data Map (Sheet 2 of 7)

Object	Indices	Description
10,12	58–63	Reserved for future breakers
10,12	64	Open/Close pair for Breaker S
10,12	65	Open/Close pair for Breaker T
10,12	66	Open/Close pair for Breaker U
10,12	67	Open/Close pair for Breaker W
10,12	68	Open/Close pair for Breaker X
10,12	69–71	Reserved for future breaker pairs
10,12	72	Reset demands
10,12	73	Reset peak demands
10,12	74	Reset energies
10,12	75	Reset front panel targets
10,12	76	Read next relay event
10,12	77–79	Reserved
10,12	80	Reset breaker monitor S
10,12	81	Reset breaker monitor T
10,12	82	Reset breaker monitor U
10,12	83	Reset breaker monitor W
10,12	84	Reset breaker monitor X
10,12	85–87	Reserved
10,12	88	Pulse Open Disconnect 1 (89OC1)
10,12	89	Pulse Close Disconnect 1 (89CC1)
10,12	90	Pulse Open Disconnect 2 (89OC2)
10,12	91	Pulse Close Disconnect 2 (89CC2)
10,12	92	Pulse Open Disconnect 3 (89OC3)
10,12	93	Pulse Close Disconnect 3 (89CC3)
10,12	94	Pulse Open Disconnect 4 (89OC4)
10,12	95	Pulse Close Disconnect 4 (89CC4)
10,12	96	Pulse Open Disconnect 5 (89OC5)
10,12	97	Pulse Close Disconnect 5 (89CC5)
10,12	98	Pulse Open Disconnect 6 (89OC6)
10,12	99	Pulse Close Disconnect 6 (89CC6)
10,12	100	Pulse Open Disconnect 7 (89OC7)
10,12	101	Pulse Close Disconnect 7 (89CC7)
10,12	102	Pulse Open Disconnect 8 (89OC8)
10,12	103	Pulse Close Disconnect 8 (89CC8)
10,12	104	Open/Close pair for Disconnect 1
10,12	105	Open/Close pair for Disconnect 2
10,12	106	Open/Close pair for Disconnect 3
10,12	107	Open/Close pair for Disconnect 4
10,12	108	Open/Close pair for Disconnect 5
10,12	109	Open/Close pair for Disconnect 6

Table E.12 SEL-487E DNP3 Default Data Map (Sheet 3 of 7)

Object	Indices	Description
10,12	110	Open/Close pair for Disconnect 7
10,12	111	Open/Close pair for Disconnect 8
		Counters
20,22	00	Active settings group
20,22	01	Reserved
20,22	02	Reserved
20,22	03	Number of unread event reports
20,22	04	Number of breaker operations on breaker S (BS_TRP_cnt)
20,22	05	Number of breaker operations on breaker T (BT_TRP_cnt)
20,22	06	Number of breaker operations on breaker U (BU_TRP_cnt)
20,22	07	Number of breaker operations on breaker W (BW_TRP_cnt)
20,22	08	Number of breaker operations on breaker X (BX_TRP_cnt)
		Analog Inputs
30,32	00, 01[a]	IAS magnitude and angle (IASFMC, IASFAC)[b]
30,32	02, 03[a]	IBS magnitude and angle (IBSFMC, IBSFAC)[b]
30,32	04, 05[a]	ICS magnitude and angle (ICSFMC, ICSFAC)[b]
30,32	06, 07[a]	Terminal S zero-sequence current (3I0SMC, 3I0SAC)[b]
30,32	08, 09[a]	Terminal S positive-sequence current (I1SMC, I1SAC)[b]
30,32	10, 11[a]	Terminal S negative-sequence current (3I2SMC, 3I2SAC)[b]
30,32	12, 13[a]	IAT magnitude and angle (IATFMC, IATFAC)[b]
30,32	14, 15[a]	IBT magnitude and angle (IBTFMC, IBTFAC)[b]
30,32	16, 17[a]	ICT magnitude and angle (ICTFMC, ICTFAC)[b]
30,32	18, 19[a]	Terminal T zero-sequence current (3I0TMC, 3I0TAC)[b]
30,32	20, 21[a]	Terminal T positive-sequence current (I1TMC, I1TAC)[b]
30,32	22, 23[a]	Terminal T negative-sequence current (3I2TMC, 3I2TAC)[b]
30,32	24, 25[a]	IAU magnitude and angle (IAUFMC, IAUFAC)[b]
30,32	26, 27[a]	IBU magnitude and angle (IBUFMC, IBUFAC)[b]
30,32	28, 29[a]	ICU magnitude and angle (ICUFMC, ICUFAC)[b]
30,32	30, 31[a]	Terminal U zero-sequence current (3I0UMC, 3I0UAC)[b]
30,32	32, 33[a]	Terminal U positive-sequence current (I1UMC, I1UAC)[b]
30,32	34, 35[a]	Terminal U negative-sequence current (3I2UMC, 3I2UAC)[b]
30,32	36, 37[a]	IAW magnitude and angle (IAWFMC, IAWFAC)[b]
30,32	38, 39[a]	IBW magnitude and angle (IBWFMC, IBWFAC)[b]
30,32	40, 41[a]	ICW magnitude and angle (ICWFMC, ICWFAC)[b]
30,32	42, 43[a]	Terminal W zero-sequence current (3I0WMC, 3I0WAC)[b]
30,32	44, 45[a]	Terminal W positive-sequence current (I1WMC, I1WAC)[b]
30,32	46, 47[a]	Terminal W negative-sequence current (3I2WMC, 3I2WAC)[b]
30,32	48, 49[a]	IAX magnitude and angle (IAXFMC, IAXFAC)[b]
30,32	50, 51[a]	IBX magnitude and angle (IBXFMC, IBXFAC)[b]
30,32	52, 53[a]	ICX magnitude and angle (ICXFMC, ICXFAC)[b]
30,32	54, 55[a]	Terminal X zero-sequence current (3I0XMC, 3I0XAC)[b]

Table E.12 SEL-487E DNP3 Default Data Map (Sheet 4 of 7)

Object	Indices	Description
30,32	56, 57[a]	Terminal X positive-sequence current (I1XMC, I1XAC)[b]
30,32	58, 59[a]	Terminal X negative-sequence current (3I2XMC, 3I2XAC)[b]
30,32	60, 61[a]	IAY magnitude and angle (IAYFMC, IAYFAC)[b]
30,32	62, 63[a]	IBY magnitude and angle (IBYFMC, IBYFAC)[b]
30,32	64, 65[a]	ICY magnitude and angle (ICYFMC, ICYFAC)[b]
30,32	66, 67[a]	IAST magnitude and angle (IASTFMC, IASTFAC)[b]
30,32	68, 69[a]	IBST magnitude and angle (IBSTFMC, IBSTFAC)[b]
30,32	70, 71[a]	ICST magnitude and angle (ICSTFMC, ICSTFAC)[b]
30,32	72, 73[a]	Combined Terminal ST zero-sequence current (3I0STMC, 3I0STAC)[b]
30,32	74, 75[a]	Combined Terminal ST positive-sequence current (I1STMC, I1STAC)[b]
30,32	76, 77[a]	Combined Terminal ST negative-sequence current (3I2STMC, 3I2STAC)[b]
30,32	78, 79[a]	IATU magnitude and angle (IATUFMC, IATUFAC)[b]
30,32	80, 81[a]	IBTU magnitude and angle (IBTUFMC, IBTUFAC)[b]
30,32	82, 83[a]	ICTU magnitude and angle (ICTUFMC, ICTUFAC)[b]
30,32	84, 85[a]	Combined Terminal TU zero-sequence current (3I0TUMC, 3I0TUAC)[b]
30,32	86, 87[a]	Combined Terminal TU positive-sequence current (I1TUMC, I1TUAC)[b]
30,32	88, 89[a]	Combined Terminal TU negative-sequence current (3I2TUMC, 3I2TUAC)[b]
30,32	90, 91[a]	IAUW magnitude and angle (IAUWFMC, IAUWFAC)[b]
30,32	92, 93[a]	IBUW magnitude and angle (IBUWFMC, IBUWFAC)[b]
30,32	94, 95[a]	ICUW magnitude and angle (ICUWFMC, ICUWFAC)[b]
30,32	96, 97[a]	Combined Terminal UW zero-sequence current (3I0UWMC, 3I0UWAC)[b]
30,32	98, 99[a]	Combined Terminal UW positive-sequence current (I1UWMC, I1UWAC)[b]
30,32	100, 101[a]	Combined Terminal UW negative-sequence current (3I2UWMC, 3I2UWAC)[b]
30,32	102, 103[a]	IAWX magnitude and angle (IAWXFMC, IAWXFAC)[b]
30,32	104, 105[a]	IBWX magnitude and angle (IBWXFMC, IBWXFAC)[b]
30,32	106, 107[a]	ICWX magnitude and angle (ICWXFMC, ICWXFAC)[b]
30,32	108, 109[a]	Combined Terminal WX zero-sequence current (3I0WXMC, 3I0WXAC)[b]
30,32	110, 111[a]	Combined Terminal WX positive-sequence current (I1WXMC, I1WXAC)[b]
30,32	112, 113[a]	Combined Terminal WX negative-sequence current (3I2WXMC, 3I2WXAC)[b]
30,32	114, 115[c]	VAV magnitude and angle (VAVFMC, VAVFAC)[b]
30,32	116, 117[c]	VBV magnitude and angle (VBVFMC, VBVFAC)[b]
30,32	118, 119[c]	VCV magnitude and angle (VCVFMC, VCVFAC)[b]
30,32	120, 121[c]	VABV magnitude and angle (VABVFMC, VABVFAC)[b]
30,32	122, 123[c]	VBCV magnitude and angle (VBCVFMC, VBCVFAC)[b]
30,32	124, 125[c]	VCAV magnitude and angle (VCAVFMC, VCAVFAC)[b]
30,32	126, 127[c]	Terminal V zero-sequence voltage (3V0VMC, 3V0VAC)[b]
30,32	128, 129[b]	Terminal V positive-sequence voltage (V1VMC, V1VAC)[b]
30,32	130, 131[c]	Terminal V negative-sequence voltage (3V2VMC, 3V2VAC)[b]
30,32	132, 133[c]	VAZ magnitude and angle (VAZFMC, VAZFAC)[b]
30,32	134, 135[c]	VBZ magnitude and angle (VBZFMC, VBZFAC)[b]
30,32	136, 137[c]	VCZ magnitude and angle (VCZFMC, VCZFAC)[b]

Table E.12 SEL-487E DNP3 Default Data Map (Sheet 5 of 7)

Object	Indices	Description
30,32	138, 139[c]	VABZ magnitude and angle (VABZFMC, VABZFAC)[b]
30,32	140, 141[c]	VBCZ magnitude and angle (VBCZFMC, VBCZFAC)[b]
30,32	142, 143[c]	VCAZ magnitude and angle (VCAZFMC, VCAZFAC)[b]
30,32	144, 145[c]	Terminal Z zero-sequence voltage (3V0ZMC, 3V0ZAC)[b]
30,32	146, 147[c]	Terminal Z positive-sequence voltage (V1ZMC, V1ZAC)[b]
30,32	148, 149[c]	Terminal Z negative-sequence voltage (3V2ZMC, 3V2ZAC)[b]
30,32	150, 151, 152[d]	Terminal S, phase A power (PASFS, QASFS, SASFS)[b]
30,32	153, 154, 155[d]	Terminal S, phase B power (PBSFS, QBSFS, SBSFS)[b]
30,32	156, 157, 158[d]	Terminal S, phase C power (PCSFS, QCSFS, SCSFS)[b]
30,32	159, 160, 161[d]	Terminal S, 3 phase power (3PSFS, 3QSFS, 3SSFS)[b]
30,32	162, 163, 164[d]	Terminal T, phase A power (PATFS, QATFS, SATFS)[b]
30,32	165, 166, 167[d]	Terminal T, phase B power (PBTFS, QBTFS, SBTFS)[b]
30,32	168, 169, 170[d]	Terminal T, phase C power (PCTFS, QCTFS, SCTFS)[b]
30,32	171, 172, 173[d]	Terminal T, 3 phase power (3PTFS, 3QTFS, 3STFS)[b]
30,32	174, 175, 176[d]	Terminal U, phase A power (PAUFS, QAUFS, SAUFS)[b]
30,32	177, 178, 179[d]	Terminal U, phase B power (PBUFS, QBUFS, SBUFS)[b]
30,32	180, 181, 182[d]	Terminal U, phase C power (PCUFS, QCUFS, SCUFS)[b]
30,32	183, 184, 185[d]	Terminal U, 3 phase power (3PUFS, 3QUFS, 3SUFS)[b]
30,32	186, 187, 188[d]	Terminal W, phase A power (PAWFS, QAWFS, SAWFS)[b]
30,32	189, 190, 191[d]	Terminal W, phase B power (PBWFS, QBWFS, SBWFS)[b]
30,32	192, 193, 194[d]	Terminal W, phase C power (PCWFS, QCWFS, SCWFS)[b]
30,32	195, 196, 197[d]	Terminal W, 3 phase power (3PWFS, 3QWFS, 3SWFS)[b]
30,32	198, 199, 200[d]	Terminal X, phase A power (PAXFS, QAXFS, SAXFS)[b]
30,32	201, 202, 203[d]	Terminal X, phase B power (PBXFS, QBXFS, SBXFS)[b]
30,32	204, 205, 206[d]	Terminal X, phase C power (PCXFS, QCXFS, SCXFS)[b]
30,32	207, 208, 209[d]	Terminal X, 3 phase power (3PXFS, 3QXFS, 3SXFS)[b]
30,32	210, 211, 212[d]	Combined Terminal ST, phase A power (PASTFS, QASTFS, SASTFS)[b]
30,32	213, 214, 215[d]	Combined Terminal ST, phase B power (PBSTFS, QBSTFS, SBSTFS)[b]
30,32	216, 217, 218[d]	Combined Terminal ST, phase C power (PCSTFS, QCSTFS, SCSTFS)[b]
30,32	219, 220, 221[d]	Combined Terminal ST, 3 phase power (3PSTFS, 3QSTFS, 3SSTFS)[b]
30,32	222, 223, 224[d]	Combined Terminal TU, phase A power (PATUFS, QATUFS, SATUFS)[b]
30,32	225, 226, 227[d]	Combined Terminal TU, phase B power (PBTUFS, QBTUFS, SBTUFS)[b]
30,32	228, 229, 230[d]	Combined Terminal TU, phase C power (PCTUFS, QCTUFS, SCTUFS)[b]
30,32	231, 232, 233[d]	Combined Terminal TU, 3 phase power (3PTUFS, 3QTUFS, 3STUFS)[b]
30,32	234, 235, 236[d]	Combined Terminal UW, phase A power (PAUWFS, QAUWFS, SAUWFS)[b]
30,32	237, 238, 239[d]	Combined Terminal UW, phase B power (PBUWFS, QBUWFS, SBUWFS)[b]
30,32	240, 241, 242[d]	Combined Terminal UW, phase C power (PCUWFS, QCUWFS, SCUWFS)[b]
30,32	243, 244, 245[d]	Combined Terminal UW, 3 phase power (3PUWFS, 3QUWFS, 3SUWFS)[b]
30,32	246, 247, 248[d]	Combined Terminal WX, phase A power (PAWXFS, QAWXFS, SAWXFS)[b]
30,32	249, 250, 251[d]	Combined Terminal WX, phase B power (PBWXFS, QBWXFS, SBWXFS)[b]
30,32	252, 253, 254[d]	Combined Terminal WX, phase C power (PCWXFS, QCWXFS, SCWXFS)[b]

Table E.12 SEL-487E DNP3 Default Data Map (Sheet 6 of 7)

Object	Indices	Description
30,32	255, 256, 257[d]	Combined Terminal WX, 3 phase power (3PWXFS, 3QWXFS, 3SWXFS)[b]
30,32	258–261[d]	Terminal S power factors (DPFAS, DPFBS, DPFCS, 3DPFS)[b]
30,32	262–265[d]	Terminal T power factors (DPFAT, DPFBT, DPFCT, 3DPFT)[b]
30,32	266–269[d]	Terminal U power factors (DPFAU, DPFBU, DPFCU, 3DPFU)[b]
30,32	270–273[d]	Terminal W power factors (DPFAW, DPFBW, DPFCW, 3DPFW)[b]
30,32	274–277[d]	Terminal X power factors (DPFAX, DPFBX, DPFCX, 3DPFX)[b]
30,32	278–281[d]	Combined Terminal ST power factors (DPFAST, DPFBST, DPFCST, 3DPFST)[b]
30,32	282–285[d]	Combined Terminal TU power factors (DPFATU, DPFBTU, DPFCTU, 3DPFTU)[b]
30,32	286–289[d]	Combined Terminal UW power factors (DPFAUW, DPFBUW, DPFCUW, 3DPFUW)[b]
30,32	290–293[d]	Combined Terminal WX power factors (DPFAWX, DPFBWX, DPFCWX, 3DPFWX)[b]
30,32	294–296	Terminal S active energy import, export, and total (3PSN_MWh, 3PSP_MWh, 3PST_MWh)[b]
30,32	297–299	Terminal S reactive energy import, export, and total (3QSN_MVARh, 3QSP_MVARh, 3QST_MVARh)[b]
30,32	300–302	Terminal T active energy import, export, and total (3PTN_MWh, 3PTP_MWh, 3PTT_MWh)[b]
30,32	303–305	Terminal T reactive energy import, export, and total (3QTN_MVARh, 3QTP_MVARh, 3QTT_MVARh)[b]
30,32	306–308	Terminal U active energy import, export, and total (3PUN_MWh, 3PUP_MWh, 3PUT_MWh)[b]
30,32	309–311	Terminal U reactive energy import, export, and total (3QUN_MVARh, 3QUP_MVARh, 3QUT_MVARh)[b]
30,32	312–314	Terminal W active energy import, export, and total (3PWN_MWh, 3PWP_MWh, 3PWT_MWh)[b]
30,32	315–317	Terminal W reactive energy import, export, and total (3QWN_MVARh, 3QWP_MVARh, 3QWT_MVARh)[b]
30,32	318–320	Terminal X active energy import, export, and total (3PXN_MWh, 3PXP_MWh, 3PXT_MWh)[b]
30,32	321–323	Terminal X reactive energy import, export, and total (3QXN_MVARh, 3QXP_MVARh, 3QXT_MVARh)[b]
30,32	324–326	Combined Terminal ST active energy import, export, and total (3PSTN_MWh, 3PSTP_MWh, 3PSTT_MWh)[b]
30,32	327–329	Combined Terminal ST reactive energy import, export, and total (3QSTN_MVARh, 3QSTP_MVARh, 3QSTT_MVARh)[b]
30,32	330–332	Combined Terminal TU active energy import, export, and total (3PTUN_MWh, 3PTUP_MWh, 3PTUT_MWh)[b]
30,32	333–335	Combined Terminal TU reactive energy import, export, and total (3QTUN_MVARh, 3QTUP_MVARh, 3QTUT_MVARh)[b]
30,32	336–338	Combined Terminal UW active energy import, export, and total (3PUWN_MWh, 3PUWP_MWh, 3PUWT_MWh)[b]
30,32	339–341	Combined Terminal UW reactive energy import, export, and total (3QUWN_MVARh, 3QUWP_MVARh, 3QUWT_MVARh)[b]
30,32	342–344	Combined Terminal WX active energy import, export, and total (3PWXN_MWh, 3PWXP_MWh, 3PWXT_MWh)[b]
30,32	345–347	Combined Terminal WX reactive energy import, export, and total (3QWXN_MVARh, 3QWXP_MVARh, 3QWXT_MVARh)[b]
30,32	348[d]	IOPA per-unit operating current (87IOPAC)[b]
30,32	349[d]	IOPB per-unit operating current (87IOPBC)[b]
30,32	350[d]	IOPC per-unit operating current (87IOPCC)[b]
30,32	351[d]	IRTA per-unit restraint current (87IRTAC)[b]

Table E.12 SEL-487E DNP3 Default Data Map (Sheet 7 of 7)

Object	Indices	Description
30,32	352[d]	IRTB per-unit restraint current (87IRTBC)[b]
30,32	353[d]	IRTC per-unit restraint current (87IRTCC)[b]
30,32	354[e]	DC1 battery voltage (in volts)
30,32	355[e]	Frequency (Hz) (FREQ)[b]
30,32	356	Internal temperature (RLYTEMP)[b]
30,32	357	Reserved
30,32	358–367	Demand values: DM_01 – DM_10[b]
30,32	368–377	Peak Demand values (DMM_01 – DMM_10)[b]
30,32	378–380	Breaker S contact wear percentage (BSBCWPA, BSBCWPB, BSBCWPC)[b]
30,32	381–383	Breaker T contact wear percentage (BTBCWPA, BTBCWPB, BTBCWPC)[b]
30,32	384–386	Breaker U contact wear percentage (BUBCWPA, BUBCWPB, BUBCWPC)[b]
30,32	387–389	Breaker W contact wear percentage (BWBCWPA, BWBCWPB, BWBCWPC)[b]
30,32	390–392	Breaker X contact wear percentage (BXBCWPA, BXBCWPB, BXBCWPC)[b]
30,32	393–399	Reserved
30,32	400[f]	Fault type (*Table E.15* and *Table E.16*)
30,32[f]	401[f]	Fault targets (the two relay target rows)
30,32	402[f]	Fault target (3rd target row in upper byte, lower byte is 0)
30,32	403[f]	Reserved
30,32	404[f]	Fault frequency
30,32	405[f]	Fault settings group
30,32	406,407[f]	Reserved
30,32	408–410[f]	Fault time in DNP3 format (high, middle, and low 16 bits)
30,32	411–419[f]	Reserved for additional fault information
30,32	420–451	First 32 automation math variables (AMV01–AMV32)
		Analog Inputs
40,41	00	Active settings group (1–6)

[a] Default current scaling DECPLA on magnitudes and scale factor of 100 on angles. Dead band ANADBA on magnitudes and ANADBM on angles.
[b] Analog quantity labels.
[c] Default voltage scaling DECPLV on magnitudes and scale factor of 100 M angles. Deadband ANADBV on magnitudes and ANDBM on angles.
[d] Default miscellaneous scaling DECPLM and deadband ANADBM.
[e] Default scale factor of 100.
[f] Event data shall only be generated for the fault summary information if the relay is operating in single event mode.

With the base reference map, the Relay Word bits mapped into Objects 1 and 2 are shown in *Table E.13*. For non-SER points in the range 0–799, use the Index Range column directly. For SER points in the range 800–1599, add 800 to the indices in *Table E.13*. The table lists eight bits in each row and the index range for each row. To determine the index for a specific point, add the Relay Word bit number (0 to 7) to the smaller number in the range listed in the first column. For example, the index of TLED_4 is 12 (the bit number, 4, plus the smaller number in the range, 8).

Table E.13 SEL-487E Object 1, 2 Relay Word Bit Mapping (Sheet 1 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
7-0	EN	TRIPLED	*	*	*	*	*	*
15-8	TLED_1	TLED_2	TLED_3	TLED_4	TLED_5	TLED_6	TLED_7	TLED_8
23-16	TLED_9	TLED_10	TLED_11	TLED_12	TLED_13	TLED_14	TLED_15	TLED_16
31-24	TLED_17	TLED_18	TLED_19	TLED_20	TLED_21	TLED_22	TLED_23	TLED_24
39-32	52CLS	52ALS	52CLT	52ALT	52CLU	52ALU	52CLW	52ALW
47-40	52CLX	52ALX	*	*	*	*	*	*
55-48	89CL1	89CL2	89CL3	89CL4	89CL5	89CL6	89CL7	89CL8
63-56	89OPN1	89OPN2	89OPN3	89OPN4	89OPN5	89OPN6	89OPN7	89OPN8
71-64	89AL1	89AL2	89AL3	89AL4	89AL5	89AL6	89AL7	89AL8
79-72	89OIP	89AL	*	*	*	*	*	*
87-80	EBSMON	BSBCWAL	BSESOAL	BSBITAL	BSKAIAL	BSMSOAL	BSMRTAL	*
95-88	EBTMON	BTBCWAL	BTESOAL	BTBITAL	BTKAIAL	BTMSOAL	BTMRTAL	*
103-96	EBUMON	BUBCWAL	BUESOAL	BUBITAL	BUKAIAL	BUMSOAL	BUMRTAL	*
111-104	EBWMON	BWBCWAL	BWESOAL	BWBITAL	BWKAIAL	BWMSOAL	BWMRTAL	*
119-112	EBXMON	BXBCWAL	BXESOAL	BXBITAL	BXKAIAL	BXMSOAL	BXMRTAL	*
127-120	TO1_1	TO2_1	TO3_1	TO1	TO1_2	TO2_2	TO3_2	TO2
135-128	HS1_1	HS2_1	HS3_1	HS1	HS1_2	HS2_2	HS3_2	HS2
143-136	FAA1_1	FAA2_1	FAA3_1	FAA1	FAA1_2	FAA2_2	FAA3_2	FAA2
151-144	RLL_1	RLL_2	RLL_3	RLL	TLL_1	TLL_2	TLL_3	TLL
159-152	CSE_1	CSE_2	CSE_3	CSE	CSCM_1	CSCM_2	CSCM_3	CSCM
167-160	CSALRM	*	*	*	MAMB_OK	MTO1_OK	MTO2_OK	MTO3_OK
175-168	RTD08OK	RTD07OK	RTD06OK	RTD05OK	RTD04OK	RTD03OK	RTD02OK	RTD01OK
183-176	*	*	*	*	RTD09OK	RTD10OK	RTD11OK	RTD12OK
191-184	*	*	*	*	*	*	RTDCOMF	RTDFL
199-192	DC1F	DC1W	DC1G	DC1R	*	*	*	*
207-200	RB25	RB26	RB27	RB28	RB29	RB30	RB31	RB32
215-208	RB17	RB18	RB19	RB20	RB21	RB22	RB23	RB24
223-216	RB09	RB10	RB11	RB12	RB13	RB14	RB15	RB16
231-224	RB01	RB02	RB03	RB04	RB05	RB06	RB07	RB08
239-232	SG6	SG5	SG4	SG3	SG2	SG1	CHSG	*
247-240	*	IN107	1N106	IN105	IN104	IN103	IN102	IN101
255-248	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
263-256	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
271-264	IN224	IN223	IN222	IN221	IN220	IN219	IN218	IN217
279-272	IN308	IN307	IN306	IN305	IN304	IN303	IN302	IN301
287-280	IN316	IN315	IN314	IN313	IN312	IN311	IN310	IN309
295-288	IN324	IN323	IN322	IN321	IN320	IN319	IN318	IN317
303-296	PSV08	PSV07	PSV06	PSV05	PSV04	PSV03	PSV02	PSV01
311-304	PSV16	PSV15	PSV14	PSV13	PSV12	PSV11	PSV10	PSV09

Table E.13 SEL-487E Object 1, 2 Relay Word Bit Mapping (Sheet 2 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
319-312	PSV24	PSV23	PSV22	PSV21	PSV20	PSV19	PSV18	PSV17
327-320	PSV32	PSV31	PSV30	PSV29	PSV28	PSV27	PSV26	PSV25
335-328	PLT08	PLT07	PLT0	PLT05	PLT04	PLT03	PLT02	PLT01
343-336	PLT16	PLT15	PLT14	PLT13	PLT12	PLT11	PLT10	PLT09
351-344	PCT08Q	PCT07Q	PCT06Q	PCT05Q	PCT04Q	PCT03Q	PCT02Q	PCT01Q
359-352	PCT16Q	PCT15Q	PCT14Q	PCT13Q	PCT12Q	PCT11Q	PCT10Q	PCT09Q
367-360	PST08Q	PST07Q	PST06Q	PST05Q	PST04Q	PST03Q	PST02Q	PST01Q
375-368	PST16Q	PST15Q	PST14Q	PST13Q	PST12Q	PST11Q	PST10Q	PST09Q
383-376	PCN08Q	PCN07Q	PCN06Q	PCN05Q	PCN04Q	PCN03Q	PCN02Q	PCN01Q
391-384	PCN16Q	PCN15Q	PCN14Q	PCN13Q	PCN12Q	PCN11Q	PCN10Q	PCN09Q
399-392	ASV008	ASV007	ASV006	ASV005	ASV004	ASV003	ASV002	ASV001
407-400	ASV016	ASV015	ASV014	ASV013	ASV012	ASV011	ASV010	ASV009
415-408	ASV024	ASV023	ASV022	ASV021	ASV020	ASV019	ASV018	ASV017
423-416	ASV032	ASV031	ASV030	ASV029	ASV028	ASV027	ASV026	ASV025
431-424	ALT08	ALT07	ALT06	ALT05	ALT04	ALT03	ALT02	ALT01
439-432	ALT16	ALT15	ALT14	ALT13	ALT12	ALT11	ALT10	ALT09
447-440	AST08Q	AST07Q	AST06Q	AST05Q	AST04Q	AST03Q	AST02Q	AST01Q
455-448	AST16Q	AST15Q	AST14Q	AST13Q	AST12Q	AST11Q	AST10Q	AST09Q
463-456	ACN08Q	ACN07Q	ACN06Q	ACN05Q	ACN04Q	ACN03Q	ACN02Q	ACN01Q
471-464	ACN16Q	ACN15Q	ACN14Q	ACN13Q	ACN12Q	ACN11Q	ACN10Q	ACN09Q
479-472	PUNRLBL	PFRTEX	MATHERR	*	*	*	*	*
487-480	AUNRLBL	AFRTEXP	AFRTEXA	*	*	*	*	*
495-488	SALARM	HALARM	BADPASS	CCALARM	*	*	*	*
503-496	TIRIG	TUPDH	TSYNCA	TSOK	PMDOK	*	*	*
511-504	OUT108	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
519-512	OUT208	OUT207	OUT206	OUT205	OUT204	OUT203	OUT202	OUT201
527-520	OUT216	OUT215	OUT214	OUT213	OUT212	OUT211	OUT210	OUT209
535-528	OUT308	OUT307	OUT306	OUT305	OUT304	OUT303	OUT302	OUT301
543-536	OUT316	OUT315	OUT314	OUT313	OUT312	OUT311	OUT310	OUT309
551-544	PB1	PB2	PB3	PB4	PB5	PB6	PB7	PB8
559-552	PB9	PB10	PB11	PB12	*	*	*	*
567-560	PB1_LED	PB2_LED	PB3_LED	PB4_LED	PB5_LED	PB6_LED	PB7_LED	PB8_LED
575-568	PB9_LED	PB10LED	PB11LED	PB12LED	*	*	*	*
583-576	RST_DEM	RST_PDM	RST_ENE	RST_BKS	RST_BKT	RST_BKU	RST_BKW	RST_BKX
591-584	RST_BAT	RSTTRGT	RSTDNPE	*	*	*	*	*
599-592	TRGTR	PHASE_A	PHASE_B	PHASE_C	*	*	ER	FAULT
607-600	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A
615-608	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
623-616	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
631-624	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B

Table E.13 SEL-487E Object 1, 2 Relay Word Bit Mapping (Sheet 3 of 3)

Index Range	Relay Word Bits[a]							
	7	6	5	4	3	2	1	0
639-632	ROKA	RBADA	CBADA	LBOKA	ANOKA	DOKA	*	*
647-640	ROKB	RBADB	CBADB	LBOKB	ANOKB	DOKB	*	*
655-648	TESTDNP	TESTDB	TESTFM	TESTPUL	*	*	*	*
663-656	CCIN025	CCIN026	CCIN027	CCIN028	CCIN029	CCIN030	CCIN031	CCIN032
671-664	CCIN017	CCIN018	CCIN019	CCIN020	CCIN021	CCIN022	CCIN023	CCIN024
679-672	CCIN009	CCIN010	CCIN011	CCIN012	CCIN013	CCIN014	CCIN015	CCIN016
687-680	CCIN001	CCIN002	CCIN003	CCIN004	CCIN005	CCIN006	CCIN007	CCIN008
695-688	CCOUT25	CCOUT26	CCOUT27	CCOUT28	CCOUT29	CCOUT30	CCOUT31	CCOUT32
703-696	CCOUT17	CCOUT18	CCOUT19	CCOUT20	CCOUT21	CCOUT22	CCOUT23	CCOUT24
711-704	CCOUT09	CCOUT10	CCOUT11	CCOUT12	CCOUT13	CCOUT14	CCOUT15	CCOUT16
719-712	CCOUT01	CCOUT02	CCOUT03	CCOUT04	CCOUT05	CCOUT06	CCOUT07	CCOUT08
719-712	CCSTA01	CCSTA02	CCSTA03	CCSTA04	CCSTA05	CCSTA06	CCSTA07	CCSTA08
727-720	CCSTA09	CCSTA10	CCSTA11	CCSTA12	CCSTA13	CCSTA14	CCSTA15	CCSTA16
735-728	CCSTA17	CCSTA18	CCSTA19	CCSTA20	CCSTA21	CCSTA22	CCSTA23	CCSTA24
742-736	CCSTA25	CCSTA26	CCSTA27	CCSTA28	CCSTA29	CCSTA30	CCSTA31	CCSTA32
750-743	FSERP1	FSERP2	FSERP3	FSERPF	*	*	*	*

[a] An * denotes reserved for future use.

Object 1, 2 indices 1600–1615 and 1624–1631 represent the front-panel target Relay Word bits as listed in *Table E.14*.

Table E.14 Object 1, 2 Indices 1600–1615 Front-Panel Targets (Sheet 1 of 2)

Index	Relay Word Bit	Description
1600	TLED_8	Front-panel target 8
1601	TLED_7	Front-panel target 7
1602	TLED_6	Front-panel target 6
1603	TLED_5	Front-panel target 5
1604	TLED_4	Front-panel target 4
1605	TLED_3	Front-panel target 3
1606	TLED_2	Front-panel target 2
1607	TLED_1	Front-panel target 1
1608	TLED_16	Front-panel target 16
1609	TLED_15	Front-panel target 15
1610	TLED_14	Front-panel target 14
1611	TLED_13	Front-panel target 13
1612	TLED_12	Front-panel target 12
1613	TLED_11	Front-panel target 11
1614	TLED_10	Front-panel target 10
1615	TLED_9	Front-panel target 9
1624	TLED_24	Front-panel target 24
1625	TLED_23	Front-panel target 23

Table E.14 Object 1, 2 Indices 1600–1615 Front-Panel Targets (Sheet 2 of 2)

Index	Relay Word Bit	Description
1626	TLED_22	Front-panel target 22
1627	TLED_21	Front-panel target 21
1628	TLED_20	Front-panel target 20
1629	TLED_19	Front-panel target 19
1630	TLED_18	Front-panel target 18
1631	TLED_17	Front-panel target 17

Object 30, Index 176 is a 16-bit composite value, where the upper byte value indicates an event cause as shown in *Table E.15* and a fault type shown in *Table E.17*.

Reading Relay Event Data

The SEL-487E provides protective relay event history information in one of two modes: single event or with a first-in, first-out (FIFO) multi-event access method. The default mode is single event. Single event mode provides the most recent tripping event. The relay shall than ignore any subsequent events for EVELOCK (port setting) time. This data shall be reset to 0 on a rising edge of RSTDNPE (global SELOGIC control equation result). The relay element EVELOCK shall be set when the fault is triggered and reset when EVELOCK time expires.

Multi-event mode shall be initiated if the next event control is operated. The master should monitor binary input point 1619 (MAPSEL := B; see *Table E.12*) or point 3 (MAPSEL := E; see *Table E.12*), which will be asserted when there is an unread relay event summary. To read the oldest relay event summary, the master should pulse-on binary output point 41 (see *Table E.17*). This will load the relay event summary analogs (points 176 through 181 *Table E.12*) with information from the oldest relay event summary, discarding the values from the previous load. After reading the analogs, the master should again check binary input point 1619 (point 3 when MAPSEL := E), which will be on if there is another unread relay event summary. The master should continue this process until binary input point 1619 (point 3 when MAPSEL := E) is deasserted. If the master attempts to load values using output point 41 when binary input point 1619 (point 3 when MAPSEL := E) is deasserted, the relay event type analog (point 176) will be loaded with zero. With the FIFO method, the relay event summaries will always be collected in chronological order.

Table E.15 Object 30, 32, Index 400 Upper Byte–Event Cause

Index	Description	Comment
1	Trigger command	Supported
2	Pulse command	Not supported
4	Trip element	Supported
8	Event report element	Supported
16	Breaker failure trip	Supported
32	Differential trip	Supported

Table E.16 Object 30, 132, Index 400 Lower Byte—Fault Type

Index	Description	Comment
1	A-phase	Not supported
2	B-phase	Not supported
4	C-phase	Not supported
8	Ground	Not supported

Control Point Operation

Use the Trip and Close operations with Object 12 control relay output block command messages to operate the points shown in *Table E.17*. Pulse operations provide a pulse with a duration of one protection processing interval.

Table E.17 SEL-487E Object 12 Trip/Close Pair Operation (Sheet 1 of 2)

Indices	Close	Trip
0–31	Set remote bits RB01–RB32	Clear remote bits RB01–RB32
32–47	Pulse RB02–32 (even)	Pulse RB01–31 (odd)
48	Open circuit breaker S (Pulse OCS)	No action
49	Close circuit breaker S (Pulse CCS)	No action
50	Open circuit breaker T (Pulse OCT)	No action
51	Close circuit breaker T (Pulse CCT)	No action
52	Open circuit breaker U (Pulse OCU)	No action
53	Close circuit breaker U (Pulse CCU)	No action
54	Open circuit breaker W (Pulse OCW)	No action
55	Close circuit breaker W (Pulse CCW)	No action
56	Open circuit breaker X (Pulse OCX)	No action
57	Close circuit breaker X (Pulse CCX)	No action
58–63	Reserved (no action)	Reserved (no action)
64	Pulse CCS, circuit breaker S close bit	Pulse OCS, circuit breaker S open bit
65	Pulse CCT, circuit breaker T close bit	Pulse OCT, circuit breaker T open bit
66	Pulse CCU, circuit breaker U close bit	Pulse OCU, circuit breaker U open bit
67	Pulse CCW, circuit breaker W close bit	Pulse OCW, circuit breaker W open bit
68	Pulse CCX, circuit breaker X close bit	Pulse OCX, circuit breaker X open bit
69–71	Reserved (no action)	Reserved (no action)
72	Reset Demand meter (pulse RSS_DEM)	Reset Demand meter
73	Reset Peak Demand (pulse RSS_PDM)	Reset Peak Demand
74	Reset Energies (pulse RSS_ENE)	Reset Energies
75	Reset front panel targets (pulse RSTTRGT)	Reset front panel targets
76	Read next relay event	Read next relay event
77–79	Reserved (no action)	Reserved (no action)
80	Reset breaker monitor S (pulse RSS_BKS)	Reset breaker monitor S (pulse RSS_BKS)
81	Reset breaker monitor T (pulse RSS_BKT)	Reset breaker monitor T (pulse RSS_BKT)
82	Reset breaker monitor U (pulse RSS_BKU)	Reset breaker monitor U (pulse RSS_BKU)
83	Reset breaker monitor W (pulse RSS_BKW)	Reset breaker monitor W (pulse RSS_BKW)
84	Reset breaker monitor X (pulse RSS_BKX)	Reset breaker monitor X (pulse RSS_BKX)

Table E.17 SEL-487E Object 12 Trip/Close Pair Operation (Sheet 2 of 2)

Indices	Close	Trip
85–87	Reserved (no action)	Reserved (no action)
88	Open Disconnect 1	No action
89	Close Disconnect 1	No action
90	Open Disconnect 2	No action
91	Close Disconnect 2	No action
92	Open Disconnect 3	No action
93	Close Disconnect 3	No action
94	Open Disconnect 4	No action
95	Close Disconnect 4	No action
96	Open Disconnect 5	No action
97	Close Disconnect 5	No action
98	Open Disconnect 6	No action
99	Close Disconnect 6	No action
100	Open Disconnect 7	No action
101	Close Disconnect 7	No action
102	Open Disconnect 8	No action
103	Close Disconnect 8	No action
104	Close Disconnect 1	Open Disconnect 1
105	Close Disconnect 2	Open Disconnect 2
106	Close Disconnect 3	Open Disconnect 3
107	Close Disconnect 4	Open Disconnect 4
108	Close Disconnect 5	Open Disconnect 5
109	Close Disconnect 6	Open Disconnect 6
110	Close Disconnect 7	Open Disconnect 7
111	Close Disconnect 8	Open Disconnect 8

The SEL-487E assigns some special operations to the code portion of the control relay output block command. The special operations are shown in *Table E.18*. Pulse operations provide a pulse duration of one protection-processing interval.

Table E.18 SEL-487E Object 12 Code Selection Operation (Sheet 1 of 3)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
0–31	Set remote bit RB01–RB32	Clear remote bit RB01–RB32	Pulse remote bit RB01–RB32	Clear remote bit RB01–RB32
32–47	Pulse RB02–RB32 (even)	Pulse RB01–RB31 (odd)	Pulse RB02–RB32 (even)	Pulse RB01–RB31 (odd)
48	Pulse OCS, circuit breaker S open bit	No action	Pulse OCS, circuit breaker S open bit	No action
49	Pulse CCS, circuit breaker S close bit	No action	Pulse CCS, circuit breaker S close bit	No action
50	Pulse OCT, circuit breaker T open bit	No action	Pulse OCT, circuit breaker T open bit	No action
51	Pulse CCT, circuit breaker T close bit	No action	Pulse CCT, circuit breaker T close bit	No action

Table E.18 SEL-487E Object 12 Code Selection Operation (Sheet 2 of 3)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
52	Pulse OCU, circuit breaker U open bit	No action	Pulse OCU, circuit breaker U open bit	No action
53	Pulse CCU, circuit breaker U close bit	No action	Pulse CCU, circuit breaker U close bit	No action
54	Pulse OCW, circuit breaker W open bit	No action	Pulse OCW, circuit breaker W open bit	No action
55	Pulse CCW, circuit breaker W close bit	No action	Pulse CCW, circuit breaker W close bit	No action
56	Pulse OCX, circuit breaker X open bit	No action	Pulse OCX, circuit breaker X open bit	No action
57	Pulse CCX, circuit breaker X close bit	No action	Pulse CCX, circuit breaker X close bit	No action
58–63	Reserved (no action)	Reserved (no action)	Reserved (no action)	Reserved (no action)
64	Pulse CCS	Pulse OCS	Pulse CCS	Pulse OCS
65	Pulse CCT	Pulse OCT	Pulse CCT	Pulse OCT
66	Pulse CCU	Pulse OCU	Pulse CCU	Pulse OCU
67	Pulse CCW	Pulse OCW	Pulse CCW	Pulse OCW
68	Pulse CCX	Pulse OCX	Pulse CCX	Pulse OCX
69–71	Reserved (no action)	Reserved (no action)	Reserved (no action)	Reserved (no action)
72	Reset Demand meter	No action	Reset Demand meter	No action
73	Reset Peak Demand	No action	Reset Peak Demand	No action
74	Reset Energies	No action	Reset Energies	No action
75	Reset front panel targets	No action	Reset front panel targets	No action
76	Read next relay event	No action	Read next relay event	No action
77–79	Reserved (no action)	Reserved (no action)	Reserved (no action)	Reserved (no action)
80	Pulse RSS_BKS, Reset breaker monitor S	No action	Pulse RSS_BKS, Reset breaker monitor S	No action
81	Pulse RSS_BKT, Reset breaker monitor T	No action	Pulse RSS_BKT, Reset breaker monitor T	No action
82	Pulse RSS_BKU, Reset breaker monitor U	No action	Pulse RSS_BKU, Reset breaker monitor U	No action
83	Pulse RSS_BKW, Reset breaker monitor W	No action	Pulse RSS_BKW,Reset breaker monitor W	No action
84	Pulse RSS_BKX, Reset breaker monitor X	No action	Pulse RSS_BKX, Reset breaker monitor X	No action
85–87	Reserved (no action)	Reserved (no action)	Reserved (no action)	Reserved (no action)
88	Pulse 89OC1, open Disconnect 1	No action	Pulse 89OC1, open Discon-nect 1	No action
89	Pulse 89CC1, close Disconnect 1	No action	Pulse 89CC1, close Disconnect 1	No action
90	Pulse 89OC2, open Disconnect 2	No action	Pulse 89OC2, open Disconnect 2	No action
91	Pulse 89CC2, close Disconnect 2	No action	Pulse 89CC2, close Disconnect 2	No action
92	Pulse 89OC3, open Disconnect 3	No action	Pulse 89OC3, open Disconnect 3	No action

Table E.18 SEL-487E Object 12 Code Selection Operation (Sheet 3 of 3)

Indices	Latch On	Latch Off	Pulse On	Pulse Off
93	Pulse 89CC3, close Disconnect 3	No action	Pulse 89CC3, close Disconnect 3	No action
94	Pulse 89OC4, open Disconnect 4	No action	Pulse 89OC4, open Disconnect 4	No action
95	Pulse 89CC4, close Disconnect 4	No action	Pulse 89CC4, close Disconnect 4	No action
96	Pulse 89OC5, open Disconnect 5	No action	Pulse 89OC5, open Disconnect 5	No action
97	Pulse 89CC5, close Disconnect 5	No action	Pulse 89CC5, close Disconnect 5	No action
98	Pulse 89OC6, open Disconnect 6	No action	Pulse 89OC6, open Disconnect 6	No action
99	Pulse 89CC6, close Disconnect 6	No action	Pulse 89CC6, close Disconnect 6	No action
100	Pulse 89OC17open Disconnect 7	No action	Pulse 89OC7, open Disconnect 7	No action
101	Pulse 89CC7, close Disconnect 7	No action	Pulse 89CC7, close Disconnect 7	No action
102	Pulse 89OC8, open Disconnect 8	No action	Pulse 89OC8, open Disconnect 8	No action
103	Pulse 89CC8, close Disconnect 8	No action	Pulse 89CC8, close Disconnect 8	No action
104	Pulse Close Disconnect 1	Pulse Open Disconnect 1	Pulse Close Disconnect 1	Pulse Open Disconnect 1
105	Pulse Close Disconnect 2	Pulse Open Disconnect 2	Pulse Close Disconnect 2	Pulse Open Disconnect 2
106	Pulse Close Disconnect 3	Pulse Open Disconnect 3	Pulse Close Disconnect 3	Pulse Open Disconnect 3
107	Pulse Close Disconnect 4	Pulse Open Disconnect 4	Pulse Close Disconnect 4	Pulse Open Disconnect 4
108	Pulse Close Disconnect 5	Pulse Open Disconnect 5	Pulse Close Disconnect 5	Pulse Open Disconnect 5
109	Pulse Close Disconnect 6	Pulse Open Disconnect 6	Pulse Close Disconnect 6	Pulse Open Disconnect 6
110	Pulse Close Disconnect 7	Pulse Open Disconnect 7	Pulse Close Disconnect 7	Pulse Open Disconnect 7
111	Pulse Close Disconnect 8	Pulse Open Disconnect 8	Pulse Close Disconnect 8	Pulse Open Disconnect 8

Application Example

Application

This example uses an SEL-487E connected to an RTU over an EIA-485 network. The RTU collects basic metering information from the relay. The network for this example is shown in *Figure E.4*.

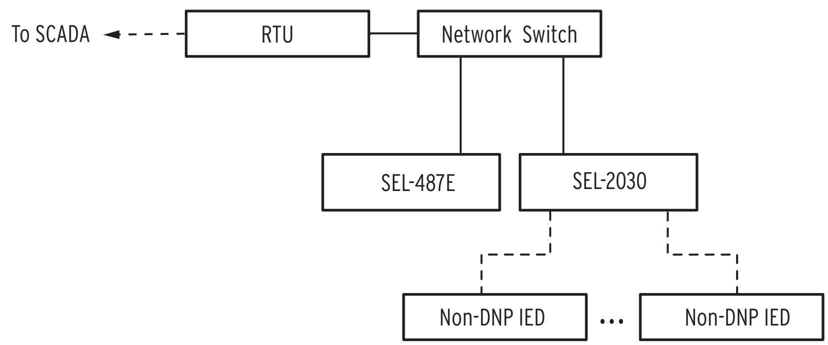


Figure E.4 DNP3 Application Network Diagram

The metering and status data that the RTU collects from the relay are listed in *Table E.19*.

Table E.19 DNP3 Application Example Data Map (Sheet 1 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
EN	1, 2	7	1	Relay enabled
TRIPLED	1, 2	6	2	Transformer tripped
IN101	1, 2	1048	3	Relay Discrete Input 1
IN102	1, 2	1049	4	Relay Discrete Input 2
IN103	1, 2	1050	5	Relay Discrete Input 3
IN104	1, 2	1051	6	Relay Discrete Input 4
SALARM	1, 2	503	7	Relay software alarm
HALARM	1, 2	502	8	Relay hardware alarm
TIRIG	1, 2	511	9	High-quality IRIG available
RB01	10, 12	0	1	General use Control Point 1
RB02	10, 12	1	2	General use Control Point 1
RB03	10, 12	2	3	General use Control Point 1
RB04	10, 12	3	4	General use Control Point 1
RB05	10, 12	4	5	General use Control Point 1
RB06	10, 12	5	6	General use Control Point 1
IASFMC[a] IASFAC[b]	30	0,1	1,2	A-phase, Terminal S (IAS) current magnitude and angle
IBSFMC[a] IBSFAC[b]	30	2,3	3,4	B-phase, Terminal S (IBS) current magnitude and angle
ICSFMC[a] ICSFAC[b]	30	4,5	5,6	C-phase, Terminal S (ICS) current magnitude and angle
VAVFMC[c] VAVFAC[b]	30	114,115	7,8	VAV magnitude and angle
VBVFMC[c] VBVFAC[b]	30	116,117	9,10	VBV magnitude and angle

Table E.19 DNP3 Application Example Data Map (Sheet 2 of 2)

Name	Object	Default Map Index	Custom Map Index	Description
VCVFM[c] VCVFAC[b]	30	118,119	11,12	VBV magnitude and angle
3PSFS[d] 3QSFS[d] 3SSFS[d]	30	159, 160, 161	13,14,15	Terminal S, 3-phase Real Power, Reactive Power, and Apparent Power
DC1[e]	30	354	16	DC1 voltage multiplied by 100
ACTGRP	40	0	0	Active settings group

[a] Assume the largest expected current is 2000 A, scale the analog value by a factor of 10 to provide a resolution of 0.1 A and a maximum current of 3276.7 A. Report change events on a change of 5 A.
[b] Angles are scaled to 1/100 of a degree. Report change events on a change of 2 degrees.
[c] For a nominal voltage of 230 kV, scale the analog value by a factor of 100 to provide a resolution of 10 V and a maximum value of 327.67 kV. Report 1 kV for change event reporting.
[d] For a maximum load of 800 MW (or 800 mVar), scale the power by a factor of 40 to provide a resolution of 0.025 MW, and a maximum value of 819.175 MW. Report 1 MW for change event reporting.
[e] VDC1 is scaled by a factor of 1/100 of a volt. Report change events on a change of 2 V.

Settings

Figure E.5 shows how to enter the new map into the relay. Use the **SET D** command and enter **N** at the prompts shown in *Figure E.5* to allow changes to the existing maps. Press **<Enter>** at the line prompt to advance to the next map. For example, press **<Enter>** at line 10 of the Binary Input Map to advance to the Binary Output Map.

```
=>>SET D <Enter>
DNP
DNP Reference Map Selection
Reference Map Selection (B,E)                    MAPSEL   := B      ? <Enter>
DNP Object Default Map Enables
Use default DNP map for Binary Inputs (Y/N)      DNPBID   := Y      ?N <Enter>
Use default DNP map for Binary Outputs (Y/N)     DNPBOD   := Y      ?N <Enter>
Use default DNP map for Counters (Y/N)           DNPCOD   := Y      ? <Enter>
Use default DNP map for Analog Inputs (Y/N)      DNPAID   := Y      ?N <Enter>
Use default DNP map for Analog Outputs (Y/N)     DNPAOD   := Y      ? <Enter>
Binary Input Map
(Index Number)
? 7 <Enter>
2:
? 6 <Enter>
3:
? 1048 <Enter>
4:
? 1049 <Enter>
5:
? 1050 <Enter>
6:
? 1052 <Enter>
7:
? 503 <Enter>
8:
? 502 <Enter>
9:
? 511 <Enter>
10:
? <Enter>

Binary Output Map
(Index Number)
1:
? 0 <Enter>
2:
? 1 <Enter>
3:
? 2 <Enter>
4:
? 3 <Enter>
5:
? 4 <Enter>
6:
? 5 <Enter>
7:
? <Enter>
```

(Continued on next page)

(Continued from previous page)

```
Analog Input Map
(Index Number, Scale Factor, Deadband)
1:
? 0 <Enter>
2:
? 1,1,200 <Enter>
3:
? 2 <Enter>
4:
? 3,1,200 <Enter>
5:
? 4 <Enter>
6:
? 5,1,200 <Enter>
7:
? 36 <Enter>
8:
? 37,1,200 <Enter>
9:
? 38 <Enter>
10:
? 39,1,200 <Enter>
11:
? 40 <Enter>
12:
? 41,1,200 <Enter>
13:
? 87,40,40 <Enter>
14:
? 91,40,40 <Enter>
15:
? 100,,200 <Enter>
16:
? <Enter>
Analog Output Map
(Index Number)
1:
? 0 <Enter>
2:
? <Enter>

Save settings (Y,N)  ?Y <Enter>
Saving Settings, Please Wait..........
Settings Saved

=>>
```

Figure E.5 SEL-487E Example DNP3 Map Settings

DNP3 LAN/WAN

The installation of an Ethernet card in an SEL-487E Relay provides a DNP3 Level 2 Outstation interface for direct Ethernet network connections to the relay.

Because of the benefits that local- and wide-area networks provide, they have become ubiquitous throughout utilities. Networks are now found in control rooms, substations, and other areas where they were rarely seen until just recently. In line with this trend, the DNP User's Group produced an extension of the DNP3 specification with recommendations for implementing DNP3 LAN/WAN networks.

The specification contains several key recommendations about DNP3 operation over LAN and Wide Area Network (WAN) links. The most significant recommendations are listed below:

- ➤ DNP3 will use the TCP/IP and UDP/IP protocol suite, also known as "The Internet Protocol Suite."
- ➤ Ethernet is the recommended physical layer, but the recommended implementation will function over any link where the TCP/IP and UDP/IP protocol suite is present.

- ➤ All devices must support messaging through both TCP (connection oriented) and UDP (connectionless) mechanisms.
- ➤ The full DNP3 protocol stack is retained. It is supplemented by the network protocol layers so that major restructuring of DNP3 is unnecessary.
- ➤ Link layer confirmations, which are optional but discouraged for serial DNP3, are specifically not allowed for DNP3 LAN/WAN. The IP Suite already provides a reliable delivery mechanism that is backed up by confirmations at the application layer when required.

DNP3 LAN/WAN in the SEL-487E

See *Introduction to DNP3 on page E.2* for an introduction to DNP3.

Ethernet Card

Installation of the Ethernet card in an SEL-487E provides a high-performance network interface that enables the use of industry-standard SCADA network protocols, including DNP3 Level 2 outstation functionality. DNP3 over the SEL-487E Ethernet port incorporates most Serial DNP3 functions, and includes event data reporting with direct time tags, customized data maps and session settings, and operator-initiated control through remote bits.

Configuration and operation of the DNP3 LAN/WAN interface in the SEL-487E is completely independent of the Serial DNP3 interface, but is just as integrated. In this section, DNP3 LAN/WAN is discussed as a function of the SEL-487E, with the implication that this refers to the operation of an Ethernet card (with the DNP3 option) installed in an SEL-487E.

Data Access

The data access methods listed for Serial DNP3 in *Table E.6* are also available for DNP3 LAN/WAN, with the exception of Virtual Terminal classes. *Table E.20* lists the appropriate settings for DNP3 LAN/WAN. The DNP3 master session must be configured for one of the data access methods below.

Table E.20 DNP3 LAN/WAN Access Methods

Access Method	Master Polling	SEL-487E Settings
Polled static	Class 0	Set ECLASSB, ECLASSC, ECLASSA to Off, UNSL*nn* to No (where *nn* is the session number from 01–10).
Polled report-by-exception	Class 0 occasionally, Class 1, 2, 3 frequently	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, UNSL*nn* to No.
Unsolicited report-by-exception	Class 0 occasionally, optional Class 1, 2, 3 less frequently, mainly relies on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, set UNSL*nn* to Yes and PUNSL*nn* to Yes or No.
Quiescent	Class 0, 1, 2, 3 never, relies completely on unsolicited messages	Set ECLASSB, ECLASSC, ECLASSA to the desired event class, set UNSL*nn* and PUNSL*nn* to Yes.

As with Serial DNP3, in both the unsolicited report-by-exception and quiescent polling methods shown in *Table E.20*, you must make a selection for the session's PUNSL*nn* setting. This setting enables or disables unsolicited data reporting at power up for this session. If your master can send the DNP3 message to enable unsolicited reporting from the SEL-487E, you should set the session's PUNSL*nn* to No.

See *DNP3 in the SEL-487E on page E.7* for more information on configuring DNP3 LAN/WAN sessions.

Event Data

The same serial DNP3 event data objects are available for DNP3 over an Ethernet network. However, configuration is slightly different. You can still configure the SEL-487E to either report the data without a polling request from the master (unsolicited data) or hold the data until the master requests it with an event poll message.

With the event class settings ECLASSB, ECLASSC, and ECLASSA, you can set the event class for binary, counter, and analog information. Virtual terminal information is not supported for DNP3 LAN/WAN since Telnet is available to provide this capability. As with serial DNP3, you can also use the classes as a simple priority system for collecting event data.

NOTE: Most RTUs that act as substation DNP3 masters perform an event poll that collects event data of all classes simultaneously. Confirm that the polling configuration of your master allows independent polling for each class before implementing separate classes in the SEL-487E.

For event data collection, you must also consider and enter appropriate settings for dead band and scaling operations on analog points shown in *Table E.21*. You can set and use either default dead band and scaling according to data type or use a custom data map to select dead bands on a point-by-point basis. See *Custom Data Mapping on page E.43* for a discussion of how to set scaling and dead-band operations on a point-by-point basis.

The setting ANADB defines default dead-band operation for analog events. A DNP3 master may also impose its own default dead band that it will use for event data for a specific channel that override the relay's ANADB setting. Because the default variations of DNP3 Objects 30 and 32 use integer data, you must use scaling to send digits after the decimal point and avoid rounding to a simple integer value. Scaling on the Ethernet DNP3 connection is subject to the same limitations of the serial interface. The master should also be configured to perform the appropriate arithmetic conversion on the incoming value to display it in proper engineering units.

Set the default analog value scaling with the DECPL setting. Application of event reporting dead bands occurs after scaling the incoming value with 10^{DECPL}. For example, if you set DECPL to 2 and ANADB to 10, a measured current of 10.14 amps would be scaled to the value 1014 (10.14×10^2) and would have to increase to more than 1024 or decrease to less than 1004 (a dead band of 0.2 amps) for the relay to report a new event value.

As with the DNP3 serial connection, the NUMEVE and AGEEVE settings are used to decide when to send unsolicited data to the master. The relay sends an unsolicited report when the total number of events accumulated in the event buffer reaches NUMEVE.

The relay also sends an unsolicited report if the age of the oldest event in the buffer exceeds AGEEVE. The SEL-487E uses the same buffer capacities with DNP3 LAN/WAN as through the serial connection, listed in *Table E.8*.

Time Synchronization

Time synchronization is not supported for DNP3 over the Ethernet port. However, it will accept messages that contain a Record Current Time (Function Code 24) request and return a Null Response.

DNP3 Settings

The DNP3 protocol settings that become available for DNP3 on the SEL-487E Ethernet port are shown in *Table E.21*. The DNP3 protocol settings are for the port assigned to the Ethernet port: PORT 5. Please keep in mind that any settings for the SEL-487E DNP3 Ethernet port will not affect any DNP3 serial port configuration or operation and vice-versa.

It may be useful to note a few parameters that are unique to configuring DNP LAN/WAN:

- The ENDNP setting allows the user to enable or disable all DNP3 sessions on the Ethernet interface.
- The DNPMAP setting enables the usage of custom DNP3 maps to define the data/control maps for the DNP3 sessions. The DNPMAP setting can have one of two values: AUTO or CUSTOM. AUTO is intended for the SEL-2032, SEL-2030, or SEL-2020 Communications Processor applications. With the SEL-487E, we recommend that you always use CUSTOM.
- DECPL indicates an exponential scaling factor, 10^{DECPL}, to multiply by the raw value to calculate engineering units. Thus the default value of DECPL, 0, will still result in the raw value being multiplied by 1 (10^0).

Up to 10 sets of unique master station parameters can be configured for implementation when the relay communicates with a specified DNP3 host. These parameters include: DNPIP*xx*, DNPTR*xx*, DNPUP*xx*, UNSL*xx*, PUNSL*xx*, DNPMP*xx*, and DNPCL*xx*, where *xx* is a master station number from 01–10. These allow you to specify, for all communication sessions with a particular master, whether or not to:

- enable or disable unsolicited reporting at power-up,
- enable or disable unsolicited reporting for normal operation,
- indicate which custom DNP3 map is associated with it, and
- enable or disable controls

Note that although 10 masters are supported by the SEL-487E, only five unique configuration files are available. These mapping files follow the naming convention SET_DNP*n*.TXT, where *n* indicates the DNP3 map from 1 to 5. These files reside in the SEL-487E card settings subdirectory and are associated with the DNPMP*nn* setting of DNP3 Master *nn*, where *nn* is the master's number from 01 to 10. The DNPMP*nn* setting determines which configuration is used for communication sessions with master *nn*. For example, if DNPMP01 is set to 3, DNP3 LAN/WAN sessions between the SEL-487E and DNP3 Master 01 will employ the custom mapping file named SET_DNP3.TXT. Mapping files may be used by a single session, multiple sessions, or not at all.

See *Custom Data Mapping* for a discussion of how to configure custom DNP3 maps.

Table E.21 SEL-487E Ethernet Port DNP3 Protocol Settings (Sheet 1 of 4)

Name	Description	Range	Default
ENDNP	Enable DNP3 (Y, N)	Y, N	N
DNPADR	DNP3 Address (0–65519)	0–65519	0
DNPPNUM	DNP3 Port Number for TCP and UDP (1–65534)	1–65534	20000
DNPMAP	DNP3 map Mode (AUTO, CUSTOM)	AUTO, CUSTOM	AUTO
RPADR01	DNP3 Address for Master 1 (0–65519)	0–65519	1
DNPIP01	IP Address for Master 1 (www.xxx.yyy.zzz)	20 Char String	“”
DNPTR01	Transport Protocol for Master 1 (UDP, TCP)	TCP, UDP	TCP
DNPUP01	UDP Response Port Number for Master 1 (1–65534, REQ)	REQ, 1–65534	20000
UNSL01	Enable Unsolicited Reporting for Master 1 (Y,N)	Y,N	N
PUNSL01	Enable Unsolicited Reporting at Powerup for Master 1 (Y, N)	Y,N	N
DNPMP01	CUSTOM Mode: DNP3 map associated with Master 1 (1–5)	1–5	“1”
DNPCL01	Enable Controls for Master 1 (Y, N)	Y, N	N
RPADR02	DNP3 Address for Master 2 (0–65519)	0–65519	1
DNPIP02	IP Address for Master 2 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			
DNPCL02	Enable Controls for Master 2 (Y, N)	Y,N	N
RPADR03	DNP3 Address for Master 3 (0–65519)	0–65519	1
DNPIP03	IP Address for Master 3 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			

Table E.21 SEL-487E Ethernet Port DNP3 Protocol Settings (Sheet 2 of 4)

Name	Description	Range	Default
DNPCL03	Enable Controls for Master 3 (Y,N)	Y,N	N
RPADR04	DNP3 Address for Master 4 (0–65519)	0–65519	1
DNPIP04	IP Address for Master 4 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			
DNPCL04	Enable Controls for Master 4 (Y, N)	Y,N	N
RPADR05	DNP3 Address for Master 5 (0–65519)	0–65519	1
DNPIP05	IP Address for Master 5 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			
DNPCL05	Enable Controls for Master 5 (Y, N)	Y,N	N
RPADR06	DNP3 Address for Master 6 (0–65519)	0–65519	1
DNPIP06	IP Address for Master 6 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			
DNPCL06	Enable Controls for Master 4 (Y, N)	Y,N	N
RPADR07	DNP3 Address for Master 7 (0–65519)	0–65519	1
DNPIP07	IP Address for Master 7 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			
DNPCL07	Enable Controls for Master 7 (Y, N)	Y,N	N
RPADR08	DNP3 Address for Master 8 (0–65519)	0–65519	1
DNPIP08	IP Address for Master 8 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			

Table E.21 SEL-487E Ethernet Port DNP3 Protocol Settings (Sheet 3 of 4)

Name	Description	Range	Default
DNPCL08	Enable Controls for Master 8 (Y, N)	Y, N	N
RPADR09	DNP3 Address for Master 9 (0–65519)	0–65519	1
DNPIP09	IP Address for Master 9 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			
DNPCL09	Enable Controls for Master 9 (Y, N)	Y, N	N
RPADR10	DNP3 Address for Master 10 (0–65519)	0–65519	1
DNPIP10	IP Address for Master 10 (www.xxx.yyy.zzz)	20 Char String	“”
. . .			
DNPCL10	Enable Controls for Master 10 (Y, N)	Y, N	N
ECLASSA	Class for Analog Event Data (0–3)	0–3	2
ECLASSB	Class for Binary Event Data (0–3)	0–3	1
ECLASSC	Class for Counter Event Data (0–3)	0–3	0
DECPL	Data Scaling Decimal Places (0–3)	0–3	0
ANADB	Data Reporting Deadband Counts (0–32767)	0–32767	100
16BIT	DNP3 analog input objects default variation size. 16- or 32-bit default variations for analog inputs (16/32)	16, 32	16
STIMEO	Seconds to Select/ Operate Time-out (0.0–30.0)	0.0–30.0	1.0
DNPPAIR	AUTO Mode: Enable Use of DNP3 Trip Close Pairs (Y, N)	Y, N	N
DNPINA	Seconds to send Inactive Heartbeat (0=Off, 1–7200)	0–7200	120

Table E.21 SEL-487E Ethernet Port DNP3 Protocol Settings (Sheet 4 of 4)

Name	Description	Range	Default
NUMEVE	Number of Events to Transmit On (1–200)	1–200	10
AGEEVE	Age of Oldest Event to Transmit On (0–100000 sec)	0–100000	2
ETIMEO	Event Message Confirm Timeout (1–50 sec)	1–50	2
URETRY	Unsolicited Message Max Retry Attempts (2–10)	2–10	3
UTIMEO	Unsolicited Message Offline Timeout (1–5000 sec)	1–5000	60

Custom Data Mapping

Installing an Ethernet card with DNP3 LAN/WAN into an SEL-487E adds the ability to make relay data available over Ethernet to a properly configured DNP3 Master. However, by default, DNPMAP = AUTO, which includes only the relay Digital and Analog Outputs. If Digital or Analog Inputs or Counters need to be available to DNP3, each point must be specified in a custom data map. Setting DNPMAP = CUSTOM enables you to specify the DNP3 data points available for up to 10 unique master sessions using any of 5 distinct DNP3 data maps.

The SEL-487E relay's DNP3 LAN/WAN interface also maps incoming control points either to remote bits within the relay or to internal command bits that cause circuit breaker operations. Please see *Table E.26* for a list of control points and control methods available in the SEL-487E.

When the Ethernet port has been configured to use custom DNP3 maps, the SEL-487E will obtain these maps from the Ethernet card Settings subdirectory. Custom setting files have the filename SET_DNP*x*.TXT, where *x* is the map number from 1 to 5.

The settings described in *Table E.22* below are used to define the custom DNP3 maps. Please note that these settings are only accessible as files in the SETTINGS/CARD subdirectory. The best way to operate on these settings is by using the ACSELERATOR QuickSet settings assistant.

Table E.22 SEL-487E DNP3 LAN/WAN Map Settings (Sheet 1 of 2)

Name	Type	Range	Default	Description
BIM0000–BIM1023	Binary Input Point	String of form "1:addr:bit" where addr must be in range 0–65534 and bit must be in range 0–15.	""	These settings correlate specific database bits with binary input indexes.
BIC0000–BIC1023	Binary Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSB setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
BOM0000–BOM0511	Binary Output Point	OFF, 0–(*MAX* as defined by *Table E.26*)	OFF	These settings correlate specific control operations from *Table E.26* to binary output indexes. A value of OFF indicates no object at that index.

Table E.22 SEL-487E DNP3 LAN/WAN Map Settings (Sheet 2 of 2)

Name	Type	Range	Default	Description
CIM0000–CIM0127	Counter Input Point	String of form “1:addr” where addr must be in range 0–65534.	“”	These settings correlate specific database registers with counter indexes.
CIC0000–CIC0127	Counter Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSC setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
AIM0000–AIM0511	Analog Input Point	String of form “1:addr[,t]” where addr must be in range 0–65534 and t must be i, u, il, ul, or f.	“”	These settings correlate specific database registers with analog input indexes. The optional “treat-as” qualifier (t) is used to indicate that the data at the referenced database address is to be treated as if is of this type, rather than the type indicated in the database. i = integer, u = unsigned integer, il = long integer, ul = unsigned long integer, f = floating point
AIC0000–AIC0511	Analog Input Class	DFLT, 0–3	DFLT	These settings specify the event class for that index. A value of DFLT indicates to use the ECLASSA setting, 0 indicates to not generate events, and 1–3 provide the specific class to place the point events into.
AIS0000–AIS0511	Analog Input Scaling	DFLT, 0.000001–1000000.0	DFLT	A value of DFLT indicates to use the DECPL setting for determining the scaling of a point. The given point will be multiplied by this value before being reported through DNP3.
AID0000–AID0511	Analog Input Deadband	DFLT, 0–32767	DFLT	This is the deadband to use for the point at the given index. A value of DFLT indicates to use the scaling on the ANADB setting.
AOM0000–AOM0063	Analog Output Point	OFF, 0–255	OFF	These settings correlate addresses within the card-controlled D1 region to analog output indexes. A value of OFF indicates no object at that index.

When DNPMAP = CUSTOM, the points that are included in the DNP3 map are defined by the contents of the custom DNP3 map files. The database capacity for each point type per map and system-wide is discussed below:

- The total number of Binary Input points allowed per map is 1024. The total system capacity (all custom DNP3 maps) is 2048 Digital Input points with unique references.
- The total number of Analog Input points allowed per map is 512. The total system capacity is 2048 Analog Inputs with unique references.
- The total number of Binary Output control points allowed per map is 512.
- The total number of Analog Output control points allowed per map is 64. The total system capacity, for all the custom DNP3 maps, is 256 Analog Output points with unique references.

Binary Inputs

The DNP3 index for any data point within a custom DNP3 map is assigned based on the associated setting name (i.e., BIM*xxxx* for a Binary Input, where *xxxx* is the DNP3 index).

In order for Binary Input points to have SOE-quality timestamps, each point must be listed in the SER and the corresponding STATE region points mapped to DNP3 (see *DNP LAN/WAN Application Example on page E.56*).

Analog Inputs

Analog dead bands and scaling factors may be set for each individual point. Use the AID*xxxx* setting to impose a dead band of 0–32767. This may be used in conjunction with a scaling factor of 0.000001–1000000.0 entered in AIS*xxxx*.

Binary Outputs

NOTE: When DNPMAP = CUSTOM, the DNPPAIR setting is ignored. The user must choose the appropriate CPId(s) to select paired or unpaired points for custom BO maps. For example, you may set BOM000 = 160, BOM001 = 130 to set the first DNP3 BO point to the remote bit pair RB02/RB01 and the second to RB03.

A Binary Output manipulates a control point, which is associated to the Binary Output by a Control Point Identifier (CPId). The CPId represents either a non-paired (single) control point or a paired (two control points) control point, where the operation selects the control point. The control points correspond to all paired and unpaired remote bits and all breaker controls plus the CCIN*x* bits. CPIds for the SEL-487E Relay, which has 128 CCIN*x* points, 32 Remote Bits, 16 Remote Bit pairs, and controls for 2 Circuit Breakers, are given in *Table E.23*.

Table E.23 SEL-487E Binary Output CPId Values

CPId	Description
0–127	CCIN001–CCIN128
128–159	Remote Bits RB01–RB32
160–175	Remote Bit Pairs RB02/RB01–RB32/RB31
176	Open/Close Pair for Circuit Breaker S (OCS–CCS)
177	Open/Close Pair for Circuit Breaker T (OCT–CCT)
178	Open/Close Pair for Circuit Breaker U (OCU–CCU)
179	Open/Close Pair for Circuit Breaker W (OCW–CCW)
180	Open/Close Pair for Circuit Breaker X (OCX–CCX)
181	Open/Close Pair for Disconnect 1 (89OC1–89CC1)
182	Open/Close Pair for Disconnect 2 (89OC2–89CC2)
183	Open/Close Pair for Disconnect 3 (89OC3–89CC3)
184	Open/Close Pair for Disconnect 4 (89OC4–89CC4)
185	Open/Close Pair for Disconnect 5 (89OC5–89CC5)
186	Open/Close Pair for Disconnect 6 (89OC6–89CC6)
187	Open/Close Pair for Disconnect 7 (89OC7–89CC7)
188	Open/Close Pair for Disconnect 8 (89OC8–89CC8)

Analog Outputs

Any of the 256 Analog Output Quantities in the D1 Region, RA001–RA256, can be included in a custom data map. Up to 64 Analog Outputs can be assigned to a custom map. Please note that you must subtract 1 from the Analog Quantity number to get the correct index. For example, if you want to specify RA064, use index 63.

DNP3 Map Command

Use the **POR 5** and Ethernet card **DNPMAP** command to display the data (object types, indices, default variation and source) and controls (object type, indices and destination) that are accessible via DNP3 LAN/WAN. The output of the **DNPMAP** command documents the DNP3 data map(s) in the Ethernet card to help with the configuration of the DNP3 master.

If the DNPMAP setting is set to CUSTOM, then you can specify an additional integer parameter corresponding to a DNPMAP number (1–5) to view each custom DNP3 data map. For example, the command **DNPMAP 2** would be used to view the custom data map for DNP3 session 2. If a DNPMAP number is not specified, a summary of DNP3 map settings for all configured sessions will be displayed.

Summary and detailed map configurations are also available in the DNPMAP.TXT and DNPMAP*nn*.TXT files from the SEL-487E FTP interface. The individual file names associated with the detailed custom map settings follow the DNPMAP*nn*.TXT naming convention.

Testing

Use the **TEST DB** command to test the communications card relay database. The **TEST DB** command can be used to override any value in the relay database. Since the relay database provides data to the communications card interfaces, the **TEST DB** command can also be used to test the data read operations of any of the protocols on an installed Ethernet card. Use the **MAP 1** command and the **VIEW 1** command to inspect the relay database (see *MAP on page 13.26*). You must be familiar with the relay database structure to use the **TEST DB** command effectively; see *Communications Card Database on page I.15* for more information.

DNP3 LAN/WAN Documentation

The following section contains information specific to the DNP3 LAN/WAN implementation.

Device Profile

Table E.24 contains the standard DNP3 LAN/WAN device profile information. Rather than checkboxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

Table E.24 SEL-487E DNP3 LAN/WAN Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-487E Relay with Ethernet card
Highest DNP3 request level	Level 2
Highest DNP3 response level	Level 2
Device function	Outstation
Notable objects, functions, and/or qualifiers supported	None
Maximum data link frame size transmitted/ received (octets)	292
Maximum data link retries	0

Table E.24 SEL-487E DNP3 LAN/WAN Device Profile (Sheet 2 of 2)

Parameter	Value
Requires data link layer confirmation	No
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE-NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch On	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary input change with time
Sends unsolicited responses	Configurable with unsolicited message enable settings
Sends static data in unsolicited responses	Never
Default counter object/variation	Object 20, Variation 6
Counter roll-over	N/A
Sends multifragment responses	Yes

Object List

The list of DNP3 objects given in *Table E.26* lists the supported objects for DNP3 LAN/WAN. Please note the added support of object 34, and removed support of objects 112 and 113.

Table E.25 SEL-487E DNP3 Object List (Sheet 1 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
1	0	Binary Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
1	1[e]	Binary Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
1	1	Binary Input With Status	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
2	0	Binary Input Change—All Variations	1	6, 7, 8		
2	1	Binary Input Change Without Time	1	6, 7, 8	129	17, 28
2	2[e]	Binary Input Change With Time	1	6, 7, 8	129, 130	17, 28
2	3	Binary Input Change With Relative Time	1	6, 7, 8	129	17, 28
10	0	Binary Output—All Variations	1	0, 1, 6, 7, 8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0, 1, 6, 7, 8	129	0, 1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3, 4, 5, 6	17, 28	129	echo of request
12	2	Pattern Control Block				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1	0, 1, 6, 7, 8, 17, 28		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	6[e]	16-Bit Binary Counter Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
20	7	32-Bit Delta Counter Without Flag				
20	8	16-Bit Delta Counter Without Flag				
21	0	Frozen Counter—All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				

Table E.25 SEL-487E DNP3 Object List (Sheet 2 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6, 7, 8		
22	1	32-Bit Counter Change Event Without Time	1	6, 7, 8	129	17, 28
22	2[e]	16-Bit Counter Change Event Without Time	1	6, 7, 8	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	6	16-Bit Counter Change Event With Time	1	6, 7, 8	129	17, 28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				
23	3	32-Bit Frozen Delta Counter Event Without Time				

Table E.25 SEL-487E DNP3 Object List (Sheet 3 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
23	4	16-Bit Frozen Delta Counter Event Without Time				
23	5	32-Bit Frozen Counter Event With Time				
23	6	16-Bit Frozen Counter Event With Time				
23	7	32-Bit Frozen Delta Counter Event With Time				
23	8	16-Bit Frozen Delta Counter Event With Time				
30	0	Analog Input—All Variations	1	0, 1, 6, 7, 8, 17, 28		
30	1	32-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	2	16-Bit Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	3	32-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	4[e]	16-Bit Analog Input Without Flag	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	5	Short Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
30	6	Long Floating Point Analog Input	1	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input With Time of Freeze				
31	4	16-Bit Frozen Analog Input With Time of Freeze				
31	5	32-Bit Frozen Analog Input Without Flag				
31	6	16-Bit Frozen Analog Input Without Flag				
32	0	Analog Change Event—All Variations	1	6, 7, 8		
32	1	32-Bit Analog Change Event Without Time	1	6, 7, 8	129	17, 28
32	2[e]	16-Bit Analog Change Event Without Time	1	6, 7, 8	129, 130	17, 28

Table E.25 SEL-487E DNP3 Object List (Sheet 4 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
32	3	32-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	4	16-Bit Analog Change Event With Time	1	6, 7, 8	129	17, 28
32	5	Short Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
32	6	Long Floating Point Analog Change Event	1	6, 7, 8	129	17, 28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event Without Time				
33	2	16-Bit Frozen Analog Event Without Time				
33	3	32-Bit Frozen Analog Event With Time				
33	4	16-Bit Frozen Analog Event With Time				
34	0	Analog Input Reporting Dead-Band Setting—All Variations	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	0	Analog Input Reporting Dead-Band Setting—All Variations	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	1[e]	16-Bit Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	1[e]	16-Bit Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	2	32-Bit Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	2	32-Bit Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
34	3	Floating Point Analog Input Reporting Dead-Band Setting	1	1, 6, 7, 8, 17, 28	129	1, 17, 28
34	3	Floating Point Analog Input Reporting Dead-Band Setting	2	0, 1, 6, 7, 8, 17, 28	129	0, 1, 17, 28
40	0	Analog Output Status—All Variations	1	0, 1, 6, 7, 8	139	
40	1	32-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28
40	2[e]	16-Bit Analog Output Status	1	0, 1, 6, 7, 8	129	0, 1, 17, 28

Table E.25 SEL-487E DNP3 Object List (Sheet 5 of 6)

Obj.	Var.	Description	Request[a]		Response[b]	
			Funct. Codes[c]	Qual. Codes[d]	Funct. Codes[c]	Qual. Codes[d]
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
41	2	16-Bit Analog Output Block	3, 4, 5, 6	17, 28	129	echo of request
50	0	Time and Date—All Variations				
50	1	Time and Date			129	07, quantity=1
50	2	Time and Date With Interval				
50	3	Time and Date at Last Recorded Time	1	7, 8 index=0	129	07, quantity=1
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO	07, quan-ity=1			
52	0	Time Delay—All Variations				
52	1	Time Delay, Coarse				
52	2	Time Delay, Fine			129	07, quantity=1
60	0	All Classes of Data	1, 20, 21	6		
60	1	Class 0 Data	1	6	129	0, 1
60	2	Class 1 Data	1, 20, 21	6, 7, 8	129	17, 28
60	3	Class 2 Data	1, 20, 21	6, 7, 8	129	17, 28
60	4	Class 3 Data	1, 20, 21	6, 7, 8	129	17, 28
70	1	File Identifier				
80	1	Internal Indications	2	0, 1 index=7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary—Coded Decimal				

Table E.25 SEL-487E DNP3 Object List (Sheet 6 of 6)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
101	2	Medium Packed Binary—Coded Decimal				
101	3	Large Packed Binary—Coded Decimal				
112	all	Virtual Terminal Output Block				
113	all	Virtual Terminal Event Data				
N/A		No object required for the following function codes: 13 cold start 14 warm start 24 record current time	13, 14, 24			

[a] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation

Control Point Operation

Control point operation for DNP LAN/WAN is functionally identical to Serial DNP3 operation. Use Trip and Close or Code Selection operations with Object 12 control relay output block command messages to operate the points shown in *Table E.26*. Use the Control Point ID (CPId) shown to select the desired control points to build the Custom Binary Output map. Note that all Binary outputs (paired and non-paired) are available to the DNP LAN/WAN interface. Pulse operations provide a pulse duration of at least one protection-processing interval.

Table E.26 SEL-487E DNP LAN/WAN Object 12 Control Point Operation (Sheet 1 of 3)

Indices	Control Points	Trip / Close Pairs: Close (0x4X)	Trip / Close Pairs: Trip (0x8X)	Code Selection Operation: Latch On (3)	Code Selection Operation: Latch Off (4)	Code Selection Operation: Pulse On (1)	Code Selection Operation: Pulse Off (2)
0–127	CCIN001–CCIN128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128	SET Comms Card input 001–128	CLEAR Comms Card input 001–128
128	RB01	SET remote bit RB01	CLEAR remote bit RB01	SET remote bit RB01	CLEAR remote bit RB01	SET remote bit RB01	CLEAR remote bit RB01
129	RB02	SET remote bit RB02	CLEAR remote bit RB02	SET remote bit RB02	CLEAR remote bit RB02	SET remote bit RB02	CLEAR remote bit RB02
130	RB03	SET remote bit RB03	CLEAR remote bit RB03	SET remote bit RB03	CLEAR remote bit RB03	SET remote bit RB03	CLEAR remote bit RB03
. . .							
143	RB16	SET remote bit RB16	CLEAR remote bit RB16	SET remote bit RB16	CLEAR remote bit RB16	SET remote bit RB16	CLEAR remote bit RB16

Table E.26 SEL-487E DNP LAN/WAN Object 12 Control Point Operation (Sheet 2 of 3)

Indices	Control Points	Trip / Close Pairs		Code Selection Operation			
		Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
144	RB17	SET remote bit RB17	CLEAR remote bit RB17	SET remote bit RB17	CLEAR remote bit RB17	SETSet remote bit RB17	CLEAR remote bit RB17
. . .							
159	RB32	SET remote bit RB32	CLEAR remote bit RB32	SET remote bit RB32	CLEAR remote bit RB32	SET remote bit RB32	CLEAR remote bit RB32
160	RB02/RB01	PULSE remote bit RB02	PULSE remote bit RB01	PULSE remote bit RB02	PULSE remote bit RB01	PULSE remote bit RB02	PULSE remote bit RB01
161	RB04/RB03	PULSE remote bit RB04	PULSE remote bit RB03	PULSE remote bit RB04	PULSE remote bit RB03	PULSE remote bit RB04	PULSE remote bit RB03
162	RB06/RB05	PULSE remote bit RB06	PULSE remote bit RB05	PULSE remote bit RB06	PULSE remote bit RB05	PULSE remote bit RB06	PULSE remote bit RB05
. . .							
167	RB16/RB15	PULSE remote bit RB16	PULSE remote bit RB15	PULSE remote bit RB16	PULSE remote bit RB15	PULSE remote bit RB16	PULSE remote bit RB15
168	RB18/RB17	PULSE remote bit RB18	PULSE remote bit RB17	PULSE remote bit RB18	PULSE remote bit RB17	PULSE remote bit RB18	PULSE remote bit RB17
. . .							
175	RB32/RB31	PULSE remote bit RB32	PULSE remote bit RB31	PULSE remote bit RB32	PULSE remote bit RB31	PULSE remote bit RB32	PULSE remote bit RB31
176	CBS	PULSE CCS, Circuit Breaker S close bit	PULSE OCS, Circuit Breaker S open bit	PULSE OCS, Circuit Breaker S open bit	PULSE CCS, Circuit Breaker S close bit	PULSE OCS, Circuit Breaker S open bit	PULSE CCS, Circuit Breaker S close bit
177	CBT	PULSE CCT, Circuit Breaker T close bit	PULSE OCT, Circuit Breaker T open bit	PULSE OCT, Circuit Breaker T open bit	PULSE CCT, Circuit Breaker T close bit	PULSE OCT, Circuit Breaker T open bit	PULSE CCT, Circuit Breaker T close bit
178	CBU	PULSE CCU Circuit Breaker U close bit	PULSE OCU Circuit Breaker U close bit	PULSE CCU Circuit Breaker U close bit	PULSE OCU Circuit Breaker U close bit	PULSE CCU Circuit Breaker U close bit	PULSE OCU Circuit Breaker U close bit
179	CBW	PULSE CCW Circuit Breaker W close bit	PULSE OCW Circuit Breaker W close bit	PULSE CCW Circuit Breaker W close bit	PULSE OCW Circuit Breaker W close bit	PULSE CCW Circuit Breaker W close bit	PULSE OCW Circuit Breaker W close bit

Table E.26 SEL-487E DNP LAN/WAN Object 12 Control Point Operation (Sheet 3 of 3)

Indices	Control Points	Trip / Close Pairs		Code Selection Operation			
		Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
180	CBX	PULSE CCX Circuit Breaker X close bit	PULSE OCX Circuit Breaker X close bit	PULSE CCX Circuit Breaker X close bit	PULSE OCX Circuit Breaker X close bit	PULSE CCX Circuit Breaker X close bit	PULSE OCX Circuit Breaker X close bit
181	Dis1	PULSE 89CC1, Disconnect Switch 1close bit	PULSE 89OC1, Disconnect Switch 1 open bit	PULSE 89OC1, Disconnect Switch 1 open bit	PULSE 89CC1, Disconnect Switch 1 close bit	PULSE 89OC1, Disconnect Switch 1 open bit	PULSE 89CC1, Disconnect Switch 1 close bit
182	Dis2	PULSE 89CC2, Disconnect Switch 2 close bit	PULSE 89OC2, Disconnect Switch 2 open bit	PULSE 89OC2, Disconnect Switch 2 open bit	PULSE 89CC2, Disconnect Switch 2 close bit	PULSE 89OC2, Disconnect Switch 2 open bit	PULSE 89CC2, Disconnect Switch 2 close bit
183	Dis3	PULSE 89CC3, Disconnect Switch 3 close bit	PULSE 89OC3, Disconnect Switch 3 open bit	PULSE 89OC3, Disconnect Switch 3 open bit	PULSE 89CC3, Disconnect Switch 3 close bit	PULSE 89OC3, Disconnect Switch 3 open bit	PULSE 89CC3, Disconnect Switch 3 close bit
184	Dis4	PULSE 89CC4, Disconnect Switch 4 close bit	PULSE 89OC4, Disconnect Switch 4 open bit	PULSE 89OC4, Disconnect Switch 4 open bit	PULSE 89CC4, Disconnect Switch 4 close bit	PULSE 89OC4, Disconnect Switch 4 open bit	PULSE 89CC4, Disconnect Switch 4 close bit
185	Dis5	PULSE 89CC5, Disconnect Switch 5 close bit	PULSE 89OC5, Disconnect Switch 5 open bit	PULSE 89OC5, Disconnect Switch 5 open bit	PULSE 89CC5, Disconnect Switch 5 close bit	PULSE 89OC5, Disconnect Switch 5 open bit	PULSE 89CC5, Disconnect Switch 5 close bit
186	Dis6	PULSE 89CC6, Disconnect Switch 6 close bit	PULSE 89OC6, Disconnect Switch 6 open bit	PULSE 89OC6, Disconnect Switch 6 open bit	PULSE 89CC6, Disconnect Switch 6 close bit	PULSE 89OC6, Disconnect Switch 6 open bit	PULSE 89CC6, Disconnect Switch 6 close bit
187	Dis7	PULSE 89CC7, Disconnect Switch 7 close bit	PULSE 89OC7, Disconnect Switch 7 open bit	PULSE 89OC7, Disconnect Switch 7 open bit	PULSE 89CC7, Disconnect Switch 7 close bit	PULSE 89OC7, Disconnect Switch 7 open bit	PULSE 89CC7, Disconnect Switch 7 close bit
188	Dis8	PULSE 89CC8, Disconnect Switch 8 close bit	PULSE 89OC8, Disconnect Switch 8 open bit	PULSE 89OC8, Disconnect Switch 8 open bit	PULSE 89CC8, Disconnect Switch 8 close bit	PULSE 89OC8, Disconnect Switch 8 open bit	PULSE 89CC8, Disconnect Switch 8 close bit

DNP LAN/WAN Application Example

Application

This example uses an SEL-487E connected to an RTU over an Ethernet (TCP) network. The RTU collects basic metering information from the relay. The network for this example is shown in *Figure E.4*.

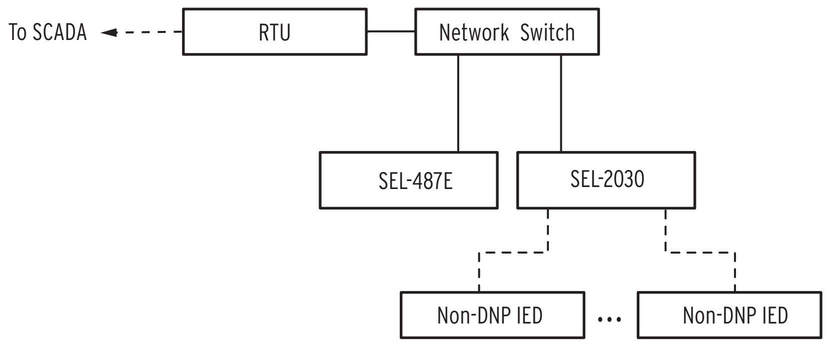


Figure E.6 DNP LAN/WAN Application Example Ethernet Network

The polling method employed by the RTU DNP3 master is polled report-by-exception, so it normally only does event polls. Once every 25 event polls, the master polls for Class 0 data (status of all points). This polling method allows the master to collect data efficiently from the IEDs by only polling and receiving data that has changed.

The RTU, which will act as the DNP3 master to the SEL-487E outstation, has an IP address of 192.9.0.1 and a DNP3 address of 12. The SEL-487E should be assigned a DNP3 address of 101.

All event data (analog, binary, counter) should be assigned to CLASS 1.

All Binary Inputs should have SOE-quality timestamps.

The metering, status data and controls that the RTU will receive and/or send to the relay are listed in *Table E.19*.

Table E.27 DNP LAN/WAN Application Example Custom Data Map (Sheet 1 of 2)

Name	Object Type	Custom Map Index	Description
EN	Binary Input	0	Relay enabled
TRIPLED	Binary Input	1	
IN101	Binary Input	2	
IN102	Binary Input	3	
IN103	Binary Input	4	
IN104	Binary Input	5	
SALARM	Binary Input	6	
HALARM	Binary Input	7	
TESTDNP	Binary Input	8	
RB01	Binary Output	0	General use Control Point (Remote Bit) 1
RB02	Binary Output	1	General use Control Point (Remote Bit) 2
RB03	Binary Output	2	General use Control Point (Remote Bit) 3

Table E.27 DNP LAN/WAN Application Example Custom Data Map (Sheet 2 of 2)

Name	Object Type	Custom Map Index	Description
RB04	Binary Output	3	General use Control Point (Remote Bit) 4
RB05	Binary Output	4	General use Control Point (Remote Bit) 5
RB06	Binary Output	5	General use Control Point (Remote Bit) 6
OCS, CCS	Binary Output	6	Circuit Breaker 1 trip/close

Settings

Use the ACSELERATOR QuickSet® SEL-5030 software to enter the DNP3 protocol settings and new data map into the relay.

Table E.28 DNP LAN/WAN Application Example Protocol Settings

Setting Name	Setting	Description
ENDNP	Y	Enable DNP3
DNPADR	101	DNP3 Address for Relay is 101
DNPPNUM	20000[a]	DNP3 Port Number for TCP
DNPMAP	CUSTOM	CUSTOM DNP3 map Mode
ECLASSA	1	Analog Event Data = Class 1
ECLASSB	1	Binary Event Data = Class 1
ECLASSC	1	Counter Event Data = Class 1
DECPL	2	Scale analog data, multiplying by 10 to send whole numbers and tenths. The relay would report a value of 5.25 as 525, which would remain unscaled at the master. (102=100)
ANADB	200	Analog Deadband Counts, set to 2 engineering units, based on DECPL scaling factor
STIMEO	1.0[a]	1.0 Second to Select/Operate Time-out
DNPPAIR	N[a]	AUTO Mode: Disable Use of DNP3 Trip Close Pairs
DNPINA	120[a]	Wait 120 Seconds to send Inactive Heartbeat
NUMEVE	10[a]	Transmit after 10 Events
AGEEVE	2[a]	Transmit when Age of Oldest Event = 2 sec
ETIMEO	2[a]	Event Message Confirm Timeout (2 sec)
URETRY	3[a]	3 Max Retry Attempts per Unsolicited Message
UTIMEO	60[a]	60 sec for Unsolicited Message Offline Timeout
RPADR01	12	DNP3 Address for Master 1 is 12
DNPIP01	192.9.0.1	IP Address for Master 1 (www.xxx.yyy.zzz)
DNPTR01	TCP	Transport Protocol for Master 1 (UDP, TCP)
DNPUP01	20000[a]	UDP Response Port Number for Master 1
UNSL01	N	Disable Unsolicited Reporting for Master 1
PUNSL01	N	Disable Unsolicited Reporting at Powerup for Master 1
DNPMP01	1	CUSTOM Mode: DNP3 map associated with Master 1 (Map 1)
DNPCL01	Y	Enable Controls for Master 1

[a] Default value

To meet the requirement for SOE-quality timestamps, enter all binary inputs into the SER report. See *Figure E.7* for a screenshot of the process.

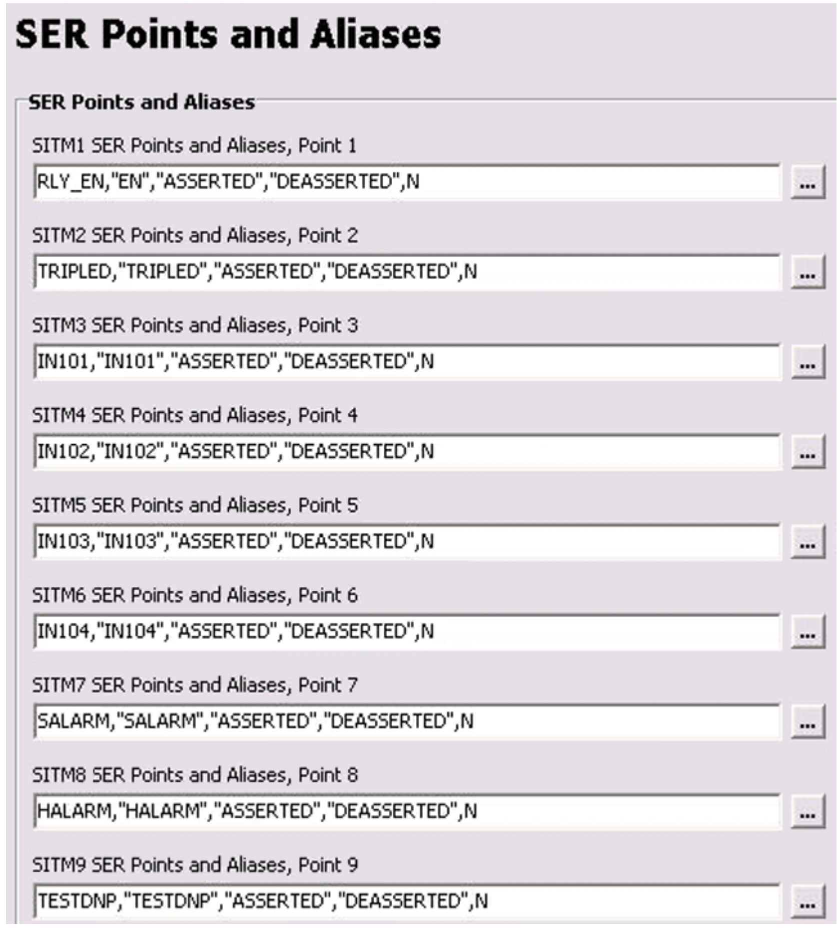


Figure E.7 Add Binary Inputs to SER Point List

Pass the Binary Input states and timestamps to the DNP3 master by mapping the SER points from the STATE region, as demonstrated in *Table E.29*.

Table E.29 DNP3 LAN/WAN Application Example Binary Input Map

Setting Name	Setting	Description
BIM0000 Database Address	1:STATE:ELEMENTS:0	SER Point 1 (EN)
BIM0001 Database Address	1:STATE:ELEMENTS:1	SER Point 2 (TRIPLED)
BIM0002 Database Address	1:STATE:ELEMENTS:2	SER Point 3 (IN101)
BIM0003 Database Address	1:STATE:ELEMENTS:3	SER Point 4 (IN102)
BIM0004 Database Address	1:STATE:ELEMENTS:4	SER Point 5 (IN103)
BIM0005 Database Address	1:STATE:ELEMENTS:5	SER Point 6 (IN104)
BIM0006 Database Address	1:STATE:ELEMENTS:6	SER Point 7 (SALARM)
BIM0007 Database Address	1:STATE:ELEMENTS:7	SER Point 8 (HALARM)
BIM0008 Database Address	1:STATE:ELEMENTS:8	SER Point 9 (TESTDNP)

Table E.30 DNP3 LAN/WAN Application Example Binary Output Map

Setting Name	Setting	Description
BOM0000 Database Address	128	Custom BO map position for RB01 Control
BOM0001 Database Address	129	Custom BO map position for RB02 Control
BOM0002 Database Address	130	Custom BO map position for RB03 Control
BOM0003 Database Address	131	Custom BO map position for RB04 Control
BOM0004 Database Address	132	Custom BO map position for RB05 Control
BOM0005 Database Address	133	Custom BO map position for RB06 Control
BOM0006 Database Address	176	Custom BO map position for Circuit Breaker S trip/close Control

Table E.31 DNP3 LAN/WAN Application Example Analog Input Map

Setting Name	Point	Scale Factor	Deadband	Description
AIM0000 Database Address	1:METER:IA1 (Meter Region > IA1)	1	50	Custom map position for IA1 magnitude, scale by 10 and report 5 amp change events
AIM0001 Database Address	1:100Ch			Custom map position for IA1 angle[a], scale by 100 and report 2 degree change events
AIM0002 Database Address	1:METER:IB1 (Meter Region > IB1)	1	50	Custom map position for IB1 magnitude[a], scale by 10 and report 5 amp change events
AIM0003 Database Address	1:1010h			Custom map position for IB1 angle[a], scale by 100 and report 2 degree change events
AIM0004 Database Address	1:METER:IC1 (Meter Region > IC1)	1	50	Custom map position for IC1 magnitude[a], scale by 10 and report 5 amp change events
AIM0005 Database Address	1:1014h			Custom map position for IC1 angle[a], scale by 100 and report 2 degree change events
AIM0006 Database Address	1:METER:VA (Meter Region > VA)	1	10000	Custom map position for VA magnitude, scale by 10 and report 1 kv change events
AIM0007 Database Address	1:103Ch			Custom map position for VA angle[a], scale by 100 and report 2 degree change events
AIM0008 Database Address	1:METER:VB (Meter Region > VB)	1	10000	Custom map position for VB magnitude, scale by 10 and report 1 kv change events
AIM0009 Database Address	1:1040h			Custom map position for VB angle[a], scale by 100 and report 2 degree change events
AIM0010 Database Address	1:METER:VC (Meter Region > VC)	1	10000	Custom map position for VC magnitude, scale by 10 and report 1 kv change events
AIM0011 Database Address	1:1044h			Custom map position for VC angle[a], scale by 100 and report 2 degree change events
AIM0012 Database Address	1:METER:P (Meter Region > P)	3	500	Custom map position for three-phase real power in MW scaled by 1000 with an event dead band of 0.5 MW
AIM0013 Database Address	1:METER:Q (Meter Region > Q)	3	500	Custom map position for three-phase real power in MW scaled by 1000 with an event dead band of 0.5 MW
AIM0014 Database Address	1:METER:VDC1 (Meter Region > VDC1)			DC1 voltage[a] multiplied by 100, with a dead band of 2 volts

[a] Uses default scaling and dead band.

Table E.32 DNP3 LAN/WAN Application Example Analog Output Map

Setting Name	Setting	Description
AOM0000 Database Address	0	Active Settings Group

Appendix F

IEC 61850

Features

NOTE: The SEL-487E supports one CID file, which should be transferred only if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will no longer have a valid IEC 61850 configuration, and the protocol will stop operating. To restart protocol operation, a valid CID must be transferred to the relay.

The SEL-487E Relay supports the following features using Ethernet and IEC 61850:

- **SCADA**—Connect up to six simultaneous Ethernet client sessions. The SEL-487E also supports up to six buffered and six unbuffered report control blocks.
- **Real-Time Status and Control**—Use GOOSE with as many as 24 incoming (receive) and 8 outgoing (transmit) messages.
- **Configuration**—Use FTP client software or ACSELERATOR Architect® SEL-5032 Software to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) file to the relay.
- **Commissioning and Troubleshooting**—Use software such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc., to browse the relay logical nodes and verify functionality.

This section presents the information you need to use the IEC 61850 features of the SEL-487E:

Introduction to IEC 61850

In the early 1990s, the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE) began to define a Utility Communications Architecture (UCA). They initially focused on inter-control center and substation-to-control center communications and produced the Inter-Control Center Communications Protocol (ICCP) specification. This specification, later adopted by the IEC as 60870-6 TASE.2, became the standard protocol for real-time exchange of data between databases.

In 1994, EPRI and IEEE began work on UCA 2.0 for Field Devices (simply referred to as UCA2). In 1997, they combined efforts with Technical Committee 57 of the IEC to create a common international standard. Their joint efforts created the current IEC 61850 standard.

The IEC 61850 standard, a superset of UCA2, contains most of the UCA2 specification, plus additional functionality. The standard describes client/server and peer-to-peer communications, substation design and configuration, testing, and project standards.

The IEC 61850 standard consists of the parts listed in *Table F.1*.

Table F.1 IEC 61850 Document Set

IEC 61850 Sections	Definitions
IEC 61850-1	Introduction and overview
IEC 61850-2	Glossary
IEC 61850-3	General requirements
IEC 61850-4	System and project management
IEC 61850-5	Communication requirements
IEC 61850-6	Configuration description language for substation IEDs
IEC 61850-7-1	Basic communication structure for substations and feeder equipment—Principles and models
IEC 61850-7-2	Basic communication structure for substations and feeder equipment—Abstract communication service interface (ACSI)
IEC 61850-7-3	Basic communication structure for substations and feeder equipment—Common data classes
IEC 61850-7-4	Basic communication structure for substations and feeder equipment—Compatible logical node (LN) classes and data classes
IEC 61850-8-1	SCSM—Mapping to Manufacturing Messaging Specification (MMS) (ISO/IEC 9506-1 and ISO/IEC 9506-2 over ISO/IEC 8802-3)
IEC 61850-9-1	SCSM—Sampled values over serial multidrop point-to-point link
IEC 61850-9-2	SCSM—Sampled values over ISO/IEC 8802-3
IEC 61850-10	Conformance testing

The IEC 61850 document set, available directly from the IEC at http://www.iec.ch, contains information necessary for successful implementation of this protocol. SEL strongly recommends that anyone involved with the design, installation, configuration, or maintenance of IEC 61850 systems be familiar with the appropriate sections of this standard.

IEC 61850 Operation

Ethernet Networking

IEC 61850 and Ethernet networking model options are available when ordering a new SEL-487E and may also be available as field upgrades to relays equipped with the Ethernet card. In addition to IEC 61850, the Ethernet card provides support protocols and data exchange, including FTP and Telnet, to SEL devices. Access the SEL-487E Port 5 settings to configure all of the Ethernet settings, including IEC 61850 network settings.

The SEL-487E Ethernet card supports IEC 61850 services, including transport of Logical Node objects, over TCP/IP. The Ethernet card can coordinate a maximum of six concurrent IEC 61850 sessions.

Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ACSI) models to define a set of services and the responses to those services. In terms of network behavior, abstract modeling enables all IEDs to act identically. These abstract models are used to create objects (data items) and services that exist independently of any underlying protocols. These objects are in conformance with the common data class (CDC) specification IEC 61850-7-3, which describes the type and structure of each element within a logical node. CDCs for status, measurements, controllable analogs and statuses, and settings all have unique CDC attributes. Each CDC attribute belongs to a set of functional constraints that groups the attributes into specific categories such as status (ST), description (DC), and substituted value (SV). Functional constraints, CDCs, and CDC attributes are used as building blocks for defining Logical Nodes.

UCA2 used GOMSFE (Generic Object Models for Substation and Feeder Equipment) to present data from station IEDs as a series of objects called models or bricks. The IEC working group has incorporated GOMSFE concepts into the standard, with some modifications to terminology; one change was the renaming of bricks to logical nodes. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function. For example, the MMXU logical node (polyphase measurement unit) contains measurement data and other points associated with three-phase metering including voltages and currents. Each IED may contain many functions such as protection, metering, and control. Multiple logical nodes represent the functions in multifunction devices.

Logical nodes can be organized into logical devices that are similar to directories on a computer disk. As represented in the IEC 61850 network, each physical device can contain many logical devices and each logical device can contain many logical nodes. Many relays, meters, and other IEC 61850 devices contain one primary logical device where all models are organized.

IEC 61850 devices are capable of self-description. You do not need to refer to the specifications for the logical nodes, measurements, and other components to request data from another IEC 61850 device. IEC 61850 clients can request and display a list and description of the data available in an IEC 61850 server device. This process is similar to the autoconfiguration process used within SEL communications processors (SEL-2032 and SEL-2030). Simply run an MMS browser to query devices on an IEC 61850 network and discover what data are available. Self-description also permits extensions to both standard and custom data models. Instead of having to look up data in a profile stored in its database, an IEC 61850 client can simply query an IEC 61850 device and receive a description of all logical devices, logical nodes, and available data.

Unlike other Supervisory Control and Data Acquisition (SCADA) protocols that present data as a list of addresses or indices, IEC 61850 presents data with descriptors in a composite notation made up of components. *Table F.2* shows how the A-phase current expressed as MMXUAphsA$cVal is broken down into its component parts.

Table F.2 Example IEC 61850 Descriptor Components

Component		Description
MMXU	Logical Node	Polyphase measurement unit
A	Data Object	Phase-to-ground amperes
PhsA	Sub-Data Object	Phase A
CVal	Data Attribute	Complex value

Data Mapping

Device data is mapped to IEC 61850 Logical Nodes (LN) according to rules defined by SEL. Refer to IEC 61850-5:2003(E) and IEC 61850-7-4:2003(E) for the mandatory content and usage of these LNs. The SEL-487E logical nodes are grouped under Logical Devices for organization based on function. See *Table F.3* for descriptions of the Logical Devices in an SEL-487E. See *Logical Nodes on page F.12* for a description of the LNs that make up these Logical Devices.

Table F.3 SEL-487E Logical Devices

Logical Device	Description
ANN	Annunciator elements—alarms, status values
CFG	Configuration elements—datasets and report control blocks
CON	Control elements—remote bits
MET	Metering or Measurement elements—currents, voltages, power, etc.
PRO	Protection elements—protection functions and breaker control

MMS

Manufacturing Messaging Specification (MMS) provides services for the application-layer transfer of real-time data within a substation LAN. MMS was developed as a network independent data exchange protocol for industrial networks in the 1980s and standardized as ISO 9506.

In theory, you can map IEC 61850 to any protocol. However, it can become unwieldy and quite complicated to map objects and services to a protocol that only provides access to simple data points via registers or index numbers. MMS supports complex named objects and flexible services that enable mapping to IEC 61850 in a straightforward manner. This was why the UCA users group used MMS for UCA from the start, and why the IEC chose to keep it for IEC 61850.

GOOSE

The Generic Object Oriented Substation Event (GOOSE) object within IEC 61850 is for high-speed control messaging. IEC 61850 GOOSE automatically broadcasts messages containing status, controls, and measured values onto the network for use by other devices. IEC 61850 GOOSE sends the message several times, increasing the likelihood that other devices receive the messages.

IEC 61850 GOOSE objects can quickly and conveniently transfer status, controls, and measured values between peers on an IEC 61850 network. Configure SEL devices to respond to GOOSE messages from other network devices with ACSELERATOR Architect. Also, configure outgoing GOOSE messages for SEL devices in ACSELERATOR Architect. See the ACSELERATOR Architect instruction manual or online help for more information.

Each IEC 61850 GOOSE sender includes a text identification string (GOOSE Control Block Reference) in each outgoing message and an Ethernet multicast group address. Devices that receive GOOSE messages use the text identification and multicast group to identify and filter incoming GOOSE messages.

CCIN (Communications Card Input) bits are control inputs that you can map to GOOSE receive messages using the ACSELERATOR Architect software. See the CCIN*nn* bits in *Table F.14* for details on which logical nodes and names are used for these bits. This information can be useful when searching through device data with MMS browsers. If you intend to use any SEL-421 CCIN bits for controls, you must create SELOGIC® equations to define these operations.

The CCIN Logical Nodes only contain CCIN status, and only those CCINs that are part of the SER dataset will be able to track CCIN transitions (via reporting) between LN data update scans.

File Services

The Ethernet File System allows reading or writing data as files. The File System supports FTP and, for the SEL-487E, the Shared Memory File Transfer service. The File System provides:

- ➤ A means for the device to transfer data as files.
- ➤ A hierarchal file structure for the device data.

SCL Files

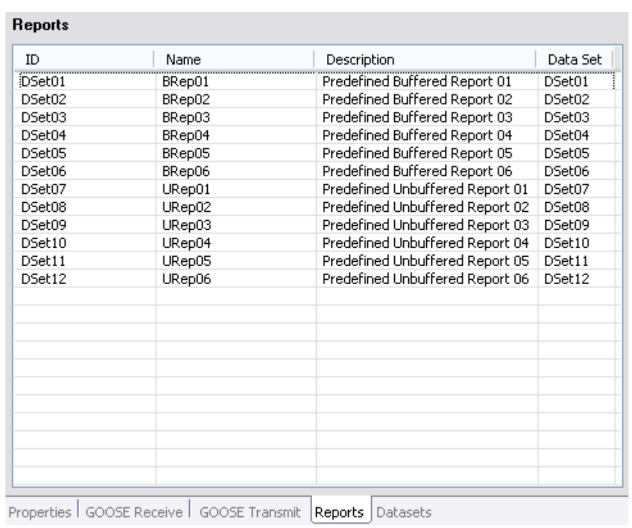
Substation Configuration Language (SCL) is an XML-based configuration language used to support the exchange of database configuration data between different tools, which may come from different manufacturers. There are four types of SCL files:

- ➤ IED Capability Description file (.ICD)
- ➤ System Specification Description (.SSD) file
- ➤ Substation Configuration Description file (.SCD)
- ➤ Configured IED Description file (.CID)

The ICD file describes the capabilities of an IED, including information on LN and GOOSE support. The SSD file describes the single-line diagram of the substation and the required LNs. The SCD file contains information on all IEDs, communications configuration data, and a substation description. The CID file, of which there may be several, describes a single instantiated IED within the project, and includes address information.

Reports

SEL-487E supports buffered and unbuffered report control blocks in the report model as defined in IEC 61850-8-1:2004(E). The predefined reports shown in *Figure F.1* are available by default via IEC 61850.


Reports

ID	Name	Description	Data Set
DSet01	BRep01	Predefined Buffered Report 01	DSet01
DSet02	BRep02	Predefined Buffered Report 02	DSet02
DSet03	BRep03	Predefined Buffered Report 03	DSet03
DSet04	BRep04	Predefined Buffered Report 04	DSet04
DSet05	BRep05	Predefined Buffered Report 05	DSet05
DSet06	BRep06	Predefined Buffered Report 06	DSet06
DSet07	URep01	Predefined Unbuffered Report 01	DSet07
DSet08	URep02	Predefined Unbuffered Report 02	DSet08
DSet09	URep03	Predefined Unbuffered Report 03	DSet09
DSet10	URep04	Predefined Unbuffered Report 04	DSet10
DSet11	URep05	Predefined Unbuffered Report 05	DSet11
DSet12	URep06	Predefined Unbuffered Report 06	DSet12

Figure F.1 SEL-487E Predefined Reports

There are twelve report control blocks (six buffered and unbuffered reports). For each report control block, there can be just one client association, i.e., only one client can be associated to a report control block (BRCB or URCB) at any given time. The number of reports (12) and the type of reports (buffered or unbuffered) cannot be changed. However, by using ACSELERATOR Architect, you can reallocate data within each report dataset to present different data attributes for each report beyond the predefined datasets.

For buffered reports, connected clients may edit the report parameters shown in *Table F.4*.

Table F.4 Buffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		FALSE
RptEna	YES	YES	FALSE
OptFlds	YES		segNum
			timeStamp
			dataSet
			reasonCode
			dataRef
BufTm	YES		500
TrgOp	YES		dchg
			qchg
IntgPd	YES		FALSE
GI	YES[a b]	YES[a]	FALSE
PurgeBuf	YES[a]		FALSE
EntryId	YES		0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.
[b] When disabled, a GI will be processed and the report buffered if a buffer has been previously established. A buffer is established when the report is enabled for the first time.

Similarly, for unbuffered reports, connected clients may edit the report parameters shown in *Table F.5*.

Table F.5 Unbuffered Report Control Block Client Access

RCB Attribute	User Changeable (Report Disabled)	User Changeable (Report Enabled)	Default Values
RptId	YES		FALSE
RptEna	YES	YES	FALSE
Resv	YES		FALSE
OptFlds	YES		segNum
			timeStamp
			dataSet
			reasonCode
			dataRef
BufTm	YES		250
TrgOps	YES		dchg
			qchg
IntgPd	YES		FALSE
GI		YES[a]	0

[a] Exhibits a pulse behavior. Write a one to issue the command. Once command is accepted will return to zero. Always read as zero.

For buffered reports, only one client can enable the RptEna attribute of the BRCB at a time resulting in a client association for that BRCB. Once enabled, the associated client has exclusive access to the BRCB until the connection is closed or the client disables the RptEna attribute. Once enabled, all unassociated clients have read only access to the BRCB.

For unbuffered reports, up to six clients can enable the RptEna attribute of an URCB at a time resulting in multiple client associations for that URCB. Once enabled, each client has independent access to a copy of that URCB.

The Resv attribute is writable, however, the SEL-487E does not support reservations. Writing any field of the URCB causes the client to obtain their own copy of the URCB-in essence, acquiring a reservation.

Reports are serviced at a 2 Hz rate. The client can set the IntgPd to any value with a resolution of 1 ms. However, the integrity report is only sent when the period has been detected as having expired. The report service rate of 2 Hz results in a report being sent within 500 ms of expiration of the IntgPd. The new IntgPd will begin at the time that the current report is serviced.

Datasets

The list of datasets in *Figure F.2* are the defaults for an SEL-487E device.

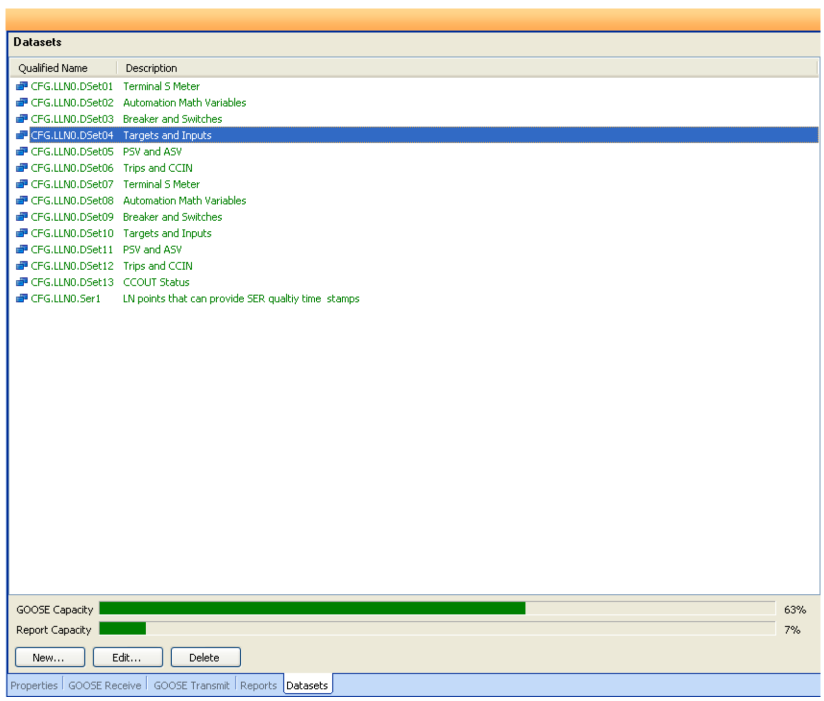


Figure F.2 SEL-487E Datasets

Within ACSELERATOR Architect, IEC 61850 datasets have two main purposes:

- GOOSE: You can use predefined or edited datasets, or create new datasets for outgoing GOOSE transmission.
- Reports: Twelve predefined datasets (DSet01 to DSet12) correspond to the default six buffered and six unbuffered reports. Note that you cannot change the number (12) or type of reports (buffered or unbuffered) within ACSELERATOR Architect. However, you can alter the data attributes that a dataset contains and so define what data an IEC 61850 client receives with a report.

NOTE: Do not edit the dataset names used in reports. Changing or deleting any of those dataset names will cause a failure in generating the corresponding report.

The SER dataset, CFG.LLN0.SER1, is a listing of the predetermined LN data attributes that are available with SER quality timestamps in the SEL-487E. Modifications to this dataset *do not* modify which data attributes have SER quality timestamps.

Supplemental Software

Examine the data structure and values of the supported IEC 61850 LNs with an MMS browser such as MMS Object Explorer and AX-S4 MMS from Sisco, Inc.

The settings needed to browse an SEL-487E with an MMS browser are shown below.

OSI-PSEL (Presentation Selector)	00000001
OSI-SSEL (Session Selector)	0001
OSI-TSEL (Transport Selector)	0001

Time Stamps and Quality

In addition to the various data values, the two attributes quality and t (time stamp) are available at any time. The timestamp is determined when data or quality change is detected. A change in the quality attribute can also be used to issue an internal event.

The timestamp is applied to all data and quality attributes (Boolean, Bstrings, Analogs, etc.) in the same fashion when a data or quality change is detected. However, there is a difference in how the change is detected between the different attribute types. For points that are assigned as SER points, i.e., listed in the SER dataset, the change is detected as the receipt of an SER record (which contains the SER timestamp) from the relay to the card. For all other Booleans or Bstrings, the change is detected via the scanner, which compares the last state against the previous state to detect the change. For analogs, the scanner looks at the amount of change relative to the deadband configured for the point to indicate a change and apply the timestamp. In all cases, these timestamps are used for the reporting model.

The SEL-487E has predetermined LN data attributes that are available with SER quality timestamps. These data attributes are listed in the SER dataset in the default relay ICD file. Modifications to this dataset *do not* modify which data attributes have SER quality timestamps. If your application requires SER quality timestamps on data attributes not in this dataset, contact SEL for possible modification to your relay default configuration.

LN data attributes listed in the SER dataset have SER accurate timestamps of 1 ms for data change events. All other LN data attributes are scanned on a 1/2-second interval for data change and have 1/2-second timestamp accuracy.

The SEL-487E uses GOOSE quality attributes to indicate the quality of the data in its transmitted GOOSE messages. Under normal conditions, all attributes are zero, indicating good quality data. *Figure F.3* shows the GOOSE quality attributes available to devices that subscribe to GOOSE messages from SEL-487E datasets that contain them. Internal status indicators provide the information necessary for the device to set these attributes. For example, if the device becomes disabled, as shown via status indications (e.g., an internal self-test failure), the SEL-487E will set the Validity attribute to invalid and the Failure attribute to TRUE. Note that the SEL-487E does not set any of the other quality attributes. These attributes will always indicate FALSE (0). See the ACSELERATOR Architect online help for additional information on GOOSE Quality attributes.

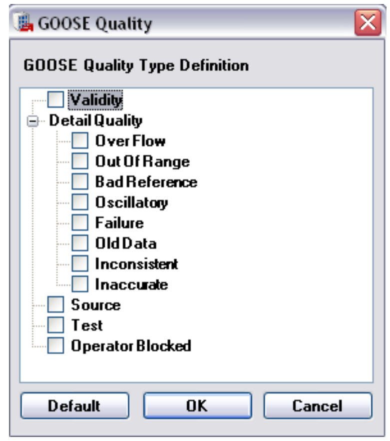


Figure F.3 GOOSE Quality

GOOSE Processing

SEL devices support GOOSE processing as defined by IEC 61850-7-1:2003(E), IEC 61850-7-2:2003(E), and IEC 61850-8-1:2004(E) via the installed Ethernet card.

Outgoing GOOSE messages are processed in accordance with the following constraints:

- The user can define up to 8 outgoing GOOSE messages consisting of any Data Attribute (DA) from any Logical Node. A single DA can be mapped to one or more outgoing GOOSE, or one or more times within the same outgoing GOOSE. A user can also map a single GOOSE dataset to multiple GOOSE control blocks.
- High-speed GOOSE messaging (as defined under *GOOSE Performance on page F.10*) is only available for CCOUT*n* data.
- The SEL-487E will transmit all configured GOOSE immediately upon successful initialization. If a GOOSE is not retriggered, then following initial transmission, the SEL-487E will retransmit that GOOSE on a curve. The curve begins at 4 ms and doubles for each retransmission until leveling at the maximum specified in the CID file for that GOOSE. For example, a message with a maximum retransmit interval of 50 ms is retransmitted at intervals of 4 ms, 8 ms, 16 ms, 32 ms and 50 ms, then repeated every 50 ms until a trigger causes the transmission sequence to be repeated. The time-to-live reported in each transmitted message, is three times the current interval, or two times the interval, if the maximum time-to-live has been reached (12 ms, 24 ms, 48 ms, 96 ms and 100 ms for the example above. See IEC 61850-8-1, sec. 18.1).
- GOOSE transmission is squelched (silenced) if the SEL-487E stops responding to the Ethernet card, or after a permanent (latching) self-test failure.
- Each outgoing GOOSE includes communication parameters (VLAN, Priority, and Multicast Address) and is transmitted entirely in a single network frame.
- The SEL-487E will maintain the configuration of outgoing GOOSE through a power cycle and device reset.

Incoming GOOSE messages are processed in accordance with the following constraints:

- The user can configure the SEL-487E to subscribe to as many as 24 incoming GOOSE messages.
- Control bits in the SEL-487E get data from incoming GOOSE messages which are mapped to CCIN*n* bits. Note: MMS can independently operate these bits.
- The SEL-487E will recognize incoming GOOSE messages as valid based on the following content:
  - Source broadcast MAC address.
  - Dataset Reference
  - Application ID
  - GOOSE Control Reference

  Any GOOSE message that fails these checks shall be rejected.
- Every received and validated GOOSE message that indicates a data change, by an incremented status number, is evaluated as follows:
  - Data within the received GOOSE dataset that are mapped to host data bits are identified.
  - Mapped bits are compared against a local version of the available host data bits.
  - If the state of the received bits is different than the local version,
    - Update the local version with the new state for that bit.
    - Pass the new state for the bit to the SEL-487E.
- Reject all DA contained in an incoming GOOSE based on the accumulation of the following error indications created by inspection of the received GOOSE:
  - **Configuration Mismatch.** The configuration number of the incoming GOOSE changes.
  - **Needs Commissioning.** This Boolean parameter of the incoming GOOSE is true.
  - **Test Mode.** This Boolean parameter of the incoming GOOSE is true.
  - **Decode Error.** The format of the incoming GOOSE is not as configured.
- The SEL-487E will discard incoming GOOSE under the following conditions:
  - after a permanent (latching) self-test failure
  - when the host is not responding
  - when EGSE is set to No

Link-layer priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2004(E).

GOOSE Performance

For outgoing high-speed data (CCOUT*n* data, as identified under *GOOSE Processing on page F.9*), transmission of GOOSE begins within 2 ms of transition of data within the SEL-487E. For all other data contained in outgoing GOOSE, transmission of GOOSE begins within 500 ms of transition of data within the SEL-487E. Appropriate control commands are issued to the SEL-487E within 2 ms of a GOOSE reception.

IEC 61850 Configuration

Settings

Table F.6 lists IEC 61850 settings. These settings are only available if your device includes the optional IEC 61850 protocol.

Table F.6 IEC 61850 Settings

Label	Description	Range	Default
E61850	IEC 61850 interface enable	Y, N	N
EGSE	Outgoing IEC 61850 GSE message enable	Y[a], N	N

[a] Requires E61850 set to Y to send IEC 61850 GSE messages.

Configure all other IEC 61850 settings, including subscriptions to incoming GOOSE messages, with ACSELERATOR Architect software.

ACSELERATOR Architect

The ACSELERATOR Architect software enables protection and integration engineers to design and commission IEC 61850 substations containing SEL IEDs.

Engineers can use ACSELERATOR Architect to:

- ➤ Organize and configure all SEL IEDs in a substation project.
- ➤ Configure incoming and outgoing GOOSE messages.
- ➤ Edit and create GOOSE datasets.
- ➤ Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options.
- ➤ Use or edit preconfigured datasets for reports.
- ➤ Load device settings and IEC 61850 CID files into SEL IEDs.
- ➤ Generate ICD files that will provide SEL IED descriptions to other manufacturers' tools so they can use SEL GOOSE messages and reporting features.
- ➤ Configure protection, logic, control, and communication settings of all SEL IEDs in the substation.

ACSELERATOR Architect provides a Graphical User Interface (GUI) for engineers to select, edit, and create IEC 61850 GOOSE messages important for substation protection, coordination, and control schemes. Typically, the engineer first places icons representing IEDs in a substation container, then edits the outgoing GOOSE messages or creates new ones for each IED. The engineer may also select incoming GOOSE messages for each IED to receive from any other IEDs in the domain. ACSELERATOR Architect has the capability to read other manufacturers' ICD and CID files, enabling the engineer to map the data seamlessly into SEL IED logic. See the ACSELERATOR Architect online help for more information.

SEL ICD File Versions

ACSELERATOR Architect version 1.1.69.0 and higher supports multiple ICD file versions for each IED in a project. Because relays with different Ethernet card firmware may require different CID file versions, this allows users to manage the CID files of all IEDs within a single project.

Ensure that you work with the appropriate version of ACSELERATOR Architect relative to your current configuration, existing project files, and ultimate goals. If you desire the best available IEC 61850 functionality for your SEL relay, obtain the latest version of ACSELERATOR Architect and select the appropriate ICD version(s) for your needs. ACSELERATOR Architect generates CID files from ICD files so the ICD file version ACSELERATOR Architect uses also determines the CID file version generated.

Logical Nodes

Table F.7 through *Table F.10* show the logical nodes (LNs) supported in the SEL-487E and the Relay Word bits or Measured Values mapped to those LNs. Any differences between ICD file versions are also indicated in the tables.

Table F.7 shows the LNs associated with protection elements, defined as Logical Device PRO.

Table F.7 Logical Device: PRO (Protection) (Sheet 1 of 7)

Logical Node	Attribute	Relay Word or Database Bit	Comment
SP1PIOC1	Op.general	50SP1	Instantaneous Phase Overcurrent, Winding S
SP2PIOC2	Op.general	50SP2	Instantaneous Phase Overcurrent, Winding S
SP3PIOC3	Op.general	50SP3	Instantaneous Phase Overcurrent, Winding S
SQ1PIOC4	Op.general	50SQ1	Instantaneous Negative-Sequence Overcurrent, Winding S
SQ2PIOC5	Op.general	50SQ2	Instantaneous Negative-Sequence Overcurrent, Winding S
SQ3PIOC6	Op.general	50SQ3	Instantaneous Negative-Sequence Overcurrent, Winding S
SG1PIOC7	Op.general	50SG1	Instantaneous Ground-Sequence Overcurrent, Winding S
SG2PIOC8	Op.general	50SG2	Instantaneous Ground-Sequence Overcurrent, Winding S
SG3PIOC9	Op.general	50SG3	Instantaneous Ground-Sequence Overcurrent, Winding S
SP1PTOC1	Str.general	67SP1	Phase Directional Element, Winding S
	Op.general	67SP1T	Time Delayed Phase Directional Element, Winding S
SP2PTOC2	Str.general	67SP2	Phase Directional Element, Winding S
	Op.general	67SP2T	Time Delayed Phase Directional Element, Winding S
SP3PTOC3	Str.general	67SP3	Phase Directional Element, Winding S
	Op.general	67SP3T	Time Delayed Phase Directional Element, Winding S
SQ1PTOC4	Str.general	67SQ1	Negative-Sequence Directional Element, Winding S
	Op.general	67SQ1T	Time Delayed Negative-Sequence Directional Element, Winding S
SQ2PTOC5	Str.general	67SQ2	Negative-Sequence Directional Element, Winding S
	Op.general	67SQ2T	Time Delayed Negative-Sequence Directional Element, Winding S
SQ3PTOC6	Str.general	67SQ3	Negative-Sequence Directional Element, Winding S
	Op.general	67SQ3T	Time Delayed Negative-Sequence Directional Element, Winding S

Table F.7 Logical Device: PRO (Protection) (Sheet 2 of 7)

Logical Node	Attribute	Relay Word or Database Bit	Comment
SG1PTOC7	Str.general	67SG1	Ground Directional Element, Winding S
	Op.general	67SG1T	Time Delayed Ground Directional Element, Winding S
SG2PTOC8	Str.general	67SG2	Ground Directional Element, Winding S
	Op.general	67SG2T	Time Delayed Ground Directional Element, Winding S
SG3PTOC9	Str.general	67SG3	Ground Directional Element, Winding S
	Op.general	67SG3T	Time Delayed Ground Directional Element, Winding S
TP1PIOC10	Op.general	50TP1	Instantaneous Phase Overcurrent, Winding T
TP2PIOC11	Op.general	50TP2	Instantaneous Phase Overcurrent, Winding T
TP3PIOC12	Op.general	50TP3	Instantaneous Phase Overcurrent, Winding T
TQ1PIOC13	Op.general	50TQ1	Instantaneous Negative-Sequence Overcurrent, Winding T
TQ2PIOC14	Op.general	50TQ2	Instantaneous Negative-Sequence Overcurrent, Winding T
TQ3PIOC15	Op.general	50TQ3	Instantaneous Negative-Sequence Overcurrent, Winding T
TG1PIOC16	Op.general	50TG1	Instantaneous Ground-Sequence Overcurrent, Winding T
TG2PIOC17	Op.general	50TG2	Instantaneous Ground-Sequence Overcurrent, Winding T
TG3PIOC18	Op.general	50TG3	Instantaneous Ground-Sequence Overcurrent, Winding T
TP1PTOC10	Str.general	67TP1	Phase Directional Element, Winding T
	Op.general	67TP1T	Time Delayed Phase Directional Element, Winding T
TP2PTOC11	Str.general	67TP2	Phase Directional Element, Winding T
	Op.general	67TP2T	Time Delayed Phase Directional Element, Winding T
TP3PTOC12	Str.general	67TP3	Phase Directional Element, Winding T
	Op.general	67TP3T	Time Delayed Phase Directional Element, Winding T
TQ1PTOC13	Str.general	67TQ1	Negative-Sequence Directional Element, Winding T
	Op.general	67TQ1T	Time Delayed Negative-Sequence Directional Element, Winding T
TQ2PTOC14	Str.general	67TQ2	Negative-Sequence Directional Element, Winding T
	Op.general	67TQ2T	Time Delayed Negative-Sequence Directional Element, Winding T
TQ3PTOC15	Str.general	67TQ3	Negative-Sequence Directional Element, Winding T
	Op.general	67TQ3T	Time Delayed Negative-Sequence Directional Element, Winding T
TG1PTOC16	Str.general	67TG1	Ground Directional Element, Winding T
	Op.general	67TG1T	Time Delayed Ground Directional Element, Winding T
TG2PTOC17	Str.general	67TG2	Ground Directional Element, Winding T
	Op.general	67TG2T	Time Delayed Ground Directional Element, Winding T
TG3PTOC18	Str.general	67TG3	Ground Directional Element, Winding T
	Op.general	67TG3T	Time Delayed Ground Directional Element, Winding T
UP1PIOC19	Op.general	50UP1	Instantaneous Phase Overcurrent, Winding U
UP2PIOC20	Op.general	50UP2	Instantaneous Phase Overcurrent, Winding U
UP3PIOC21	Op.general	50UP3	Instantaneous Phase Overcurrent, Winding U
UQ1PIOC22	Op.general	50UQ1	Instantaneous Negative-Sequence Overcurrent, Winding U
UQ2PIOC23	Op.general	50UQ2	Instantaneous Negative-Sequence Overcurrent, Winding U
UQ3PIOC24	Op.general	50UQ3	Instantaneous Negative-Sequence Overcurrent, Winding U
UG1PIOC25	Op.general	50UG1	Instantaneous Ground-Sequence Overcurrent, Winding U

Table F.7 Logical Device: PRO (Protection) (Sheet 3 of 7)

Logical Node	Attribute	Relay Word or Database Bit	Comment
UG2PIOC26	Op.general	50UG2	Instantaneous Ground-Sequence Overcurrent, Winding U
UG3PIOC27	Op.general	50UG3	Instantaneous Ground-Sequence Overcurrent, Winding U
UP1PTOC19	Str.general	67UP1	Phase Directional Element, Winding U
	Op.general	67UP1T	Time Delayed Phase Directional Element, Winding U
UP2PTOC20	Str.general	67UP2	Phase Directional Element, Winding U
	Op.general	67UP2T	Time Delayed Phase Directional Element, Winding U
UP3PTOC21	Str.general	67UP3	Phase Directional Element, Winding U
	Op.general	67UP3T	Time Delayed Phase Directional Element, Winding U
UQ1PTOC22	Str.general	67UQ1	Negative-Sequence Directional Element, Winding U
	Op.general	67UQ1T	Time Delayed Negative-Sequence Directional Element, Winding U
UQ2PTOC23	Str.general	67UQ2	Negative-Sequence Directional Element, Winding U
	Op.general	67UQ2T	Time Delayed Negative-Sequence Directional Element, Winding U
UQ3PTOC24	Str.general	67UQ3	Negative-Sequence Directional Element, Winding U
	Op.general	67UQ3T	Time Delayed Negative-Sequence Directional Element, Winding U
UG1PTOC25	Str.general	67UG1	Ground Directional Element, Winding U
	Op.general	67UG1T	Time Delayed Ground Directional Element, Winding U
UG2PTOC26	Str.general	67UG2	Ground Directional Element, Winding U
	Op.general	67UG2T	Time Delayed Ground Directional Element, Winding U
UG3PTOC27	Str.general	67UG3	Ground Directional Element, Winding U
	Op.general	67UG3T	Time Delayed Ground Directional Element, Winding U
WP1PIOC28	Op.general	50WP1	Instantaneous Phase Overcurrent, Winding W
WP2PIOC29	Op.general	50WP2	Instantaneous Phase Overcurrent, Winding W
WP3PIOC30	Op.general	50WP3	Instantaneous Phase Overcurrent, Winding W
WQ1PIOC31	Op.general	50WQ1	Instantaneous Negative-Sequence Overcurrent, Winding W
WQ2PIOC32	Op.general	50WQ2	Instantaneous Negative-Sequence Overcurrent, Winding W
WQ3PIOC33	Op.general	50WQ3	Instantaneous Negative-Sequence Overcurrent, Winding W
WG1PIOC34	Op.general	50WG1	Instantaneous Ground-Sequence Overcurrent, Winding W
WG2PIOC35	Op.general	50WG2	Instantaneous Ground-Sequence Overcurrent, Winding W
WG3PIOC36	Op.general	50WG3	Instantaneous Ground-Sequence Overcurrent, Winding W
WP1PTOC28	Str.general	67WP1	Phase Directional Element, Winding W
	Op.general	67WP1T	Time Delayed Phase Directional Element, Winding W
WP2PTOC29	Str.general	67WP2	Phase Directional Element, Winding W
	Op.general	67WP2T	Time Delayed Phase Directional Element, Winding W
WP3PTOC30	Str.general	67WP3	Phase Directional Element, Winding W
	Op.general	67WP3T	Time Delayed Phase Directional Element, Winding W
WQ1PTOC31	Str.general	67WQ1	Negative-Sequence Directional Element, Winding W
	Op.general	67WQ1T	Time Delayed Negative-Sequence Directional Element, Winding W
WQ2PTOC32	Str.general	67WQ2	Negative-Sequence Directional Element, Winding W
	Op.general	67WQ2T	Time Delayed Negative-Sequence Directional Element, Winding W

Table F.7 Logical Device: PRO (Protection) (Sheet 4 of 7)

Logical Node	Attribute	Relay Word or Database Bit	Comment
WQ3PTOC33	Str.general	67WQ3	Negative-Sequence Directional Element, Winding W
	Op.general	67WQ3T	Time Delayed Negative-Sequence Directional Element, Winding W
WG1PTOC34	Str.general	67WG1	Ground Directional Element, Winding W
	Op.general	67WG1T	Time Delayed Ground Directional Element, Winding W
WG2PTOC35	Str.general	67WG2	Ground Directional Element, Winding W
	Op.general	67WG2T	Time Delayed Ground Directional Element, Winding W
WG3PTOC36	Str.general	67WG3	Ground Directional Element, Winding W
	Op.general	67WG3T	Time Delayed Ground Directional Element, Winding W
XP1PIOC37	Op.general	50XP1	Instantaneous Phase Overcurrent, Winding X
XP2PIOC38	Op.general	50XP2	Instantaneous Phase Overcurrent, Winding X
XP3PIOC39	Op.general	50XP3	Instantaneous Phase Overcurrent, Winding X
XQ1PIOC40	Op.general	50XQ1	Instantaneous Negative-Sequence Overcurrent, Winding X
XQ2PIOC41	Op.general	50XQ2	Instantaneous Negative-Sequence Overcurrent, Winding X
XQ3PIOC42	Op.general	50XQ3	Instantaneous Negative-Sequence Overcurrent, Winding X
XG1PIOC43	Op.general	50XG1	Instantaneous Ground-Sequence Overcurrent, Winding X
XG2PIOC44	Op.general	50XG2	Instantaneous Ground-Sequence Overcurrent, Winding X
XG3PIOC45	Op.general	50XG3	Instantaneous Ground-Sequence Overcurrent, Winding X
XP1PTOC37	Str.general	67XP1	Phase Directional Element, Winding X
	Op.general	67XP1T	Time Delayed Phase Directional Element, Winding X
XP2PTOC38	Str.general	67XP2	Phase Directional Element, Winding X
	Op.general	67XP2T	Time Delayed Phase Directional Element, Winding X
XP3PTOC39	Str.general	67XP3	Phase Directional Element, Winding X
	Op.general	67XP3T	Time Delayed Phase Directional Element, Winding X
XQ1PTOC40	Str.general	67XQ1	Negative-Sequence Directional Element, Winding X
	Op.general	67XQ1T	Time Delayed Negative-Sequence Directional Element, Winding X
XQ2PTOC41	Str.general	67XQ2	Negative-Sequence Directional Element, Winding X
	Op.general	67XQ2T	Time Delayed Negative-Sequence Directional Element, Winding X
XQ3PTOC42	Str.general	67XQ3	Negative-Sequence Directional Element, Winding X
	Op.general	67XQ3T	Time Delayed Negative-Sequence Directional Element, Winding X
XG1PTOC43	Str.general	67XG1	Ground Directional Element, Winding X
	Op.general	67XG1T	Time Delayed Ground Directional Element, Winding X
XG2PTOC44	Str.general	67XG2	Ground Directional Element, Winding X
	Op.general	67XG2T	Time Delayed Ground Directional Element, Winding X
XG3PTOC45	Str.general	67XG3	Ground Directional Element, Winding X
	Op.general	67XG3T	Time Delayed Ground Directional Element, Winding X
IT1PTOC46	Str.general	51S01	Inverse time element 01 picked up
	Op.general	51T01	Inverse time element 01 timed out
IT2PTOC47	Str.general	51S02	Inverse time element 02 picked up
	Op.general	51T02	Inverse time element 02 timed out

Table F.7 Logical Device: PRO (Protection) (Sheet 5 of 7)

Logical Node	Attribute	Relay Word or Database Bit	Comment
IT3PTOC48	Str.general	51S03	Inverse time element 03 picked up
	Op.general	51T03	Inverse time element 03 timed out
IT4PTOC49	Str.general	51S04	Inverse time element 04 picked up
	Op.general	51T04	Inverse time element 04 timed out
IT5PTOC50	Str.general	51S05	Inverse time element 05 picked up
	Op.general	51T05	Inverse time element 05 timed out
IT6PTOC51	Str.general	51S06	Inverse time element 06 picked up
	Op.general	51T06	Inverse time element 06 timed out
IT7PTOC52	Str.general	51S07	Inverse time element 07 picked up
	Op.general	51T07	Inverse time element 07 timed out
IT8PTOC53	Str.general	51S08	Inverse time element 08 picked up
	Op.general	51T08	Inverse time element 08 timed out
IT9PTOC54	Str.general	51S09	Inverse time element 09 picked up
	Op.general	51T09	Inverse time element 09 timed out
IT10PTOC55	Str.general	51S10	Inverse time element 10 picked up
	Op.general	51T10	Inverse time element 10 timed out
U1P1PTUV1	Str.general	271P1	Undervoltage element 1 level 1 asserted
	Op.general	271P1T	Undervoltage element 1 level 1 timed out
U1P2PTUV1	Op.general	271P2	Undervoltage element 1 level 2 asserted
U2P1PTUV2	Str.general	272P1	Undervoltage element 2 level 1 asserted
	Op.general	272P1T	Undervoltage element 2 level 1 timed out
U2P2PTUV2	Op.general	272P2	Undervoltage element 2 level 2 asserted
U3P1PTUV3	Str.general	273P1	Undervoltage element 3 level 1 asserted
	Op.general	273P1T	Undervoltage element 3 level 1 timed out
U3P2PTUV3	Op.general	273P2	Undervoltage element 3 level 2 asserted
U4P1PTUV4	Str.general	274P1	Undervoltage element 4 level 1 asserted
	Op.general	274P1T	Undervoltage element 4 level 1 timed out
U4P2PTUV4	Op.general	274P2	Undervoltage element 4 level 2 asserted
U5P1PTUV5	Str.general	275P1	Undervoltage element 5 level 1 asserted
	Op.general	275P1T	Undervoltage element 5 level 1 timed out
U5P2PTUV5	Op.general	275P2	Undervoltage element 5 level 2 asserted
O1P1PTOV1	Str.general	591P1	Overvoltage element 1 level 1 asserted
	Op.general	591P1T	Overvoltage element 1 level 1 timed out
O1P2PTOV1	Op.general	591P2	Overvoltage element 1 level 2 asserted
O2P1PTOV2	Str.general	592P1	Overvoltage element 2 level 1 asserted
	Op.general	592P1T	Overvoltage element 2 level 1 timed out
O2P2PTOV2	Op.general	592P2	Overvoltage element 2 level 2 asserted
O3P1PTOV3	Str.general	593P1	Overvoltage element 3 level 1 asserted
	Op.general	593P1T	Overvoltage element 3 level 1 timed out
O3P2PTOV3	Op.general	593P2	Overvoltage element 3 level 2 asserted

Table F.7 Logical Device: PRO (Protection) (Sheet 6 of 7)

Logical Node	Attribute	Relay Word or Database Bit	Comment
O4P1PTOV4	Str.general	594P1	Overvoltage element 4 level 1 asserted
	Op.general	594P1T	Overvoltage element 4 level 1 timed out
O4P2PTOV4	Op.general	594P2	Overvoltage element 4 level 2 asserted
O5P1PTOV5	Str.general	595P1	Overvoltage element 5 level 1 asserted
	Op.general	595P1T	Overvoltage element 5 level 1 timed out
O5P2PTOV5	Op.general	595P2	Overvoltage element 5 level 2 asserted
D1PVPH1	Str.general	24D1	Volts/Hertz Element asserted
	Op.general	24D1T	Volts/Hertz level 1 timed out
D2PVPH2	Str.general	24D1	Volts/Hertz Element asserted
	Op.general	24D2T	Volts/Hertz level 2 timed out
U1PVPH3	Str.general	24D1	Volts/Hertz Element asserted
	Op.general	24U1T	User Defined Curve Volts/Hertz Time-Out
U2PVPH4	Str.general	24D1	Volts/Hertz Element asserted
	Op.general	24U2T	User Defined Curve Volts/Hertz Time-Out
D87RPDIF1	Op.general	87R	Restrained differential element operated
D87RAPDIF1	Str.general	P87A	Differential element phase A picked up
	Op.general	87RA	Restrained Differential element operated phase A
D87RBPDIF2	Str.general	P87B	Differential element phase B picked up
	Op.general	87RB	Restrained Differential element operated phase B
D87RCPDIF3	Str.general	P87C	Differential element phase C picked up
	Op.general	87RC	Restrained Differential element operated phase C
D87UPDIF1	Op.general	87U	Unrestrained Differential Element
HRPHAR1	Str.general	CSV01	Communication Card SELOGIC Variable 1
HBPHAR2	Str.general	CSV02	Communication Card SELOGIC Variable 1
TRIPPTRC1	Tr.general	TRIPXFMR	Transformer trip output
TRIPSPTRC2	Tr.general	TRIPS	Terminal S trip output
TRIPTPTRC3	Tr.general	TRIPT	Terminal T trip output
TRIPUPTRC4	Tr.general	TRIPU	Terminal U trip output
TRIPWPTRC5	Tr.general	TRIPW	Terminal W trip output
TRIPXPTRC6	Tr.general	TRIPX	Terminal X trip output
S52AXCBR1	Tr.general	52A_S	S Breaker Aux Contact
T52AXCBR2	Tr.general	52A_T	T Breaker Aux Contact
U52AXCBR3	Tr.general	52A_U	U Breaker Aux Contact
W52AXCBR4	Tr.general	52A_W	W Breaker Aux Contact
X52AXCBR5	Tr.general	52A_X	X Breaker Aux Contact
X89CLXSWI1	Pos.stVal	89CL1	Disconnect 1 Closed
X89CLXSWI2	Pos.stVal	89CL2	Disconnect 2 Closed
X89CLXSWI3	Pos.stVal	89CL3	Disconnect 3 Closed
X89CLXSWI4	Pos.stVal	89CL4	Disconnect 4 Closed
X89CLXSWI5	Pos.stVal	89CL5	Disconnect 5 Closed

Table F.7 Logical Device: PRO (Protection) (Sheet 7 of 7)

Logical Node	Attribute	Relay Word or Database Bit	Comment
X89CLXSWI6	Pos.stVal	89CL6	Disconnect 6 Closed
X89CLXSWI7	Pos.stVal	89CL7	Disconnect 7 Closed
X89CLXSWI8	Pos.stVal	89CL8	Disconnect 8 Closed
SBKRCSWI1	OpOpn.general	OCS	Breaker Open Command Terminal S
	OpCls.general	CCS	Breaker Close Command Terminal S
TBKRCSWI2	OpOpn.general	OCT	Breaker Open Command Terminal T
	OpCls.general	CCT	Breaker Close Command Terminal T
UBKRCSWI3	OpOpn.general	OCU	Breaker Open Command Terminal U
	OpCls.general	CCU	Breaker Close Command Terminal U
WBKRCSWI4	OpOpn.general	OCW	Breaker Open Command Terminal W
	OpCls.general	CCW	Breaker Close Command Terminal W
XBKRCSWI5	OpOpn.general	OCX	Breaker Open Command Terminal X
	OpCls.general	CCX	Breaker Close Command Terminal X
DC1CSWI6	OpOpn.general	89OPEN1	Disconnect 1 Open Command
	OpCls.general	89CLS1	Disconnect 1 Close Command
DC2CSWI7	OpOpn.general	89OPEN2	Disconnect 2 Open Command
	OpCls.general	89CLS2	Disconnect 2 Close Command
DC3CSWI8	OpOpn.general	89OPEN3	Disconnect 3 Open Command
	OpCls.general	89CLS3	Disconnect 3 Close Command
DC4CSWI9	OpOpn.general	89OPEN4	Disconnect 4 Open Command
	OpCls.general	89CLS4	Disconnect 4 Close Command
DC5CSWI10	OpOpn.general	89OPEN5	Disconnect 5 Open Command
	OpCls.general	89CLS5	Disconnect 5 Close Command
DC6CSWI11	OpOpn.general	89OPEN6	Disconnect 6 Open Command
	OpCls.general	89CLS6	Disconnect 6 Close Command
DC7CSWI12	OpOpn.general	89OPEN7	Disconnect 7 Open Command
	OpCls.general	89CLS7	Disconnect 7 Close Command
DC8CSWI13	OpOpn.general	89OPEN8	Disconnect 8 Open Command
	OpCls.general	89CLS8	Disconnect 8 Close Command

Table F.8 shows the LNs associated with measuring elements, defined as Logical Device MET.

Table F.8 Logical Device: MET (Metering) (Sheet 1 of 12)

LN	Measurand	Comment
METSMMXU1	TotW.mag.f	Total real power, Terminal S
	TotVAr.mag.f	Total reactive power, Terminal S
	TotVA.mag.f	Total apparent power, Terminal S
	TotPF.mag.f	Three-phase power factor, Terminal S
	Hz.mag.f	System frequency, Terminal S
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 2 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminal S
	A1.phsA.cVal.ang.f	Line A current angle, Terminal S
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminal S
	A1.phsB.cVal.ang.f	Line B current angle, Terminal S
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminal S
	A1.phsC.cVal.ang.f	Line C current angle, Terminal S
	W.phsA.mag.f	Phase A real power, Terminal S
	W.phsB.mag.f	Phase B real power, Terminal S
	W.phsC.mag.f	Phase C real power, Terminal S
	VAr.phsA.mag.f	Phase A reactive power, Terminal S
	VAr.phsB.mag.f	Phase B reactive power, Terminal S
	VAr.phsC.mag.f	Phase C reactive power, Terminal S
	VA.phsA.mag.f	Phase A total power, Terminal S
	VA.phsB.mag.f	Phase B total power, Terminal S
	VA.phsC.mag.f	Phase C total power, Terminal S
	PF.phsA.mag.f	Phase A power factor, Terminal S
	PF.phsB.mag.f	Phase B power factor, Terminal S
	PF.phsC.mag.f	Phase C power factor, Terminal S
METTMMXU2	TotW.mag.f	Total real power, Terminal T
	TotVAr.mag.f	Total reactive power, Terminal T
	TotVA.mag.f	Total apparent power, Terminal T
	TotPF.mag.f	Three-phase power factor, Terminal T
	Hz.mag.f	System frequency, Terminal T
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 3 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminal T
	A1.phsA.cVal.ang.f	Line A current angle, Terminal T
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminal T
	A1.phsB.cVal.ang.f	Line B current angle, Terminal T
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminal T
	A1.phsC.cVal.ang.f	Line C current angle, Terminal T
	W.phsA.mag.f	Phase A real power, Terminal T
	W.phsB.mag.f	Phase B real power, Terminal T
	W.phsC.mag.f	Phase C real power, Terminal T
	VAr.phsA.mag.f	Phase A reactive power, Terminal T
	VAr.phsB.mag.f	Phase B reactive power, Terminal T
	VAr.phsC.mag.f	Phase C reactive power, Terminal T
	VA.phsA.mag.f	Phase A total power, Terminal T
	VA.phsB.mag.f	Phase B total power, Terminal T
	VA.phsC.mag.f	Phase C total power, Terminal T
	PF.phsA.mag.f	Phase A power factor, Terminal T
	PF.phsB.mag.f	Phase B power factor, Terminal T
	PF.phsC.mag.f	Phase C power factor, Terminal T
METUMMXU3	TotW.mag.f	Total real power, Terminal U
	TotVAr.mag.f	Total reactive power, Terminal U
	TotVA.mag.f	Total apparent power, Terminal U
	TotPF.mag.f	Three-phase power factor, Terminal U
	Hz.mag.f	System frequency, Terminal U
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 4 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminal U
	A1.phsA.cVal.ang.f	Line A current angle, Terminal U
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminal U
	A1.phsB.cVal.ang.f	Line B current angle, Terminal U
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminal U
	A1.phsC.cVal.ang.f	Line C current angle, Terminal U
	W.phsA.mag.f	Phase A real power, Terminal U
	W.phsB.mag.f	Phase B real power, Terminal U
	W.phsC.mag.f	Phase C real power, Terminal U
	VAr.phsA.mag.f	Phase A reactive power, Terminal U
	VAr.phsB.mag.f	Phase B reactive power, Terminal U
	VAr.phsC.mag.f	Phase C reactive power, Terminal U
	VA.phsA.mag.f	Phase A total power, Terminal U
	VA.phsB.mag.f	Phase B total power, Terminal U
	VA.phsC.mag.f	Phase C total power, Terminal U
	PF.phsA.mag.f	Phase A power factor, Terminal U
	PF.phsB.mag.f	Phase B power factor, Terminal U
	PF.phsC.mag.f	Phase C power factor, Terminal U
METWMMXU4	TotW.mag.f	Total real power, Terminal W
	TotVAr.mag.f	Total reactive power, Terminal W
	TotVA.mag.f	Total apparent power, Terminal W
	TotPF.mag.f	Three-phase power factor, Terminal W
	Hz.mag.f	System frequency, Terminal W
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 5 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminal W
	A1.phsA.cVal.ang.f	Line A current angle, Terminal W
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminal W
	A1.phsB.cVal.ang.f	Line B current angle, Terminal W
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminal W
	A1.phsC.cVal.ang.f	Line C current angle, Terminal W
	W.phsA.mag.f	Phase A real power, Terminal W
	W.phsB.mag.f	Phase B real power, Terminal W
	W.phsC.mag.f	Phase C real power, Terminal W
	VAr.phsA.mag.f	Phase A reactive power, Terminal W
	VAr.phsB.mag.f	Phase B reactive power, Terminal W
	VAr.phsC.mag.f	Phase C reactive power, Terminal W
	VA.phsA.mag.f	Phase A total power, Terminal W
	VA.phsB.mag.f	Phase B total power, Terminal W
	VA.phsC.mag.f	Phase C total power, Terminal W
	PF.phsA.mag.f	Phase A power factor, Terminal W
	PF.phsB.mag.f	Phase B power factor, Terminal W
	PF.phsC.mag.f	Phase C power factor, Terminal W
METXMMXU5	TotW.mag.f	Total real power, Terminal X
	TotVAr.mag.f	Total reactive power, Terminal X
	TotVA.mag.f	Total apparent power, Terminal X
	TotPF.mag.f	Three-phase power factor, Terminal X
	Hz.mag.f	System frequency, Terminal X
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 6 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminal X
	A1.phsA.cVal.ang.f	Line A current angle, Terminal X
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminal X
	A1.phsB.cVal.ang.f	Line B current angle, Terminal X
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminal X
	A1.phsC.cVal.ang.f	Line C current angle, Terminal X
	W.phsA.mag.f	Phase A real power, Terminal X
	W.phsB.mag.f	Phase B real power, Terminal X
	W.phsC.mag.f	Phase C real power, Terminal X
	VAr.phsA.mag.f	Phase A reactive power, Terminal X
	VAr.phsB.mag.f	Phase B reactive power, Terminal X
	VAr.phsC.mag.f	Phase C reactive power, Terminal X
	VA.phsA.mag.f	Phase A total power, Terminal X
	VA.phsB.mag.f	Phase B total power, Terminal X
	VA.phsC.mag.f	Phase C total power, Terminal X
	PF.phsA.mag.f	Phase A power factor, Terminal X
	PF.phsB.mag.f	Phase B power factor, Terminal X
	PF.phsC.mag.f	Phase C power factor, Terminal X
METSTMMXU6	TotW.mag.f	Total real power, Terminals S,T
	TotVAr.mag.f	Total reactive power, Terminals S,T
	TotVA.mag.f	Total apparent power, Terminals S,T
	TotPF.mag.f	Three-phase power factor, Terminals S,T
	Hz.mag.f	System frequency, Terminals S,T
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 7 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminals S,T
	A1.phsA.cVal.ang.f	Line A current angle, Terminals S,T
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminals S,T
	A1.phsB.cVal.ang.f	Line B current angle, Terminals S,T
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminals S,T
	A1.phsC.cVal.ang.f	Line C current angle, Terminals S,T
	W.phsA.mag.f	Phase A real power, Terminals S,T
	W.phsB.mag.f	Phase B real power, Terminals S,T
	W.phsC.mag.f	Phase C real power, Terminals S,T
	VAr.phsA.mag.f	Phase A reactive power, Terminals S,T
	VAr.phsB.mag.f	Phase B reactive power, Terminals S,T
	VAr.phsC.mag.f	Phase C reactive power, Terminals S,T
	VA.phsA.mag.f	Phase A total power, Terminals S,T
	VA.phsB.mag.f	Phase B total power, Terminals S,T
	VA.phsC.mag.f	Phase C total power, Terminals S,T
	PF.phsA.mag.f	Phase A power factor, Terminals S,T
	PF.phsB.mag.f	Phase B power factor, Terminals S,T
	PF.phsC.mag.f	Phase C power factor, Terminals S,T
METTUMMXU7	TotW.mag.f	Total real power, Terminals T,U
	TotVAr.mag.f	Total reactive power, Terminals T,U
	TotVA.mag.f	Total apparent power, Terminals T,U
	TotPF.mag.f	Three-phase power factor, Terminals T,U
	Hz.mag.f	System frequency, Terminals T,U
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 8 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminals T,U
	A1.phsA.cVal.ang.f	Line A current angle, Terminals T,U
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminals T,U
	A1.phsB.cVal.ang.f	Line B current angle, Terminals T,U
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminals T,U
	A1.phsC.cVal.ang.f	Line C current angle, Terminals T,U
	W.phsA.mag.f	Phase A real power, Terminals T,U
	W.phsB.mag.f	Phase B real power, Terminals T,U
	W.phsC.mag.f	Phase C real power, Terminals T,U
	VAr.phsA.mag.f	Phase A reactive power, Terminals T,U
	VAr.phsB.mag.f	Phase B reactive power, Terminals T,U
	VAr.phsC.mag.f	Phase C reactive power, Terminals T,U
	VA.phsA.mag.f	Phase A total power, Terminals T,U
	VA.phsB.mag.f	Phase B total power, Terminals T,U
	VA.phsC.mag.f	Phase C total power, Terminals T,U
	PF.phsA.mag.f	Phase A power factor, Terminals T,U
	PF.phsB.mag.f	Phase B power factor, Terminals T,U
	PF.phsC.mag.f	Phase C power factor, Terminals T,U
METUWMMXU8	TotW.mag.f	Total real power, Terminals U,W
	TotVAr.mag.f	Total reactive power, Terminals U,W
	TotVA.mag.f	Total apparent power, Terminals U,W
	TotPF.mag.f	Three-phase power factor, Terminals U,W
	Hz.mag.f	System frequency, Terminals U,W
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 9 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminals U,W
	A1.phsA.cVal.ang.f	Line A current angle, Terminals U,W
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminals U,W
	A1.phsB.cVal.ang.f	Line B current angle, Terminals U,W
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminals U,W
	A1.phsC.cVal.ang.f	Line C current angle, Terminals U,W
	W.phsA.mag.f	Phase A real power, Terminals U,W
	W.phsB.mag.f	Phase B real power, Terminals U,W
	W.phsC.mag.f	Phase C real power, Terminals U,W
	VAr.phsA.mag.f	Phase A reactive power, Terminals U,W
	VAr.phsB.mag.f	Phase B reactive power, Terminals U,W
	VAr.phsC.mag.f	Phase C reactive power, Terminals U,W
	VA.phsA.mag.f	Phase A total power, Terminals U,W
	VA.phsB.mag.f	Phase B total power, Terminals U,W
	VA.phsC.mag.f	Phase C total power, Terminals U,W
	PF.phsA.mag.f	Phase A power factor, Terminals U,W
	PF.phsB.mag.f	Phase B power factor, Terminals U,W
	PF.phsC.mag.f	Phase C power factor, Terminals U,W
METWXMMXU9	TotW.mag.f	Total real power, Terminals W,X
	TotVAr.mag.f	Total reactive power, Terminals W,X
	TotVA.mag.f	Total apparent power, Terminals W,X
	TotPF.mag.f	Three-phase power factor, Terminals W,X
	Hz.mag.f	System frequency, Terminals W,X
	PhV1.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal V

Table F.8 Logical Device: MET (Metering) (Sheet 10 of 12)

LN	Measurand	Comment
	PhV1.phsA.cVal.ang.f	Phase A voltage angle, Terminal V
	PhV1.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal V
	PhV1.phsB.cVal.ang.f	Phase B voltage angle, Terminal V
	PhV1.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal V
	PhV1.phsC.cVal.ang.f	Phase C voltage angle, Terminal V
	PhV2.phsA.cVal.mag.f	Phase A voltage magnitude, Terminal Z
	PhV2.phsA.cVal.ang.f	Phase A voltage angle, Terminal Z
	PhV2.phsB.cVal.mag.f	Phase B voltage magnitude, Terminal Z
	PhV2.phsB.cVal.ang.f	Phase B voltage angle, Terminal Z
	PhV2.phsC.cVal.mag.f	Phase C voltage magnitude, Terminal Z
	PhV2.phsC.cVal.ang.f	Phase C voltage angle, Terminal Z
	PPV1.phsAB.mag.f	Phase AB voltage magnitude, Terminal V
	PPV1.phsBC.mag.f	Phase BC voltage magnitude, Terminal V
	PPV1.phsCA.mag.f	Phase CA voltage magnitude, Terminal V
	PPV2.phsAB.mag.f	Phase AB voltage angle, Terminal Z
	PPV2.phsBC.mag.f	Phase BC voltage angle, Terminal Z
	PPV2.phsCA.mag.f	Phase CA voltage angle, Terminal Z
	A1.phsA.cVal.mag.f	Line A current magnitude, Terminals W,X
	A1.phsA.cVal.ang.f	Line A current angle, Terminals W,X
	A1.phsB.cVal.mag.f	Line B current magnitude, Terminals W,X
	A1.phsB.cVal.ang.f	Line B current angle, Terminals W,X
	A1.phsC.cVal.mag.f	Line C current magnitude, Terminals W,X
	A1.phsC.cVal.ang.f	Line C current angle, Terminals W,X
	W.phsA.mag.f	Phase A real power, Terminals W,X
	W.phsB.mag.f	Phase B real power, Terminals W,X
	W.phsC.mag.f	Phase C real power, Terminals W,X
	VAr.phsA.mag.f	Phase A reactive power, Terminals W,X
	VAr.phsB.mag.f	Phase B reactive power, Terminals W,X
	VAr.phsC.mag.f	Phase C reactive power, Terminals W,X
	VA.phsA.mag.f	Phase A total power, Terminals W,X
	VA.phsB.mag.f	Phase B total power, Terminals W,X
	VA.phsC.mag.f	Phase C total power, Terminals W,X
	PF.phsA.mag.f	Phase A power factor, Terminals W,X
	PF.phsB.mag.f	Phase B power factor, Terminals W,X
	PF.phsC.mag.f	Phase C power factor, Terminals W,X
SEQSMSQI1	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminal S
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminal S
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminal S
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminal S
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminal S
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminal S

Table F.8 Logical Device: MET (Metering) (Sheet 11 of 12)

LN	Measurand	Comment
SEQTMSQI2	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminal T
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminal T
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminal T
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminal T
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminal S
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminal T
SEQUMSQI3	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminal U
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminal U
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminal U
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminal U
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminal S
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminal U
SEQWMSQI4	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminal W
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminal W
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminal W
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminal W
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminal W
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminal W
SEQXMSQI5	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminal X
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminal X
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminal X
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminal X
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminal X
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminal X
SEQSTMSQI6	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminals S,T
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminals S,T
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminals S,T
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminals S,T
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminals S,T
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminals S,T
SEQTUMSQI7	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminals T,U
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminals T,U
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminals T,U
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminals T,U
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminals T,U
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminals T,U
SEQUWMSQI8	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminals U,W
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminals U,W
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminals U,W
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminals U,W
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminals U,W

Table F.8 Logical Device: MET (Metering) (Sheet 12 of 12)

LN	Measurand	Comment
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminals U,W
SEQWXMSQI9	SeqA.c1.cVal.mag.f	Positive-Sequence Current Magnitude, Terminals W,X
	SeqA.c1.cVal.ang.f	Positive-Sequence Current Angle, Terminals W,X
	SeqA.c2.cVal.mag.f	Negative-Sequence Current Magnitude, Terminals W,X
	SeqA.c2.cVal.ang.f	Negative-Sequence Current Angle, Terminals W,X
	SeqA.c3.cVal.mag.f	Zero-Sequence Current Magnitude, Terminals W,X
	SeqA.c3.cVal.ang.f	Zero-Sequence Current Angle Terminals W,X
SEQVMSQI1	SeqV1.c1.cVal.mag.f	Positive-Sequence Voltage Magnitude, Terminal V
	SeqV1.c1.cVal.ang.f	Positive-Sequence Voltage Angle, Terminal V
	SeqV1.c2.cVal.mag.f	Negative-Sequence Voltage Magnitude, Terminal V
	SeqV1.c2.cVal.ang.f	Negative-Sequence Voltage Angle, Terminal V
	SeqV1.c3.cVal.mag.f	Zero-Sequence Voltage Magnitude, Terminal V
	SeqV1.c3.cVal.ang.f	Zero-Sequence Voltage Angle Terminal V
	SeqV2.c1.cVal.mag.f	Positive-Sequence Voltage Magnitude, Terminal Z
	SeqV2.c1.cVal.ang.f	Positive-Sequence Voltage Angle, Terminal Z
	SeqV2.c2.cVal.mag.f	Negative-Sequence Voltage Magnitude, Terminal Z
	SeqV2.c2.cVal.ang.f	Negative-Sequence Voltage Angle, Terminal Z
	SeqV2.c3.cVal.mag.f	Zero-Sequence Voltage Magnitude, Terminal Z
	SeqV2.c3.cVal.ang.f	Zero-Sequence Voltage Angle Terminal Z
METYMMXN1	Amp01.mag.f	Current Magnitude, IAY
	Amp02.mag.f	Current Magnitude, IBY
	Amp03.mag.f	Current Magnitude, ICY

Table F.9 shows the LNs associated with control elements, defined as Logical Device CON.

Table F.9 Logical Device: CON (Remote Control)

Logical Node (All ICD Versions)	Control	Relay Word or Database Bit
RBGGIO1	SPCSO01–SPCS032	RB01–RB32

Table F.10 shows the LNs associated with the annunciation element, defined as Logical Device ANN.

Table F.10 Logical Device: ANN (Annunciation) (Sheet 1 of 2)

Logical Node	Attribute	Relay Word or Database Bit	Comment
PSVGGIO1	Ind01.stVal–Ind32.stVal	PSV01–32	
PLTGGIO2	Ind01.stVal–Ind32.stVal	PLT01–32	
PMVGGIO3	AnIn01.instMag–AnIn64.instMag	PMV01–64	
ASVGGIO4	Ind01.stVal–Ind064.stVal	ASV01–64	
ALTGGIO5	Ind01.stVal–Ind32.stVal	ALT01–32	
AMVGGIO6	AnIn01.instMag–AnIn32.instMag	AMV01–32	
TLEDGGIO7	Ind01.stVal	EN	

Table F.10 Logical Device: ANN (Annunciation) (Sheet 2 of 2)

Logical Node	Attribute	Relay Word or Database Bit	Comment
	Ind02.stVal	TRIPLED	
	Ind03.stVal–Ind18.stVal	TLED_1–TLED_16	
PBLEDGGIO8	Ind01.stVal–Ind08.stVal	PB1_LED–PB8_LED	
RMBAGGIO9	Ind01.stVal–Ind08.stVal	RMB1A–RMB8A	
TMBAGGIO10	Ind01.stVal–Ind08.stVal	TMB1A–TMB8A	
RMBBGGIO11	Ind01.stVal–Ind08.stVal	RMB1B–RMB8B	
TMBBGGIO12	Ind01.stVal–Ind08.stVal	TMB1B–TMB8B	
MBOKGGIO13	Ind01.stVal	ROKA	
	Ind02.stVal	RBADA	
	Ind03.stVal	CBADA	
	Ind04.stVal	LBOKA	
	Ind05.stVal	ANOKA	
	Ind06.stVal	DOKA	
	Ind07.stVal	ROKB	
	Ind08.stVal	RBADB	
	Ind09.stVal	CBADB	
	Ind10.stVal	LBOKB	
	Ind11.stVal	ANOKB	
	Ind12.stVal	DOKB	
IN1GGIO14	Ind01.stVal–Ind07.stVal	IN101–107	
IN2GGIO15	Ind01.stVal–Ind24.stVal	IN201–IN224	
IN3GGIO16	Ind01.stVal–Ind24.stVal	IN301–IN324	
OUT1GGIO17	Ind01.stVal–Ind08.stVal	OUT101–OUT108	
OUT2GGIO18	Ind01.stVal–Ind08.stVal	OUT201–OUT208	
OUT3GGIO19	Ind01.stVal–Ind08.stVal	OUT301–OUT308	
CCINGGIO20	Ind01.stVal–Ind128.stVal	CCIN001–CCIN128	
CCOUTGGIO21	Ind01.stVal–Ind32.stVal	CCOUT01–CCOUT32	

Protocol Implementation Conformance Statement: SEL-400 Series Devices

The tables below are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that since the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

Table F.11 PICS for A-Profile Support

Profile		Client	Server	Value/Comment
A1	Client/Server	N	Y	
A2	GOOSE/GSE management	Y	Y	Only GOOSE, not GSSE management
A3	GSSE	N	N	
A4	Time Sync	N	N	

Table F.12 PICS for T-Profile Support

Profile		Client	Server	Value/Comment
T1	TCP/IP	N	Y	
T2	OSI	N	N	
T3	GOOSE/GSE	Y	Y	Only GOOSE, not GSSE
T4	GSSE	N	N	
T5	Time Sync	N	N	

Refer to the *ACSI Conformance Statements on page F.37* for information on the supported services.

MMS Conformance

The Manufacturing Message Specification (MMS) stack provides the basis for many IEC 61850 protocol services. *Table F.14* defines the service support requirement and restrictions of the MMS services in the SEL-400 series devices. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table F.13 MMS Service Supported Conformance (Sheet 1 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
status		Y
getNameList		Y
identify		Y
rename		
read		Y
write		Y
getVariableAccessAttributes		Y
defineNamedVariable		
defineScatteredAccess		
getScatteredAccessAttributes		
deleteVariableAccess		
defineNamedVariableList		
getNamedVariableListAttributes		Y
deleteNamedVariableList		
defineNamedType		
getNamedTypeAttributes		
deleteNamedType		

Table F.13 MMS Service Supported Conformance (Sheet 2 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
input		
output		
takeControl		
relinquishControl		
defineSemaphore		
deleteSemaphore		
reportPoolSemaphoreStatus		
reportSemaphoreStatus		
initiateDownloadSequence		
downloadSegment		
terminateDownloadSequence		
initiateUploadSequence		
uploadSegment		
terminateUploadSequence		
requestDomainDownload		
requestDomainUpload		
loadDomainContent		
storeDomainContent		
deleteDomain		
getDomainAttributes		Y
createProgramInvocation		
deleteProgramInvocation		
start		
stop		
resume		
reset		
kill		
getProgramInvocationAttributes		
obtainFile		
defineEventCondition		
deleteEventCondition		
getEventConditionAttributes		
reportEventConditionStatus		
alterEventConditionMonitoring		
triggerEvent		
defineEventAction		
deleteEventAction		
alterEventEnrollment		
reportEventEnrollmentStatus		
getEventEnrollmentAttributes		

Table F.13 MMS Service Supported Conformance (Sheet 3 of 3)

MMS Service Supported CBB	Client-CR Supported	Server-CR Supported
acknowledgeEventNotification		
getAlarmSummary		
getAlarmEnrollmentSummary		
readJournal		
writeJournal		
initializeJournal		
reportJournalStatus		
createJournal		
deleteJournal		
fileOpen		
fileRead		
fileClose		
fileRename		
fileDelete		
fileDirectory		
unsolicitedStatus		
informationReport		Y
eventNotification		
attachToEventCondition		
attachToSemaphore		
conclude		Y
cancel		Y
getDataExchangeAttributes		
exchangeData		
defineAccessControlList		
getAccessControlListAttributes		
reportAccessControlledObjects		
deleteAccessControlList		
alterAccessControl		
reconfigureProgramInvocation		

Table F.14 lists specific settings for the MMS parameter Conformance Building Block (CBB).

Table F.14 MMS Parameter CBB (Sheet 1 of 2)

MMS Parameter CBB	Client-CR	Server-CR
	Supported	Supported
STR1		Y
STR2		Y
VNAM		Y
VADR		Y

Table F.14 MMS Parameter CBB (Sheet 2 of 2)

MMS Parameter CBB	Client-CR	Server-CR
	Supported	Supported
VALT		Y
TPY		Y
VLIS		Y
CEI		

The following variable access conformance statements are listed in the order specified in the IEC 61850 standard, Part 8-1. Generally, only those services whose implementation is not mandatory are shown. Refer to the IEC 61850 standard Part 8-1 for more information.

Table F.15 AlternateAccessSelection Conformance Statement

AlternateAccessSelection	Client-CR	Server-CR
	Supported	Supported
accessSelection		Y
component		Y
index		
indexRange		
allElements		
alternateAccess		Y
selectAccess		Y
component		Y
index		
indexRange		
allElements		

Table F.16 VariableAccessSpecification Conformance Statement

VariableAccessSpecification	Client-CR	Server-CR
	Supported	Supported
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y
variableListName		Y

Table F.17 VariableSpecification Conformance Statement

VariableSpecification	Client-CR	Server-CR
	Supported	Supported
name		Y
address		
variableDescription		
scatteredAccessDescription		
invalidated		

Table F.18 Read Conformance Statement

Read	Client-CR Supported	Server-CR Supported
Request		
specificationWithResult		
variableAccessSpecification		
Response		
variableAccessSpecification		Y
listOfAccessResult		Y

Table F.19 GetVariableAccessAttributes Conformance Statement

GetVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
name		
address		
Response		
mmsDeletable		
address		
typeSpecification		

Table F.20 DefineNamedVariableList Conformance Statement

DefineVariableAccessAttributes	Client-CR Supported	Server-CR Supported
Request		
variableListName		
listOfVariable		
variableSpecification		
alternateAccess		
Response		

Table F.21 GetNamedVariableListAttributes Conformance Statement

GetNamedVariableListAttributes	Client-CR Supported	Server-CR Supported
Request		
ObjectName		
Response		
mmsDeletable		Y
listOfVariable		Y
variableSpecification		Y
alternateAccess		Y

Table F.22 DeleteNamedVariableList Conformance Statement

DeleteNamedVariableList	Client-CR	Server-CR
	Supported	Supported
Request		
Scope		
listOfVariableListName		
domainName		
Response		
numberMatched		
numberDeleted		
DeleteNamedVariableList-Error		

GOOSE Services Conformance Statement

Table F.23 GOOSE Conformance

	Subscriber	Publisher	Value/Comment
GOOSE Services	Y	Y	
SendGOOSEMessage		Y	
GetGoReference			
GetGOOSEElementNumber			
GetGoCBValues		Y	
SetGoCBValues			
GSENotSupported			
GOOSE Control Block (GoCB)		Y	

ACSI Conformance Statements

Table F.24 ACSI Basic Conformance Statement

Services		Client/Subscriber	Server/Publisher	SEL-487E Support
Client-Server Roles				
B11	Server side (of Two-Party Application-Association)	–	c1[a]	YES
B12	Client side (of Two-Party Application-Association)	c1[a]	–	
SCMS Supported				
B21	SCSM: IEC 61850-8-1 used			YES
B22	SCSM: IEC 61850-9-1 used			
B23	SCSM: IEC 61850-9-2 used			
B24	SCSM: other			
Generic Substation Event Model (GSE)				
B31	Publisher side	–	O[b]	YES
B32	Subscriber side	O[b]	–	YES
Transmission of Sampled Value Model (SVC)				
B41	Publisher side	–	O[b]	
B42	Subscriber side	O[b]	–	

[a] c1 shall be mandatory if support for LOGICAL-DEVICE model has been declared.
[b] O = optional.

Table F.25 ACSI Models Conformance Statement (Sheet 1 of 2)

Models		Client/Subscriber	Server/Publisher	SEL-487E Support
If Server Side (B11) Supported				
M1	Logical device	c2[a]	c2[a]	YES
M2	Logical node	c3[b]	c3[b]	YES
M3	Data	c4[c]	c4[c]	YES
M4	Dataset	c5[d]	c5[d]	YES
M5	Substitution	O[e]	O[e]	
M6	Setting group control	O[e]	O[e]	
Reporting				
M7	**Buffered report control**	O[e]	O[e]	YES
M7-1	sequence-number			YES
M7-2	report-time-stamp			YES
M7-3	reason-for-inclusion			YES
M7-4	data-set-name			YES
M7-5	data-reference			YES
M7-6	buffer-overflow			YES
M7-7	entryID			YES
M7-8	BufTm			YES
M7-9	IntgPd			YES

Table F.25 ACSI Models Conformance Statement (Sheet 2 of 2)

Models		Client/Subscriber	Server/Publisher	SEL-487E Support
M7-10	GI			YES
M8	**Unbuffered report control**	O[e]	O[e]	YES
M8-1	sequence-number			YES
M8-2	report-time-stamp			YES
M8-3	reason-for-inclusion			YES
M8-4	data-set-name			YES
M8-5	data-reference			YES
M8-6	BufTm			YES
M8-7	IntgPd			YES
M8-8	GI			
	Logging	O[e]	O[e]	
M9	Log control	O[e]	O[e]	
M9-1	IntgPd			
M10	Log	O[e]	O[e]	
M11	Control	M[f]	M[f]	YES
If GSE (B31/32) Is Supported				
M12	GOOSE	O[e]	O[e]	YES
M12-1	entryID			YES
M12-2	DataReflnc			YES
M13	GSSE	O[e]	O[e]	
If GSE (B41/42) Is Supported				
M14	Multicast SVC	O[e]	O[e]	
M15	Unicast SVC	O[e]	O[e]	
M16	Time	M[f]	M[f]	
M17	File Transfer	O[e]	O[e]	

[a] c2 shall be "M" if support for LOGICAL-NODE model has been declared.
[b] c3 shall be "M" if support for DATA model has been declared.
[c] c4 shall be "M" if support for DATA-SET, Substitution, Report, Log Control, or Time model has been declared.
[d] c5 shall be "M" if support for Report, GSE, or SV models has been declared.
[e] O = optional.
[f] M = mandatory.

Table F.26 ACSI Services Conformance Statement (Sheet 1 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-487E Support
Server (Clause 6)					
S1	ServerDirectory	TP		M[a]	YES
Application Association (Clause 7)					
S2	Associate		M[a]	M[a]	YES
S3	Abort		M[a]	M[a]	YES
S4	Release		M[a]	M[a]	YES
Logical Device (Clause 8)					
S5	LogicalDeviceDirectory	TP	M[a]	M[a]	YES

Table F.26 ACSI Services Conformance Statement (Sheet 2 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-487E Support
Logical Node (Clause 9)					
S6	LogicalNodeDirectory	TP	M[a]	M[a]	YES
S7	GetAllDataValues	TP	O[b]	M[a]	YES
Data (Clause 10)					
S8	GetDataValues	TP	M[a]	M[a]	YES
S9	SetDataValues	TP	O[b]	O[b]	YES
S10	GetDataDirectory	TP	O[b]	M[a]	YES
S11	GetDataDefinition	TP	O[b]	M[a]	YES
Dataset (Clause 11)					
S12	GetDataSetValues	TP	O[b]	M[a]	YES
S13	SetDataSetValues	TP	O[b]	O[b]	YES
S14	CreateDataSet	TP	O[b]	O[b]	
S15	DeleteDataSet	TP	O[b]	O[b]	
S16	GetDataSetDirectory	TP	O[b]	O[b]	YES
Substitution (Clause 12)					
S17	SetDataValues	TP	M[a]	M[a]	
Setting Group Control (Clause 13)					
S18	SelectActiveSG	TP	O[b]	O[b]	
S19	SelectEditSG	TP	O[b]	O[b]	
S20	SetSGvalues	TP	O[b]	O[b]	
S21	ConfirmEditSGVal	TP	O[b]	O[b]	
S22	GetSGValues	TP	O[b]	O[b]	
S23	GetSGCBValues	TP	O[b]	O[b]	
Reporting (Clause 14)					
Buffered Report Control Block (BRCB)					
S24	Report	TP	c6[c]	c6[c]	YES
S24-1	data-change (dchg)				YES
S24-2	qchg-change (qchg)				YES
S24-3	data-update (dupd)				
S25	GetBRCBValues	TP	c6[c]	c6[c]	YES
S26	SetBRCBValues	TP	c6[c]	c6[c]	YES
Unbuffered Report Control Block (URCB)					
S27	Report	TP	c6[c]	c6[c]	YES
S27-1	data-change (dchg)				YES
S27-2	qchg-change (qchg)				YES
S27-3	data-update (dupd)				
S28	GetURCBValues	TP	c6[c]	c6[c]	YES
S29	SetURCBValues	TP	c6[c]	c6[c]	YES

Table F.26 ACSI Services Conformance Statement (Sheet 3 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-487E Support
Logging (Clause 14)					
Log Control Block					
S30	GetLCBValues	TP	M[a]	M[a]	
S31	SetLCBValues	TP	O[b]	M[a]	
LOG					
S32	QueryLogByTime	TP	c7[d]	M[a]	
S33	QueryLogByEntry	TP	c7[d]	M[a]	
S34	GetLogStatusValues	TP	M[a]	M[a]	
Generic Substation Event Model (GSE) (Clause 14.3.5.3.4.)					
GOOSE-Control-Block					
S35	SendGOOSEMessage	MC	c8[e]	c8[e]	YES
S36	GetReference	TP	O[b]	c9[f]	
S37	GetGOOSEElementNumber	TP	O[b]	c9[f]	
S38	GetGoCBValues	TP	O[b]	O[b]	YES
S39	SetGoCBValues	TP	O[b]	O[b]	Client/Sub ONLY
GSSE-Control-Block					
S40	SendGSSEMessage	MC	c8[e]	c8[e]	
S41	GetReference	TP	O[b]	c9[f]	
S42	GetGSSEElementNumber	TP	O[b]	c9[f]	
S43	GetGsCBValues	TP	O[b]	O[b]	
S44	SetGsCBValues	TP	O[b]	O[b]	
Transmission of Sample Value Model (SVC) (Clause 16)					
Multicast SVC					
S45	SendMSVMessage	MC	c10[g]	c10[g]	
S46	GetMSVCBValues	TP	O[b]	O[b]	
S47	SetMSVCBValues	TP	O[b]	O[b]	
Unicast SVC					
S48	SendUSVMessage	MC	c10[g]	c10[g]	
S49	GetUSVCBValues	TP	O[b]	O[b]	
S50	SetUSVCBValues	TP	O[b]	O[b]	
Control (Clause 16.4.8)					
S51	Select		M[a]	O[b]	
S52	SelectWithValue	TP	M[a]	O[b]	
S53	Cancel	TP	O[b]	M[a]	YES
S54	Operate	TP	M[a]	M[a]	YES
S55	Commmand-Termination	TP	M[a]	M[a]	
S56	TimeActivated-Operate	TP	O[b]	O[b]	

Table F.26 ACSI Services Conformance Statement (Sheet 4 of 4)

Services		AA: TP/MC	Client/ Subscriber	Server/Publisher	SEL-487E Support
File Transfer (Clause 20)					
S57	GetFile	TP	O[b]	M[a]	
S58	SetFile	TP	O[b]	O[b]	
S59	DeleteFile	TP	O[b]	O[b]	
S60	GetFileAttributeValues	TP	O[b]	M[a]	
Time (Clause 5.5)					
T1	Time resolution of internal clock (nearest negative power of 2 in seconds)			2–10 (1 ms)	T1
T2	Time accuracy of internal clock				10/9
	T1				YES
	T2				YES
	T3				YES
	T4				YES
	T5				YES
T3	Supported TimeStamp resolution (nearest negative power of 2 in seconds)			2–10 (1 ms)	10

[a] M = mandatory.
[b] O = optional.
[c] c6 shall declare support for at least one (BRCB or URCB).
[d] c7 shall declare support for at least one (QueryLogByTime or QueryLogAfter).
[e] c8 shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage).
[f] c9 shall declare support if TP association is available.
[g] c10 shall declare support for at least one (SendMSVMessage or SendUSVMessage).

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Appendix G
Relay Word Bits

This section contains a table of the Relay Word bits available within the SEL-487E Relay.

Alphabetic

Use this appendix as a reference for Relay Word bit labels in this manual and as a resource for elements you use in SELOGIC® control equation relay settings. *Table G.2* lists the Relay Word bits in alphabetic order; *Table G.3* through *Table G.66* list every Relay Word bit row and the bits contained within each row.

Table G.1 Alphabetic List of Relay Word Bits (Sheet 1 of 27)

Row	Relay Word	Description
108	24D1	Volts/Hertz Element level 1 asserted
108	24D1T	Volts/Hertz level 1 timed out
108	24D2R	Volts/Hertz elements Level 2 reset
108	24D2T	Volts/Hertz level 2 timed out
108	24TC	Volts/Hertz predefined element torque control
109	24U1R	User-defined Volts/Hertz curve 1 reset
109	24U1T	User-defined Volts/Hertz curve 1 timed out
109	24U1TC	User-defined Volts/Hertz curve 1 torque control
109	24U2R	User-defined Volts/Hertz curve 2 reset
109	24U2T	User-defined Volts/Hertz curve 2 timed out
109	24U2TC	User-defined Volts/Hertz curve 1 torque control
87	271P1	Undervoltage element 1 level 1 asserted
87	271P1T	Undervoltage element 1 level 1 timed out
87	271P2	Undervoltage element 1 level 2 asserted
87	272P1	Undervoltage element 2 level 1 asserted
87	272P1T	Undervoltage element 2 level 1 timed out
87	272P2	Undervoltage element 2 level 2 asserted
88	273P1	Undervoltage element 3 level 1 asserted
88	273P1T	Undervoltage element 3 level 1 timed out
88	273P2	Undervoltage element 3 level 2 asserted
88	274P1	Undervoltage element 4 level 1 asserted
88	274P1T	Undervoltage element 4 level 1 timed out
88	274P2	Undervoltage element 4 level 2 asserted
89	275P1	Undervoltage element 5 level 1 asserted

Table G.1 Alphabetic List of Relay Word Bits (Sheet 2 of 27)

Row	Relay Word	Description
89	275P1T	Undervoltage element 5 level 1 timed out
89	275P2	Undervoltage element 5 level 2 asserted
106	27B81	Frequency Elements blocked due to undervoltage
87	27TC1	Undervoltage element 1 Torque Control
87	27TC2	Undervoltage element 2 Torque Control
88	27TC3	Undervoltage element 3 Torque Control
88	27TC4	Undervoltage element 4 Torque Control
89	27TC5	Undervoltage element 5 Torque Control
93	32OP01	Overpower element 01 picked up
93	32OP02	Overpower element 02 picked up
94	32OP03	Overpower element 03 picked up
94	32OP04	Overpower element 04 picked up
95	32OP05	Overpower element 05 picked up
95	32OP06	Overpower element 06 picked up
96	32OP07	Overpower element 07 picked up
96	32OP08	Overpower element 08 picked up
97	32OP09	Overpower element 09 picked up
97	32OP10	Overpower element 10 picked up
93	32OPT01	Overpower element 01 timed out
93	32OPT02	Overpower element 02 timed out
94	32OPT03	Overpower element 03 timed out
94	32OPT04	Overpower element 04 timed out
95	32OPT05	Overpower element 05 timed out
95	32OPT06	Overpower element 06 timed out
96	32OPT07	Overpower element 07 timed out
96	32OPT08	Overpower element 08 timed out
97	32OPT09	Overpower element 09 timed out
97	32OPT10	Overpower element 10 timed out
98	32UP01	Underpower element 01 picked up
98	32UP02	Underpower element 02 picked up
99	32UP03	Underpower element 03 picked up
99	32UP04	Underpower element 04 picked up
100	32UP05	Underpower element 05 picked up
100	32UP06	Underpower element 06 picked up
101	32UP07	Underpower element 07 picked up
101	32UP08	Underpower element 08 picked up
102	32UP09	Underpower element 09 picked up
102	32UP10	Underpower element 10 picked up
98	32UPT01	Underpower element 01 timed out
98	32UPT02	Underpower element 02 timed out
99	32UPT03	Underpower element 03 timed out

Table G.1 Alphabetic List of Relay Word Bits (Sheet 3 of 27)

Row	Relay Word	Description
99	32UPT04	Underpower element 04 timed out
100	32UPT05	Underpower element 05 timed out
100	32UPT06	Underpower element 06 timed out
101	32UPT07	Underpower element 07 timed out
101	32UPT08	Underpower element 08 timed out
102	32UPT09	Underpower element 09 timed out
102	32UPT10	Underpower element 10 timed out
85	46SP	Current unbalance detected Terminal S
85	46ST	Current unbalance Terminal S timed out
85	46TP	Current unbalance detected Terminal T
85	46TT	Current unbalance Terminal T timed out
85	46UP	Current unbalance detected Terminal U
85	46UT	Current unbalance Terminal U timed out
85	46WP	Current unbalance detected Terminal W
85	46WT	Current unbalance Terminal W timed out
86	46XP	Current unbalance detected Terminal X
86	46XT	Current unbalance Terminal X timed out
120	50FS	Phase or Neutral current above breaker failure pickup for Terminal S
122	50FT	Phase or Neutral current above breaker failure pickup for Terminal T
124	50FU	Phase or Neutral current above breaker failure pickup for Terminal U
126	50FW	Phase or Neutral current above breaker failure pickup for Terminal W
128	50FX	Phase or Neutral current above breaker failure pickup for Terminal X
39	50SG1	Residual Definite time element 1 Terminal S asserted
39	50SG2	Residual Definite time element 2 Terminal S asserted
40	50SG3	Residual Definite time element 3 Terminal S asserted
35	50SP1	Phase Definite time element 1 Terminal S asserted
35	50SP2	Phase Definite time element 2 Terminal S asserted
36	50SP3	Phase Definite time element 3 Terminal S asserted
37	50SQ1	Negative-Sequence Definite time element 1 Terminal S asserted
37	50SQ2	Negative-Sequence Definite time element 2 Terminal S asserted
38	50SQ3	Negative-Sequence Definite time element 3 Terminal S asserted
45	50TG1	Residual Definite time element 1 Terminal T asserted
45	50TG2	Residual Definite time element 2 Terminal T asserted
46	50TG3	Residual Definite time element 3 Terminal T asserted
41	50TP1	Phase Definite time element 1 Terminal T asserted
41	50TP2	Phase Definite time element 2 Terminal T asserted
42	50TP3	Phase Definite time element 3 Terminal T asserted
43	50TQ1	Negative-Sequence Definite time element 1 Terminal T asserted
43	50TQ2	Negative-Sequence Definite time element 2 Terminal T asserted
44	50TQ3	Negative-Sequence Definite time element 3 Terminal T asserted
51	50UG1	Residual Definite time element 1 Terminal U asserted

Table G.1 Alphabetic List of Relay Word Bits (Sheet 4 of 27)

Row	Relay Word	Description
51	50UG2	Residual Definite time element 2 Terminal U asserted
52	50UG3	Residual Definite time element 3 Terminal U asserted
47	50UP1	Phase Definite time element 1 Terminal U asserted
47	50UP2	Phase Definite time element 2 Terminal U asserted
48	50UP3	Phase Definite time element 3 Terminal U asserted
49	50UQ1	Negative-Sequence Definite time element 1 Terminal U asserted
49	50UQ2	Negative-Sequence Definite time element 2 Terminal U asserted
50	50UQ3	Negative-Sequence Definite time element 3 Terminal U asserted
57	50WG1	Residual Definite time element 1 Terminal W asserted
57	50WG2	Residual Definite time element 2 Terminal W asserted
58	50WG3	Residual Definite time element 3 Terminal W asserted
53	50WP1	Phase Definite time element 1 Terminal W asserted
53	50WP2	Phase Definite time element 2 Terminal W asserted
54	50WP3	Phase Definite time element 3 Terminal W asserted
55	50WQ1	Negative-Sequence Definite time element 1 Terminal W asserted
55	50WQ2	Negative-Sequence Definite time element 2 Terminal W asserted
56	50WQ3	Negative-Sequence Definite time element 3 Terminal W asserted
63	50XG1	Residual Definite time element 1 Terminal X asserted
63	50XG2	Residual Definite time element 2 Terminal X asserted
64	50XG3	Residual Definite time element 3 Terminal X asserted
59	50XP1	Phase Definite time element 1 Terminal X asserted
59	50XP2	Phase Definite time element 2 Terminal X asserted
60	50XP3	Phase Definite time element 3 Terminal X asserted
61	50XQ1	Negative-Sequence Definite time element 1 Terminal X asserted
61	50XQ2	Negative-Sequence Definite time element 2 Terminal X asserted
62	50XQ3	Negative-Sequence Definite time element 3 Terminal X asserted
65	51MM01	Inverse time element 01 pickup setting outside of specified limits
66	51MM02	Inverse time element 02 pickup setting outside of specified limits
67	51MM03	Inverse time element 03 pickup setting outside of specified limits
68	51MM04	Inverse time element 04 pickup setting outside of specified limits
69	51MM05	Inverse time element 05 pickup setting outside of specified limits
70	51MM06	Inverse time element 06 pickup setting outside of specified limits
71	51MM07	Inverse time element 07 pickup setting outside of specified limits
72	51MM08	Inverse time element 08 pickup setting outside of specified limits
73	51MM09	Inverse time element 09 pickup setting outside of specified limits
74	51MM10	Inverse time element 10 pickup setting outside of specified limits
65	51R01	Inverse time element 01 reset
66	51R02	Inverse time element 02 reset
67	51R03	Inverse time element 03 reset
68	51R04	Inverse time element 04 reset
69	51R05	Inverse time element 05 reset

Table G.1 Alphabetic List of Relay Word Bits (Sheet 5 of 27)

Row	Relay Word	Description
70	51R06	Inverse time element 06 reset
71	51R07	Inverse time element 07 reset
72	51R08	Inverse time element 08 reset
73	51R09	Inverse time element 09 reset
74	51R10	Inverse time element 10 reset
65	51S01	Inverse time element 01 picked up
66	51S02	Inverse time element 02 picked up
67	51S03	Inverse time element 03 picked up
68	51S04	Inverse time element 04 picked up
69	51S05	Inverse time element 05 picked up
70	51S06	Inverse time element 06 picked up
71	51S07	Inverse time element 07 picked up
72	51S08	Inverse time element 08 picked up
73	51S09	Inverse time element 09 picked up
74	51S10	Inverse time element 10 picked up
65	51T01	Inverse time element 01 timed out
66	51T02	Inverse time element 02 timed out
67	51T03	Inverse time element 03 timed out
68	51T04	Inverse time element 04 timed out
69	51T05	Inverse time element 05 timed out
70	51T06	Inverse time element 06 timed out
71	51T07	Inverse time element 07 timed out
72	51T08	Inverse time element 08 timed out
73	51T09	Inverse time element 09 timed out
74	51T10	Inverse time element 10 timed out
65	51TC01	Inverse time element 01 enabled
66	51TC02	Inverse time element 02 enabled
67	51TC03	Inverse time element 03 enabled
68	51TC04	Inverse time element 04 enabled
69	51TC05	Inverse time element 05 enabled
70	51TC06	Inverse time element 06 enabled
71	51TC07	Inverse time element 07 enabled
72	51TC08	Inverse time element 08 enabled
73	51TC09	Inverse time element 09 enabled
74	51TC10	Inverse time element 10 enabled
65	51TM01	Inverse time element 01 time dial setting outside of specified limits
66	51TM02	Inverse time element 02 time dial setting outside of specified limits
67	51TM03	Inverse time element 03 time dial setting outside of specified limits
68	51TM04	Inverse time element 04 time dial setting outside of specified limits
69	51TM05	Inverse time element 05 time dial setting outside of specified limits
70	51TM06	Inverse time element 06 time dial setting outside of specified limits

Table G.1 Alphabetic List of Relay Word Bits (Sheet 6 of 27)

Row	Relay Word	Description
71	51TM07	Inverse time element 07 time dial setting outside of specified limits
72	51TM08	Inverse time element 08 time dial setting outside of specified limits
73	51TM09	Inverse time element 09 time dial setting outside of specified limits
74	51TM10	Inverse time element 10 time dial setting outside of specified limits
130	52ALS	Breaker Alarm Terminal S
130	52ALT	Breaker Alarm Terminal T
130	52ALU	Breaker Alarm Terminal U
130	52ALW	Breaker Alarm Terminal W
131	52ALX	Breaker Alarm Terminal X
130	52CLS	Breaker Closed Terminal S
130	52CLT	Breaker Closed Terminal T
130	52CLU	Breaker Closed Terminal U
130	52CLW	Breaker Closed Terminal W
131	52CLX	Breaker Closed Terminal X
90	591P1	Overvoltage element 1 level 1 asserted
90	591P1T	Overvoltage element 1 level 1 timed out
90	591P2	Overvoltage element 1 level 2 asserted
90	592P1	Overvoltage element 2 level 1 asserted
90	592P1T	Overvoltage element 2 level 1 timed out
90	592P2	Overvoltage element 2 level 2 asserted
91	593P1	Overvoltage element 3 level 1 asserted
91	593P1T	Overvoltage element 3 level 1 timed out
91	593P2	Overvoltage element 3 level 2 asserted
91	594P1	Overvoltage element 4 level 1 asserted
91	594P1T	Overvoltage element 4 level 1 timed out
91	594P2	Overvoltage element 4 level 2 asserted
92	595P1	Overvoltage element 5 level 1 asserted
92	595P1T	Overvoltage element 5 level 1 timed out
92	595P2	Overvoltage element 5 level 2 asserted
90	59TC1	Overvoltage element 1 Torque Control
90	59TC2	Overvoltage element 2 Torque Control
91	59TC3	Overvoltage element 3 Torque Control
91	59TC4	Overvoltage element 4 Torque Control
92	59TC5	Overvoltage element 5 Torque Control
39	67SG1	Residual Directional/Torque controlled element 1 Terminal S picked up
39	67SG1T	Residual Directional/Torque controlled element 1 Terminal S timed out
39	67SG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal S
39	67SG2	Residual Directional/Torque controlled element 2 Terminal S picked up
39	67SG2T	Residual Directional/Torque controlled element 2 Terminal S timed out
39	67SG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal S
40	67SG3	Residual Directional/Torque controlled element 3 Terminal S picked up

Table G.1 Alphabetic List of Relay Word Bits (Sheet 7 of 27)

Row	Relay Word	Description
40	67SG3T	Residual Directional/Torque controlled element 3 Terminal S timed out
40	67SG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal S
35	67SP1	Phase Directional/Torque controlled element 1 Terminal S picked up
35	67SP1T	Phase Directional/Torque controlled element 1 Terminal S timed out
35	67SP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal S
35	67SP2	Phase Directional/Torque controlled element 2 Terminal S picked up
35	67SP2T	Phase Directional/Torque controlled element 2 Terminal S timed out
35	67SP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal S
36	67SP3	Phase Directional/Torque controlled element 3 Terminal S picked up
36	67SP3T	Phase Directional/Torque controlled element 3 Terminal S timed out
36	67SP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal S
37	67SQ1	Negative-Sequence Directional/Torque controlled element 1 Terminal S picked up
37	67SQ1T	Negative-Sequence Directional/Torque controlled element 1 Terminal S timed out
37	67SQ1TC	Negative-Sequence Directional/Torque Control enable definite time element 1 Terminal S
37	67SQ2	Negative-Sequence Directional/Torque controlled element 2 Terminal S picked up
37	67SQ2T	Negative-Sequence Directional/Torque controlled element 2 Terminal S timed out
37	67SQ2TC	Negative-Sequence Directional/Torque Control enable definite time element 2 Terminal S
38	67SQ3	Negative-Sequence Directional/Torque controlled element 3 Terminal S picked up
38	67SQ3T	Negative-Sequence Directional/Torque controlled element 3 Terminal S timed out
38	67SQ3TC	Negative-Sequence Directional/Torque Control enable definite time element 3 Terminal S
45	67TG1	Residual Directional/Torque controlled element 1 Terminal T picked up
45	67TG1T	Residual Directional/Torque controlled element 1 Terminal T timed out
45	67TG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal T
45	67TG2	Residual Directional/Torque controlled element 2 Terminal T picked up
45	67TG2T	Residual Directional/Torque controlled element 2 Terminal T timed out
45	67TG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal T
46	67TG3	Residual Directional/Torque controlled element 3 Terminal T picked up
46	67TG3T	Residual Directional/Torque controlled element 3 Terminal T timed out
46	67TG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal T
41	67TP1	Phase Directional/Torque controlled element 1 Terminal T picked up
41	67TP1T	Phase Directional/Torque controlled element 1 Terminal T timed out
41	67TP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal T
41	67TP2	Phase Directional/Torque controlled element 2 Terminal T picked up
41	67TP2T	Phase Directional/Torque controlled element 2 Terminal T timed out
41	67TP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal T
42	67TP3	Phase Directional/Torque controlled element 3 Terminal T picked up
42	67TP3T	Phase Directional/Torque controlled element 3 Terminal T timed out
42	67TP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal T
43	67TQ1	Negative-Sequence Directional/Torque controlled element 1 Terminal T picked up
43	67TQ1T	Negative-Sequence Directional/Torque controlled element 1 Terminal T timed out
43	67TQ1TC	Negative-Sequence Directional/Torque Control enable definite time element 1 Terminal T

Table G.1 Alphabetic List of Relay Word Bits (Sheet 8 of 27)

Row	Relay Word	Description
43	67TQ2	Negative-Sequence Directional/Torque controlled element 2 Terminal T picked up
43	67TQ2T	Negative-Sequence Directional/Torque controlled element 2 Terminal T timed out
43	67TQ2TC	Negative-Sequence Directional/Torque Control enable definite time element 2 Terminal T
44	67TQ3	Negative-Sequence Directional/Torque controlled element 3 Terminal T picked up
44	67TQ3T	Negative-Sequence Directional/Torque controlled element 3 Terminal T timed out
44	67TQ3TC	Negative-Sequence Directional/Torque Control enable definite time element 3 Terminal T
51	67UG1	Residual Directional/Torque controlled element 1 Terminal U picked up
51	67UG1T	Residual Directional/Torque controlled element 1 Terminal U timed out
51	67UG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal U
51	67UG2	Residual Directional/Torque controlled element 2 Terminal U picked up
51	67UG2T	Residual Directional/Torque controlled element 2 Terminal U timed out
51	67UG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal U
52	67UG3	Residual Directional/Torque controlled element 3 Terminal U picked up
52	67UG3T	Residual Directional/Torque controlled element 3 Terminal U timed out
52	67UG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal U
47	67UP1	Phase Directional/Torque controlled element 1 Terminal U picked up
47	67UP1T	Phase Directional/Torque controlled element 1 Terminal U timed out
47	67UP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal U
47	67UP2	Phase Directional/Torque controlled element 2 Terminal U picked up
47	67UP2T	Phase Directional/Torque controlled element 2 Terminal U timed out
47	67UP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal U
48	67UP3	Phase Directional/Torque controlled element 3 Terminal U picked up
48	67UP3T	Phase Directional/Torque controlled element 3 Terminal U timed out
48	67UP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal U
49	67UQ1	Negative-Sequence Directional/Torque controlled element 1 Terminal U picked up
49	67UQ1T	Negative-Sequence Directional/Torque controlled element 1 Terminal U timed out
49	67UQ1TC	Negative-Sequence Directional/Torque Control enable definite time element 1 Terminal U
49	67UQ2	Negative-Sequence Directional /Torque controlled element 2 Terminal U picked up
49	67UQ2T	Negative-Sequence Directional/Torque controlled element 2 Terminal U timed out
49	67UQ2TC	Negative-Sequence Directional/Torque Control enable definite time element 2 Terminal U
50	67UQ3	Negative-Sequence Directional/Torque controlled element 3 Terminal U picked up
50	67UQ3T	Negative-Sequence Directional/Torque controlled element 3 Terminal U timed out
50	67UQ3TC	Negative-Sequence Directional/Torque Control enable definite time element 3 Terminal U
57	67WG1	Residual Directional/Torque controlled element 1 Terminal W picked up
57	67WG1T	Residual Directional/Torque controlled element 1 Terminal W timed out
57	67WG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal W
57	67WG2	Residual Directional/Torque controlled element 2 Terminal W picked up
57	67WG2T	Residual Directional/Torque controlled element 2 Terminal W timed out
57	67WG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal W
58	67WG3	Residual Directional/Torque controlled element 3 Terminal W picked up
58	67WG3T	Residual Directional/Torque controlled element 3 Terminal W timed out

Table G.1 Alphabetic List of Relay Word Bits (Sheet 9 of 27)

Row	Relay Word	Description
58	67WG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal W
53	67WP1	Phase Directional/Torque controlled element 1 Terminal W picked up
53	67WP1T	Phase Directional/Torque controlled element 1 Terminal W timed out
53	67WP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal W
53	67WP2	Phase Directional/Torque controlled element 2 Terminal W picked up
53	67WP2T	Phase Directional/Torque controlled element 2 Terminal W timed out
53	67WP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal W
54	67WP3	Phase Directional/Torque controlled element 3 Terminal W picked up
54	67WP3T	Phase Directional/Torque controlled element 3 Terminal W timed out
54	67WP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal W
55	67WQ1	Negative-Sequence Directional/Torque controlled element 1 Terminal W picked up
55	67WQ1T	Negative-Sequence Directional/Torque controlled element 1 Terminal W timed out
55	67WQ1TC	Negative-Sequence Directional/Torque Control enable definite time element 1 Terminal W
55	67WQ2	Negative-Sequence Directional/Torque controlled element 2 Terminal W picked up
55	67WQ2T	Negative-Sequence Directional/Torque controlled element 2 Terminal W timed out
55	67WQ2TC	Negative-Sequence Directional/Torque Control enable definite time element 2 Terminal W
56	67WQ3	Negative-Sequence Directional/Torque controlled element 3 Terminal W picked up
56	67WQ3T	Negative-Sequence Directional/Torque controlled element 3 Terminal W timed out
56	67WQ3TC	Negative-Sequence Directional/Torque Control enable definite time element 3 Terminal W
63	67XG1	Residual Directional/Torque controlled element 1 Terminal X picked up
63	67XG1T	Residual Directional/Torque controlled element 1 Terminal X timed out
63	67XG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal X
63	67XG2	Residual Directional/Torque controlled element 2 Terminal X picked up
63	67XG2T	Residual Directional/Torque controlled element 2 Terminal X timed out
63	67XG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal X
64	67XG3	Residual Directional/Torque controlled element 3 Terminal X picked up
64	67XG3T	Residual Directional/Torque controlled element 3 Terminal X timed out
64	67XG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal X
59	67XP1	Phase Directional/Torque controlled element 1 Terminal X picked up
59	67XP1T	Phase Directional/Torque controlled element 1 Terminal X timed out
59	67XP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal X
59	67XP2	Phase Directional/Torque controlled element 2 Terminal X picked up
59	67XP2T	Phase Directional/Torque controlled element 2 Terminal X timed out
59	67XP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal X
60	67XP3	Phase Directional/Torque controlled element 3 Terminal X picked up
60	67XP3T	Phase Directional/Torque controlled element 3 Terminal X timed out
60	67XP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal X
61	67XQ1	Negative-Sequence Directional/Torque controlled element 1 Terminal X picked up
61	67XQ1T	Negative-Sequence Directional/Torque controlled element 1 Terminal X timed out
61	67XQ1TC	Negative-Sequence Directional/Torque Control enable definite time element 1 Terminal X
61	67XQ2	Negative-Sequence Directional/Torque controlled element 2 Terminal X picked up

Table G.1 Alphabetic List of Relay Word Bits (Sheet 10 of 27)

Row	Relay Word	Description
61	67XQ2T	Negative-Sequence Directional/Torque controlled element 2 Terminal X timed out
61	67XQ2TC	Negative-Sequence Directional/Torque Control enable definite time element 2 Terminal X
62	67XQ3	Negative-Sequence Directional/Torque controlled element 3 Terminal X picked up
62	67XQ3T	Negative-Sequence Directional/Torque controlled element 3 Terminal X timed out
62	67XQ3TC	Negative-Sequence Directional/Torque Control enable definite time element 3 Terminal X
103	81D1	Definite time frequency element picked up level 1
103	81D1OVR	Definite time Over Frequency level 1
103	81D1T	Definite time Over/Under Frequency Element Delay for level 1
103	81D1UDR	Definite time Under Frequency level 1
103	81D2	Definite time frequency element picked up level 2
103	81D2OVR	Definite time Over Frequency level 2
103	81D2T	Definite time Over/Under Frequency Element Delay for level 2
103	81D2UDR	Definite time Under Frequency level 2
104	81D3	Definite time frequency element picked up level 3
104	81D3OVR	Definite time Over Frequency level 3
104	81D3T	Definite time Over/Under Frequency Element Delay for level 3
104	81D3UDR	Definite time Under Frequency level 3
104	81D4	Definite time frequency element picked up level 4
104	81D4OVR	Definite time Over Frequency level 4
104	81D4T	Definite time Over/Under Frequency Element Delay for level 4
104	81D4UDR	Definite time Under Frequency level 4
105	81D5	Definite time frequency element picked up level 5
105	81D5OVR	Definite time Over Frequency level 5
105	81D5T	Definite time Over/Under Frequency Element Delay for level 5
105	81D5UDR	Definite time Under Frequency level 5
105	81D6	Definite time frequency element picked up level 6
105	81D6OVR	Definite time Over Frequency level 6
105	81D6T	Definite time Over/Under Frequency Element Delay for level 6
105	81D6UDR	Definite time Under Frequency level 6
11	87ABK2	2nd and 4th harmonic blocking asserted zone A
11	87ABK5	5th harmonic blocking asserted zone A
8	87AHB	Harmonic blocking differential element picked up A
8	87AHR	Harmonic restraint differential element picked up A
11	87BBK2	2nd and 4th harmonic blocking asserted zone B
11	87BBK5	5th harmonic blocking asserted zone B
8	87BHB	Harmonic blocking differential element picked up B
8	87BHR	Harmonic restraint differential element picked up B
11	87CBK2	2nd and 4th harmonic blocking asserted zone C
11	87CBK5	5th harmonic blocking asserted zone C
8	87CHB	Harmonic blocking differential element picked up C
8	87CHR	Harmonic restraint differential element picked up C

Table G.1 Alphabetic List of Relay Word Bits (Sheet 11 of 27)

Row	Relay Word	Description
13	87Q	Negative-Sequence differential element asserted (inter turn fault detected)
11	87QB	Block negative and zero-sequence directional elements
10	87R	Restrained differential element operated
10	87RA	Restrained Differential element operated phase A
10	87RB	Restrained Differential element operated phase B
10	87RC	Restrained Differential element operated phase C
9	87U	Unrestrained element operation
9	87UA	Unrestrained element asserted zone A
9	87UB	Unrestrained element asserted zone B
9	87UC	Unrestrained element asserted zone C
11	87XBK2	Harmonic cross blocking picked up
137	89AL	Disconnect Alarm
136	89AL1–89AL8	Disconnect 1–8 Alarm
170	89CC1–89CC8	Disconnect/Isolator 1–4 close command
171	89CC5–89CC8	Disconnect/Isolator 5–8 close command
139	89CIMD1–89CIMD8	Disconnect 1–8 Close Immobility Timer timed out
132	89CL1–89CL8	Disconnect 1–8 Closed
133	89CLBZ1–89CLBZ8	Disconnect 1–8 Buszone contact closed
138	89CLS1–89CLS8	Disconnect 1–8 Close Command
140	89CSID1–89CSID8	Disconnect 1–8 Close Seal-in Timer timed out
170	89OC1–89OC4	Disconnect/Isolator 1–4 open command
171	89OC5–89OC8	Disconnect/Isolator 5–8 open command
142	89OIMD1–89OIMD8	Disconnect 1–8 Open Immobility Timer timed out
137	89OIP	Disconnect operation in progress
135	89OIP1–89OIP8	Disconnect 1–8 Operation in progress
141	89OPEN1–89OPEN8	Disconnect 1–8 Open Command
134	89OPN1–89OPN8	Disconnect 1–8 Open
143	89OSID1–89OSID8	Disconnect 1–8 Open Seal-in Timer timed out
121	ABFITS	Alternate breaker Failure Terminal S
123	ABFITT	Alternate breaker Failure Terminal T
125	ABFITU	Alternate breaker Failure Terminal U
127	ABFITW	Alternate breaker Failure Terminal W
129	ABFITX	Alternate breaker Failure Terminal X
280	ACN01Q–ACN08Q	Automation SELOGIC Counter 01–08 asserted
284	ACN01R–ACN08R	Automation SELOGIC Counter 01–08 reset
281	ACN09Q–ACN16Q	Automation SELOGIC Counter 09–16 asserted
285	ACN09R–ACN16R	Automation SELOGIC Counter 09–16 reset
282	ACN17Q–ACN24Q	Automation SELOGIC Counter 17–24 asserted
286	ACN17R–ACN24R	Automation SELOGIC Counter 17–24 reset
283	ACN25Q–ACN32Q	Automation SELOGIC Counter 25–32 asserted
287	ACN25R–ACN32R	Automation SELOGIC Counter 25–32 reset

Table G.1 Alphabetic List of Relay Word Bits (Sheet 12 of 27)

Row	Relay Word	Description
289	AFRTEXA	Automation SELOGIC control equation first execution after Automation settings change
289	AFRTEXP	Automation SELOGIC control equation first execution after Protection settings change
268	ALT01–ALT08	Automation SELOGIC Latch 01–08 asserted
269	ALT09–ALT16	Automation SELOGIC Latch 09–16 asserted
270	ALT17–ALT24	Automation SELOGIC Latch 17–24 asserted
271	ALT25–ALT32	Automation SELOGIC Latch 25–32 asserted
313	ANOKA	Analog transfer on mirrored bit channel A
314	ANOKB	Analog transfer on mirrored bit channel B
272	AST01Q–AST08Q	Automation SELOGIC Sequencing Timer 01–08 asserted
276	AST01R–AST08R	Automation SELOGIC Sequencing Timer 01–08 reset
273	AST09Q–AST16Q	Automation SELOGIC Sequencing Timer 09–16 asserted
277	AST09R–AST16R	Automation SELOGIC Sequencing Timer 09–16 reset
274	AST17Q–AST24Q	Automation SELOGIC Sequencing Timer 17–24 asserted
278	AST19R–AST24R	Automation SELOGIC Sequencing Timer 1–249 reset
275	AST25Q–AST32Q	Automation SELOGIC Sequencing Timer 25–32 asserted
279	AST25R–AST32R	Automation SELOGIC Sequencing Timer 25–32 reset
236	ASV001–ASV008	Automation SELOGIC Variable 001–008 asserted
237	ASV009–ASV016	Automation SELOGIC Variable 009–016 asserted
238	ASV017–ASV024	Automation SELOGIC Variable 017–024 asserted
239	ASV025–ASV032	Automation SELOGIC Variable 025–032 asserted
240	ASV033–ASV040	Automation SELOGIC Variable 033–040 asserted
241	ASV041–ASV048	Automation SELOGIC Variable 041–048 asserted
242	ASV049–ASV056	Automation SELOGIC Variable 049–056 asserted
243	ASV057–ASV064	Automation SELOGIC Variable 057–064 asserted
244	ASV065–ASV072	Automation SELOGIC Variable 065–072 asserted
245	ASV073–ASV080	Automation SELOGIC Variable 073–080 asserted
246	ASV081–ASV088	Automation SELOGIC Variable 081–088 asserted
247	ASV089–ASV096	Automation SELOGIC Variable 089–096 asserted
248	ASV097–ASV104	Automation SELOGIC Variable 097–104 asserted
249	ASV105–ASV112	Automation SELOGIC Variable 105–112 asserted
250	ASV113–ASV120	Automation SELOGIC Variable 113–120 asserted
251	ASV121–ASV128	Automation SELOGIC Variable 121–0128 asserted
252	ASV129–ASV136	Automation SELOGIC Variable 129–136 asserted
253	ASV137–ASV144	Automation SELOGIC Variable 137–144 asserted
254	ASV145–ASV152	Automation SELOGIC Variable 145–152 asserted
255	ASV153–ASV160	Automation SELOGIC Variable 153–160 asserted
256	ASV161–ASV168	Automation SELOGIC Variable 161–168 asserted
257	ASV169–ASV176	Automation SELOGIC Variable 169–176 asserted
258	ASV177–ASV184	Automation SELOGIC Variable 177–184 asserted
259	ASV185–ASV192	Automation SELOGIC Variable 185–192 asserted
260	ASV193–ASV200	Automation SELOGIC Variable 193–200 asserted

Table G.1 Alphabetic List of Relay Word Bits (Sheet 13 of 27)

Row	Relay Word	Description
261	ASV201–ASV208	Automation SELOGIC Variable 201–208 asserted
262	ASV209–ASV216	Automation SELOGIC Variable 209–216 asserted
263	ASV217–ASV224	Automation SELOGIC Variable 217–224 asserted
264	ASV225–ASV232	Automation SELOGIC Variable 225–232 asserted
265	ASV233–ASV240	Automation SELOGIC Variable 233–240 asserted
266	ASV241–ASV248	Automation SELOGIC Variable 241–248 asserted
267	ASV249–ASV256	Automation SELOGIC Variable 249–256 asserted
120	ATBFIS	Alternate breaker failure initiated Terminal S
122	ATBFIT	Alternate breaker failure initiated Terminal T
124	ATBFIU	Alternate breaker failure initiated Terminal U
126	ATBFIW	Alternate breaker failure initiated Terminal W
128	ATBFIX	Alternate breaker failure initiated Terminal X
120	ATBFTS	Alternate breaker failure timer timed out Terminal S
122	ATBFTT	Alternate breaker failure timer timed out Terminal T
124	ATBFTU	Alternate breaker failure timer timed out Terminal U
126	ATBFTW	Alternate breaker failure timer timed out Terminal W
128	ATBFTX	Alternate breaker failure timer timed out Terminal X
289	AUNRLBL	Automation SELOGIC control equation unresolved label
290	BADPASS	Invalid password attempt alarm
120	BFIS	Breaker Failure initiated Terminal S
121	BFISPTS	Breaker Failure Seal in timer timed out Terminal S
123	BFISPTT	Breaker Failure Seal in timer timed out Terminal T
125	BFISPTU	Breaker Failure Seal in timer timed out Terminal U
127	BFISPTW	Breaker Failure Seal in timer timed out Terminal W
129	BFISPTX	Breaker Failure Seal in timer timed out Terminal X
122	BFIT	Breaker Failure initiated Terminal T
120	BFITS	Breaker Failure Timer timed out Terminal S
122	BFITT	Breaker Failure Timer timed out Terminal T
124	BFITU	Breaker Failure Timer timed out Terminal U
126	BFITW	Breaker Failure Timer timed out Terminal W
128	BFITX	Breaker Failure Timer timed out Terminal X
124	BFIU	Breaker Failure initiated Terminal U
126	BFIW	Breaker Failure initiated Terminal W
128	BFIX	Breaker Failure initiated Terminal X
144	BSBCWAL	Breaker Contact Wear alarm Breaker S
144	BSBITAL	Inactivity Time Alarm Breaker S
144	BSESOAL	Slow Electrical Operate alarm Breaker S
144	BSKAIAL	Interrupted rms current alarm Breaker S
144	BSMRTAL	Motor run time alarm Breaker S
144	BSMSOAL	Mechanical Slow Operation Alarm Breaker S
145	BTBCWAL	Breaker Contact Wear alarm Breaker T

Table G.1 Alphabetic List of Relay Word Bits (Sheet 14 of 27)

Row	Relay Word	Description
145	BTBITAL	Inactivity Time Alarm Breaker T
145	BTESOAL	Slow Electrical Operation Alarm Breaker T
145	BTKAIAL	Interrupted rms current alarm Breaker T
145	BTMRTAL	Motor run time alarm Breaker T
145	BTMSOAL	Mechanical Slow Operation Alarm Breaker T
146	BUBCWAL	Breaker Contact Wear alarm Breaker U
146	BUBITAL	Inactivity Time Alarm Breaker U
146	BUESOAL	Slow Electrical Operation Alarm Breaker U
146	BUKAIAL	Interrupted rms current alarm Breaker U
146	BUMRTAL	Motor run time alarm Breaker U
146	BUMSOAL	Mechanical Slow Operation Alarm Breaker U
147	BWBCWAL	Breaker Contact Wear alarm Breaker W
147	BWBITAL	Inactivity Time Alarm Breaker W
147	BWESOAL	Slow Electrical Operation Alarm Breaker W
147	BWKAIAL	Interrupted rms current alarm Breaker W
147	BWMRTAL	Motor run time alarm Breaker W
147	BWMSOAL	Mechanical Slow Operation Alarm Breaker W
148	BXBCWAL	Breaker Contact Wear alarm Breaker X
148	BXBITAL	Inactivity Time Alarm Breaker X
148	BXESOAL	Slow Electrical Operation Alarm Breaker X
148	BXKAIAL	Interrupted rms current alarm Breaker X
148	BXMRTAL	Motor run time alarm Breaker X
148	BXMSOAL	Mechanical Slow Operation Alarm Breaker X
313	CBADA	Unavailability threshold exceeded for normal mirrored bit communication channel A
314	CBADB	Unavailability threshold exceeded for normal mirrored bit communication channel B
290	CCALARM	Communication card status alarm
331	CCIN001–CCIN008	Communication card input bit 001–008
330	CCIN009–CCIN016	Communication card input bit 009–016
329	CCIN017–CCIN024	Communication card input bit 017–024
328	CCIN025–CCIN032	Communication card input bit 025–032
327	CCIN033–CCIN040	Communication card input bit 033–040
326	CCIN041–CCIN048	Communication card input bit 041–048
325	CCIN049–CCIN056	Communication card input bit 049–056
324	CCIN057–CCIN064	Communication card input bit 057–064
323	CCIN065 –CCIN072	Communication card input bit 065–072
322	CCIN073–CCIN080	Communication card input bit 073–080
321	CCIN081–CCIN088	Communication card input bit 081–088
320	CCIN089–CCIN096	Communication card input bit 089–096
319	CCIN097–CCIN104	Communication card input bit 097–104
318	CCIN105–CCIN112	Communication card input bit 105–112
317	CCIN113–CCIN120	Communication card input bit 113–120

Table G.1 Alphabetic List of Relay Word Bits (Sheet 15 of 27)

Row	Relay Word	Description
316	CCIN121–CCIN128	Communication card input bit 121–128
335	CCOUT01–CCOUT08	Communication card output point 01–08
334	CCOUT09–CCOUT16	Communication card output point 09–16
333	CCOUT17–CCOUT24	Communication card output point 17–24
332	CCOUT25–CCOUT32	Communication card output point 25–32
168	CCS	Breaker Close Command Terminal S
336	CCSTA01–CCSTA08	Communication Card Status bit 01–08
337	CCSTA09–CCSTA16	Communication Card Status bit 09–16
338	CCSTA17–CCSTA24	Communication Card Self Test Register Status bit 17–24
339	CCSTA25–CCSTA32	Communication Card Self Test Register Status bit 25–32
168	CCT	Breaker Close Command Terminal T
168	CCU	Breaker Close Command Terminal U
168	CCW	Breaker Close Command Terminal W
169	CCX	Breaker Close Command Terminal X
188	CHSG	Settings Group Changed
113	CLS	Close breaker Terminal S equation
114	CLSS	Close breaker Terminal S output
114	CLST	Close breaker Terminal T output
114	CLSU	Close breaker Terminal U output
114	CLSW	Close breaker Terminal W output
114	CLSX	Close breaker Terminal X output
113	CLT	Close breaker Terminal T equation
113	CLU	Close breaker Terminal U equation
113	CLW	Close breaker Terminal W equation
113	CLX	Close breaker Terminal X equation
5	CON	Fault outside of transformer differential zone
5	CONA	External fault detected zone A
5	CONB	External fault detected zone B
5	CONC	External fault detected zone C
154	CSALRM	Cooling stage determination alarm
153	CSCM	Cooling coefficient or measurement alarm
153	CSCM_1–CSCM_3	Transformer 1–3 Cooling coefficient or measurement alarm
153	CSE	Cooling stage efficiency alarm
153	CSE_1–CSE_3	Transformer 1–3 Cooling stage efficiency alarm
12	CTUA	CT A in unsaturated state
12	CTUB	CT B in unsaturated state
12	CTUC	CT C in unsaturated state
164	DC1F	DC Channel 1 Failed
164	DC1G	DC Channel 1 Ground Fault detected
164	DC1R	DC Channel 1 Excess Ripples detected
164	DC1W	DC Channel 1 Warning

Table G.1 Alphabetic List of Relay Word Bits (Sheet 16 of 27)

Row	Relay Word	Description
165	DMP01–DMP04	Demand Metering element 01–04 asserted
166	DMP05–DMP08	Demand Metering element 05–08 asserted
167	DMP09–DMP10	Demand Metering element 09–10 asserted
313	DOKA	Mirrored bit channel A in normal mode
314	DOKB	Mirrored bit channel B in normal mode
350	DST	Daylight Savings Time
350	DSTP	Daylight Savings Time Pending
93	E32OP01–E32OP02	Overpower element 01–02 enabled
94	E32OP03–E32OP04	Overpower element 03–04 enabled
95	E32OP05–E32OP06	Overpower element 05–06 enabled
96	E32OP07–E32OP08	Overpower element 07–08 enabled
97	E32OP09–E32OP10	Overpower element 09–10 enabled
98	E32UP01–E32UP02	Underpower element 01–02 enabled
99	E32UP03–E32UP04	Underpower element 03–04 enabled
100	E32UP05–E32UP06	Underpower element 05–06 enabled
101	E32UP07–E32UP08	Underpower element 07–08 enabled
102	E32UP09–E32UP10	Underpower element 09–10 enabled
4	E87TS	Terminal S currents included in differential zone
4	E87TT	Terminal T currents included in differential zone
4	E87TU	Terminal U currents included in differential zone
4	E87TW	Terminal W currents included in differential zone
4	E87TX	Terminal X currents included in differential zone
120	EBFITS	Externally initiated breaker failure timer timed out Terminal S
122	EBFITT	Externally initiated breaker failure timer timed out Terminal T
124	EBFITU	Externally initiated breaker failure timer timed out Terminal U
126	EBFITW	Externally initiated breaker failure timer timed out Terminal W
128	EBFITX	Externally initiated breaker failure timer timed out Terminal X
144	EBSMON	Breaker Monitoring Terminal S enabled
145	EBTMON	Breaker Monitoring Terminal T enabled
146	EBUMON	Breaker Monitoring Terminal U enabled
147	EBWMON	Breaker Monitoring Terminal W enabled
148	EBXMON	Breaker Monitoring Terminal X enabled
165	EDM01–EDM04	Demand Metering element 01–04 enabled
166	EDM05–EDM08	Demand Metering element 05–08 enabled
167	EDM09–EDM10	Demand Metering element 09–10 enabled
0	EN	Enable LED on relay front panel
121	ENINBFS	Neutral/residual breaker failure function enabled Terminal S
123	ENINBFT	Neutral/residual breaker failure function enabled Terminal T
125	ENINBFU	Neutral/residual breaker failure function enabled Terminal U
127	ENINBFW	Neutral/residual breaker failure function enabled Terminal W
129	ENINBFX	Neutral/residual breaker failure function enabled Terminal X

Table G.1 Alphabetic List of Relay Word Bits (Sheet 17 of 27)

Row	Relay Word	Description
308	ER	Event report triggered
163	ETHRFLT	Through Fault Element Enabled
342	EVELOCK	Lock DNP Events
120	EXBFS	External breaker failure input initiated Terminal S
122	EXBFT	External breaker failure input initiated Terminal T
124	EXBFU	External breaker failure input initiated Terminal U
126	EXBFW	External breaker failure input initiated Terminal W
128	EXBFX	External breaker failure input initiated Terminal X
151	FAA1	aging insulation acceleration factor alarm level 1
151	FAA1_1	Transformer 1 aging insulation acceleration factor alarm Level 1
151	FAA1_2	Transformer 1 aging insulation acceleration factor alarm Level 2
151	FAA2	Aging insulation acceleration factor alarm level 2
151	FAA2_1	Transformer 2 aging insulation acceleration factor alarm Level 1
151	FAA2_2	Transformer 2 aging insulation acceleration factor alarm Level 2
151	FAA3_1	Transformer 3 aging insulation acceleration factor alarm Level 1
151	FAA3_2	Transformer 3 aging insulation acceleration factor alarm Level 2
308	FAULT	Fault detected
121	FBFS	Breaker Failure asserted/initiated Terminal S
123	FBFT	Breaker Failure asserted/initiated Terminal T
125	FBFU	Breaker Failure asserted/initiated Terminal U
127	FBFW	Breaker Failure asserted/initiated Terminal W
129	FBFX	Breaker Failure asserted/initiated Terminal X
360	FOP1_01–FOP1_08	Fast Operate Output Control Bits for Port 1, 01–08
361	FOP1_09–FOP1_16	Fast Operate Output Control Bits for Port 1, 09–16
362	FOP1_17–FOP1_24	Fast Operate Output Control Bits for Port 1, 17–24
363	FOP1_25–FOP1_32	Fast Operate Output Control Bits for Port 1, 25–32
364	FOP2_01–FOP2_08	Fast Operate Output Control Bits for Port 2, 01–08
365	FOP2_09–FOP2_16	Fast Operate Output Control Bits for Port 2, 09–16
366	FOP2_17–FOP2_24	Fast Operate Output Control Bits for Port 2, 17–24
367	FOP2_25–FOP2_32	Fast Operate Output Control Bits for Port 2, 25–32
368	FOP3_01–FOP3_08	Fast Operate Output Control Bits for Port 3, 01–08
369	FOP3_09–FOP3_16	Fast Operate Output Control Bits for Port 3, 09–16
370	FOP3_17–FOP3_24	Fast Operate Output Control Bits for Port 3, 17–24
371	FOP3_25–FOP3_32	Fast Operate Output Control Bits for Port 3, 25–32
356	FOPF_01–FOPF_08	Fast Operate Output Control Bits for Port F, 01–08
357	FOPF_09–FOPF_16	Fast Operate Output Control Bits for Port F, 09–16
358	FOPF_17–FOPF_24	Fast Operate Output Control Bits for Port F, 17–24
359	FOPF_25–FOPF_32	Fast Operate Output Control Bits for Port F, 25–32
107	FREQFZ	Frequency Calculation Frozen
107	FREQOK	Frequency Tracking OK
341	FROKPM	Synchrophasor Frequency Measurement OK

Table G.1 Alphabetic List of Relay Word Bits (Sheet 18 of 27)

Row	Relay Word	Description
340	FSERP1–FSERP3	Fast SER enabled for Port 1–3
340	FSERPF	Fast SER enabled for front port
6	GFLTA	Instantaneous fault detector asserted A
6	GFLTB	Instantaneous fault detector asserted B
6	GFLTC	Instantaneous fault detector asserted C
290	HALARM	Hardware alarm
150	HS1	Hot Spot alarm Level 1
150	HS1_1	Transformer 1 hot spot temperature Alarm Level 1
150	HS1_2	Transformer 1 hot spot temperature Alarm Level 2
150	HS2	Hot Spot alarm Level 2
150	HS2_1	Transformer 2 hot spot temperature Alarm Level 1
150	HS2_2	Transformer 2 hot spot temperature Alarm Level 2
150	HS3_1	Transformer 3 hot spot temperature Alarm Level 1
150	HS3_2	Transformer 3 hot spot temperature Alarm Level 2
121	IASBF	A-Phase current above threshold Terminal S
123	IATBF	A-Phase current above threshold Terminal T
125	IAUBF	A-Phase current above threshold Terminal U
127	IAWBF	A-Phase current above threshold Terminal W
129	IAXBF	A-Phase current above threshold Terminal X
121	IBSBF	B-Phase current above threshold Terminal S
123	IBTBF	B-Phase current above threshold Terminal T
125	IBUBF	B-Phase current above threshold Terminal U
127	IBWBF	B-Phase current above threshold Terminal W
129	IBXBF	B-Phase current above threshold Terminal X
121	ICSBF	C-Phase current above threshold Terminal S
123	ICTBF	C-Phase current above threshold Terminal T
125	ICUBF	C-Phase current above threshold Terminal U
127	ICWBF	C-Phase current above threshold Terminal W
129	ICXBF	C-Phase current above threshold Terminal X
7	IFLTA	Fault inside transformer differential zone A
7	IFLTB	Fault inside transformer differential zone B
7	IFLTC	Fault inside transformer differential zone C
192	IN101–IN107	Input 101–107 asserted
196	IN201–IN208	Input 201–208 asserted
197	IN209–IN216	Input 209–216 asserted
198	IN217–IN224	Input 217–224 asserted
200	IN301–IN308	Input 301–308 asserted
201	IN309–IN316	Input 309–316 asserted
202	IN317–IN324	Input 317–324 asserted
121	INSBF	Neutral current above threshold Terminal S
123	INTBF	Neutral/Residual current exceeds pickup threshold Terminal T

Table G.1 Alphabetic List of Relay Word Bits (Sheet 19 of 27)

Row	Relay Word	Description
125	INUBF	Neutral/Residual current exceeds pickup threshold Terminal U
127	INWBF	Neutral/Residual current exceeds pickup threshold Terminal W
129	INXBF	Neutral/Residual current exceeds pickup threshold Terminal X
180	LB_DP01–LB_DP08	Local Bit 01–08 Status Display enabled
181	LB_DP09–LB_DP16	Local Bit 09–16 Status Display enabled
182	LB_DP17–LB_DP24	Local Bit 17–24 Status Display enabled
183	LB_DP25–LB_DP32	Local Bit 25–32 Status Display enabled
176	LB_SP01–LB_SP08	Local Bit 01–08 Supervision enabled
177	LB_SP09–LB_SP16	Local Bit 09–16 Supervision enabled
178	LB_SP17–LB_SP24	Local Bit 17–24 Supervision enabled
179	LB_SP25–LB_SP32	Local Bit 25–32 Supervision enabled
172	LB01–LB08	Local Bit 01–08 asserted
173	LB09–LB16	Local Bit 09–16 asserted
174	LB17–LB24	Local Bit 17–24 asserted
175	LB25–LB32	Local Bit 25–32 asserted
313	LBOKA	Mirrored bit channel in loopback mode channel A
314	LBOKB	Mirrored bit channel in loopback mode channel B
119	LOPV	Loss of potential terminal V
119	LOPZ	Loss of potential terminal Z
350	LPSEC	Leap second is added
350	LPSECP	Leap second pending
154	MAMB_OK	Ambient temperature measurement RTD healthy
288	MATHERR	SELOGIC control equation Math error
154	MTO1_OK–MTO3_OK	Transformer 1–3 top-oil temperature measurement RTD healthy
14	NDREF1	Nondirectional REF element 1 enabled
16	NDREF2	Nondirectional REF element 2 enabled
18	NDREF3	Nondirectional REF element 3 enabled
168	OCS	Breaker Open Command Terminal S
168	OCT	Breaker Open Command Terminal T
168	OCU	Breaker Open Command Terminal U
168	OCW	Breaker Open Command Terminal W
169	OCX	Breaker Open Command Terminal X
116	OPHAS	Phase A Terminal S open
116	OPHAT	Phase A Terminal T open
117	OPHAU	Phase A Terminal U open
117	OPHAW	Phase A Terminal W open
118	OPHAX	Phase A Terminal X open
116	OPHBS	Phase B Terminal S open
116	OPHBT	Phase B Terminal T open
117	OPHBU	Phase B Terminal U open
117	OPHBW	Phase B Terminal W open

Table G.1 Alphabetic List of Relay Word Bits (Sheet 20 of 27)

Row	Relay Word	Description
118	OPHBX	Phase B Terminal X open
116	OPHCS	Phase C Terminal S open
116	OPHCT	Phase C Terminal T open
117	OPHCU	Phase C Terminal U open
117	OPHCW	Phase C Terminal W open
118	OPHCX	Phase C Terminal X open
116	OPHS	Terminal S open
116	OPHT	Terminal T open
117	OPHU	Terminal U open
117	OPHW	Terminal W open
118	OPHX	Terminal X open
292	OUT101–OUT108	Output 101–108 asserted
296	OUT201–OUT208	Output 201–208 asserted
297	OUT209–OUT216	Output 209 –216asserted
298	OUT301–OUT308	Output 301–308 asserted
299	OUT309–OUT316	Output 309–316 asserted
10	P87A	Differential element zone A picked up
10	P87B	Differential element zone B picked up
10	P87C	Differential element zone C picked up
300	PB1	Pushbutton 01 asserted
304	PB1_LED	PB01_ LED illuminated
302	PB1_PUL	Pushbutton 01 pulsed for 1 processing interval
301	PB10–PB12	Pushbutton 10–12 asserted
305	PB10LED–PB12LED	PB10_ LED–PB12_ LED illuminated
303	PB10PUL–PB12PUL	Pushbutton 10–12 pulsed for 1 processing interval
300	PB2–PB8	Pushbutton 02–08 asserted
304	PB2_LED–PB8_LED	PB02_ LED–PB08_ LED illuminated
302	PB2_PUL–PB8_PUL	Pushbutton 02–08 pulsed for 1 processing interval
301	PB9	Pushbutton 09 asserted
305	PB9_LED	PB09_ LED illuminated
303	PB9_PUL	Pushbutton 09 pulsed for 1 processing interval
228	PCN01Q–PCN08Q	Protection SELOGIC Counter 01– asserted
232	PCN01R–PCN08R	Protection SELOGIC Counter 01–08 reset
229	PCN09Q–PCN16Q	Protection SELOGIC Counter 09–16 asserted
233	PCN09R–PCN16R	Protection SELOGIC Counter 09–16 reset
230	PCN17Q–PCN24Q	Protection SELOGIC Counter 17–24 asserted
234	PCN17R–PCN24R	Protection SELOGIC Counter 17–24 reset
231	PCN25Q–PCN32Q	Protection SELOGIC Counter 25–32 asserted
235	PCN25R–PCN32R	Protection SELOGIC Counter 25–32 reset
216	PCT01Q–PCT08Q	Protection SELOGIC Conditioning Timer 01–08 asserted
217	PCT09Q–PCT16Q	Protection SELOGIC Conditioning Timer 09–16 asserted

Table G.1 Alphabetic List of Relay Word Bits (Sheet 21 of 27)

Row	Relay Word	Description
218	PCT17Q–PCT24Q	Protection SELOGIC Conditioning Timer 17–24 asserted
219	PCT25Q–PCT32Q	Protection SELOGIC Conditioning Timer 25–32 asserted
288	PFRTEX	Protection SELOGIC control equation first execution
308	PHASE_A	Faulted phase
308	PHASE_B	Faulted phase
308	PHASE_C	Faulted phase
212	PLT01–PLT08	Protection SELOGIC Latch 01–08 asserted
213	PLT09–PLT16	Protection SELOGIC Latch 09–16 asserted
214	PLT17–PLT24	Protection SELOGIC Latch 17–24 asserted
215	PLT25–PLT32	Protection SELOGIC Latch 25–32 asserted
291	PMDOK	Synchrophasor data acquisition functioning correctly
341	PMTRIG	Synchrophasor SELOGIC control equation trigger
220	PST01Q–PST08Q	Protection SELOGIC Sequencing Timer 01–08 asserted
224	PST01R–PST08R	Protection SELOGIC Sequencing Timer 01–08 reset
221	PST09Q–PST16Q	Protection SELOGIC Sequencing Timer 09–16 asserted
225	PST09R–PST16R	Protection SELOGIC Sequencing Timer 09–16 reset
222	PST17Q–PST24Q	Protection SELOGIC Sequencing Timer 17–24 asserted
226	PST17R–PST24R	Protection SELOGIC Sequencing Timer 17–24 reset
223	PST25Q–PST32Q	Protection SELOGIC Sequencing Timer 25–32 asserted
227	PST25R–PST32R	Protection SELOGIC Sequencing Timer 25–32 reset
204	PSV01–PSV08	Protection SELOGIC Variable 01–08 asserted
205	PSV09–PSV16	Protection SELOGIC Variable 09–16 asserted
206	PSV17–PSV24	Protection SELOGIC Variable 17–24 asserted
207	PSV25–PSV32	Protection SELOGIC Variable 25–32 asserted
208	PSV33–PSV40	Protection SELOGIC Variable 33–40 asserted
209	PSV41–PSV48	Protection SELOGIC Variable 41–48 asserted
210	PSV49–PSV56	Protection SELOGIC Variable 49–56 asserted
211	PSV57–PSV64	Protection SELOGIC Variable 57–64 asserted
288	PUNRLBL	Protection SELOGIC control equation unresolved label
187	RB01–RB08	Remote Bit 01–08 asserted
186	RB09–RB16	Remote Bit 09–16 asserted
185	RB17–RB24	Remote Bit 17–24 asserted
184	RB25–RB32	Remote Bit 25–32 asserted
313	RBADA	Outage to large for normal mirrored bit communication channel A
314	RBADB	Outage to large for normal mirrored bit communication channel B
14	REF501	Neutral (operating current) instantaneous over current element 1 timed out
16	REF502	Neutral (operating current) instantaneous over current element 2 timed out
18	REF503	Neutral (operating current) instantaneous over current element 3 timed out
14	REF50T1	Neutral Instantaneous overcurrent element 1 timed out
16	REF50T2	Neutral Instantaneous overcurrent element 2 timed out
18	REF50T3	Neutral Instantaneous overcurrent element 3 timed out

Table G.1 Alphabetic List of Relay Word Bits (Sheet 22 of 27)

Row	Relay Word	Description
15	REF51R1	Inverse time neutral overcurrent element 1 reset
17	REF51R2	Inverse time neutral overcurrent element 2 reset
19	REF51R3	Inverse time neutral overcurrent element 3 reset
14	REF51T1	Inverse time neutral overcurrent element 1 timed out
16	REF51T2	Inverse time neutral overcurrent element 2 timed out
18	REF51T3	Inverse time neutral overcurrent element 3 timed out
14	REFF1	Earth fault inside restricted zone 1
16	REFF2	Earth fault inside restricted zone 2
18	REFF3	Earth fault inside restricted zone 3
14	REFR1	Earth fault outside restricted zone 1
16	REFR2	Earth fault outside restricted zone 2
18	REFR3	Earth fault outside restricted zone 3
14	RF51TC1	Inverse time neutral overcurrent element 1 enabled
16	RF51TC2	Inverse time neutral overcurrent element 2 enabled
18	RF51TC3	Inverse time neutral overcurrent element 3 enabled
152	RLL	Rate of loss of life alarm
152	RLL_1	Transformer 1 rate of loss of life alarm
152	RLL_2	Transformer 2 rate of loss of life alarm
152	RLL_3	Transformer 3 rate of loss of life alarm
309	RMB1A–RMB8A	Received Mirrored bit 1–8 Channel A
311	RMB1B–RMB8B	Received Mirrored bit 1–8 Channel B
313	ROKA	Mirrored Bit Channel A normal status in non loopback mode
314	ROKB	Mirrored Bit channel B normal status in non loopback mode
307	RST_BAT	Reset Battery monitoring
306	RST_BKS	Reset Breaker S monitoring
306	RST_BKT	Reset Breaker T monitoring
306	RST_BKU	Reset Breaker U monitoring
306	RST_BKW	Reset Breaker W monitoring
306	RST_BKX	Reset Breaker X monitoring
306	RST_DEM	Reset Demand Metering
306	RST_ENE	Reset Energy metering
306	RST_PDM	Reset Peak Demand Metering
307	RSTDNPE	Reset DNP fault summary data
307	RSTTRGT	Reset Front Panel targets
344	RTCAD01–RTCAD08	RTC Remote Data Bits, Channel A, 1–8
345	RTCAD09–RTCAD16	RTC Remote Data Bits, Channel A, 9–16
346	RTCBD01–RTCBD08	RTC Remote Data Bits, Channel B, 1–8
347	RTCBD09–RTCBD16	RTC Remote Data Bits, Channel B, 9–16
342	RTCCFGA	RTC Configuration Complete, Channel A
342	RTCCFGB	RTC Configuration Complete, Channel B
343	RTCDLYA	RTC Delay Exceeded, Channel A

Table G.1 Alphabetic List of Relay Word Bits (Sheet 23 of 27)

Row	Relay Word	Description
343	RTCDLYB	RTC Delay Exceeded, Channel B
343	RTCENA	Valid Remote Synchrophasors Received on Channel A
343	RTCENB	Valid Remote Synchrophasors Received on Channel B
343	RTCROK	Valid Aligned RTC Data Available on All Enabled Channels
343	RTCROKA	Valid Aligned RTC Data Available on Channel A
343	RTCROKB	Valid Aligned RTC Data Available on Channel B
342	RTCSEQA	RTC Data In Sequence on Channel B
342	RTCSEQB	RTC Data In Sequence on Channel B
160	RTD01OC–RTD08OC	RTD01–RTD08 Open circuited
156	RTD01OK–RTD08OK	RTD01–RTD08 Healthy
158	RTD01SC–RTD08SC	RTD01–RTD08 Short circuited
161	RTD09OC–RTD12OC	RTD09–RTD12 Open circuited
157	RTD09OK–RTD12OK	RTD09–RTD09 Healthy
159	RTD09SC–RTD12SC	RTD09–RTD12 Short circuited
162	RTDCOMF	SEL 2600 Communication Failure
162	RTDFL	SEL 2600 RAM failure
120	RTS	Retrip Timer timed out/Retrip command issued Terminal S
122	RTT	Retrip Timer timed out/Retrip command issued Terminal T
124	RTU	Retrip Timer timed out/Retrip command issued Terminal U
126	RTW	Retrip Timer timed out/ Retrip command issued Terminal W
128	RTX	Retrip Timer timed out/Retrip command issued Terminal X
20	S32QE	Negative-sequence phase element Terminal S enabled
20	S32QGE	Negative-sequence ground element Terminal S enabled
20	S32VE	Zero-sequence voltage directional element Terminal S enabled
20	S50GF	Zero-sequence current Terminal S above forward threshold
20	S50GR	Zero-sequence current Terminal S above reverse threshold
20	S50QF	Negative-sequence current Terminal S above forward threshold
20	S50QR	Negative-sequence current Terminal S above reverse threshold
290	SALARM	Software alarm
21	SF32G	Forward ground fault Terminal S
30	SF32P	Forward phase direction element asserted Terminal S
30	SF32Q	Forward negative-sequence phase element asserted Terminal S
20	SF32QG	Negative-sequence ground element forward Terminal S
21	SF32V	Zero-sequence ground element forward Terminal S
188	SG1–SG6	Setting Group 1–6 is active
353	SPEN	Signal Profiling enabled
21	SR32G	Reverse ground fault Terminal S
30	SR32P	Reverse phase direction element asserted Terminal S
30	SR32Q	Reverse negative-sequence phase element asserted Terminal S
21	SR32QG	Negative-sequence ground element reverse Terminal S
21	SR32V	Zero-sequence ground element reverse Terminal S

Table G.1 Alphabetic List of Relay Word Bits (Sheet 24 of 27)

Row	Relay Word	Description
155	T1CS2	Transformer 1 Cooling Stage 2
155	T1CS3	Transformer 1 Cooling Stage 3
155	T2CS2	Transformer 2 Cooling Stage 2
155	T2CS3	Transformer 2 Cooling Stage 3
22	T32QE	Negative-sequence phase element Terminal T enabled
22	T32QGE	Negative-sequence ground element Terminal T enabled
22	T32VE	Zero-sequence voltage directional element Terminal T enabled
155	T3CS2	Transformer 3 Cooling Stage 2
155	T3CS3	Transformer 3 Cooling Stage 3
22	T50GF	Zero-sequence current Terminal T above forward threshold
22	T50GR	Zero-sequence current Terminal T above reverse threshold
22	T50QF	Negative-sequence current Terminal T above forward threshold
22	T50QR	Negative-sequence current Terminal T above reverse threshold
14	TCREF1	REF element 1 enabled
16	TCREF2	REF element 2 enabled
18	TCREF3	REF element 3 enabled
315	TESTDB	Communication card database test bit
315	TESTDNP	DNP test bit
315	TESTFM	Fast Meter test bit
315	TESTPUL	Pulse test bit
23	TF32G	Forward ground fault Terminal T
31	TF32P	Forward phase direction element asserted Terminal T
31	TF32Q	Forward negative-sequence phase element asserted Terminal T
22	TF32QG	Negative-sequence ground element forward Terminal T
23	TF32V	Zero-sequence ground element forward Terminal T
163	TFLTALA	Through fault alarm phase A
163	TFLTALB	Through fault alarm phase B
163	TFLTALC	Through fault alarm phase C
12	TH5AD	Fifth harmonic operate current content timed out
12	TH5AP	Fifth harmonic content of operate current above pickup
291	TIRIG	Time based on IRIG for both mark and value
1	TLED_1–TLED_8	Target LED 1–LED8 on relay front panel
2	TLED_9–TLED_16	Target LED 9–LED16 on relay front panel
3	TLED_17–TLED_24	Target LED 17–LED 24 on relay front panel
152	TLL	Total loss of life alarm
152	TLL_1	Transformer 1 total loss of life alarm
152	TLL_2	Transformer 2 total loss of life alarm
152	TLL_3	Transformer 3 total loss of life alarm
310	TMB1A–TMB8A	Transmitted Mirrored bit 1–8 Channel A
312	TMB1B–TMB8B	Transmitted Mirrored bit 1–8 Channel B
149	TO1	Top-oil temperature Alarm level 1

Table G.1 Alphabetic List of Relay Word Bits (Sheet 25 of 27)

Row	Relay Word	Description
149	TO1_1	Transformer 1 Top-oil temperature alarm level 1
149	TO1_2	Transformer 1 Top-oil temperature alarm level 2
149	TO2	Top-oil Temperature Alarm level 2
149	TO2_1	Transformer 2 Top-oil temperature alarm level 1
149	TO2_2	Transformer 2 Top-oil temperature alarm level 2
149	TO3_1	Transformer 3 Top-oil temperature alarm level 1
149	TO3_2	Transformer 3 Top-oil temperature alarm level 2
350	TQUAL1	Time quality binary add 1 when asserted
350	TQUAL2	Time quality binary add 2 when asserted
350	TQUAL4	Time quality binary add 4 when asserted
350	TQUAL8	Time quality binary add 8 when asserted
23	TR32G	Reverse ground fault Terminal T
31	TR32P	Reverse phase direction element asserted Terminal T
31	TR32Q	Reverse negative-sequence phase element asserted Terminal T
23	TR32QG	Negative-sequence ground element reverse Terminal T
23	TR32V	Zero-sequence ground element reverse Terminal T
155	TRDE	Transformer de-energize
341	TREA1	Synchrophasor SELOGIC control equation trigger reason 1
341	TREA2	Synchrophasor SELOGIC control equation trigger reason 2
341	TREA3	Synchrophasor SELOGIC control equation trigger reason 3
341	TREA4	Synchrophasor SELOGIC control equation trigger reason 4
308	TRGTR	Target reset
111	TRIP	Transformer or Terminal Trip signal asserted
0	TRIPLED	Trip LED on front of relay front panel
111	TRIPS	Terminal S trip output asserted
111	TRIPT	Terminal T trip output asserted
111	TRIPU	Terminal U trip output asserted
111	TRIPW	Terminal W trip output asserted
111	TRIPX	Terminal X trip output asserted
111	TRPXFMR	Transformer trip output asserted
110	TRS	Terminal S trip equation asserted
110	TRT	Terminal T trip equation asserted
110	TRU	Terminal U trip equation asserted
110	TRW	Terminal W trip equation asserted
110	TRX	Terminal X trip equation asserted
110	TRXFMR	Transformer trip equation asserted
291	TSOK	Time source accuracy meets synchrophasor requirement
291	TSYNCA	Time mark from time source not synchronized
291	TUPDH	Update source is a high-accuracy time source
349	TUTC1	Offset hours from UTC time binary add 1 if asserted
349	TUTC2	Offset hours from UTC time binary add 2 if asserted

Table G.1 Alphabetic List of Relay Word Bits (Sheet 26 of 27)

Row	Relay Word	Description
349	TUTC4	Offset hours from UTC time binary add 4 if asserted
349	TUTC8	Offset hours from UTC time binary add 8 if asserted
349	TUTCH	Offset half-hour from UTC time binary add 0.5 if asserted
349	TUTCS	Offset hours sign from UTC time subtract the UTC offset if TUTCS is asserted add otherwise
24	U32QE	Negative-sequence phase element Terminal U enabled
24	U32QGE	Negative-sequence ground element Terminal U enabled
24	U32VE	Zero-sequence voltage directional element Terminal U enabled
24	U50GF	Zero-sequence current Terminal U above forward threshold
24	U50GR	Zero-sequence current Terminal U above reverse threshold
24	U50QF	Negative-sequence current Terminal U above forward threshold
24	U50QR	Negative-sequence current Terminal U above reverse threshold
25	UF32G	Forward ground fault Terminal U
32	UF32P	Forward phase direction element asserted Terminal U
32	UF32Q	Forward negative-sequence phase element asserted Terminal U
24	UF32QG	Negative-sequence ground element forward Terminal U
25	UF32V	Zero-sequence ground element forward Terminal U
115	ULCLS	Unlatch close Terminal S
115	ULCLT	Unlatch close Terminal T
115	ULCLU	Unlatch close Terminal U
115	ULCLW	Unlatch close Terminal W
115	ULCLX	Unlatch close Terminal X
112	ULTRS	Unlatch Terminal S trip
112	ULTRT	Unlatch Terminal T trip
112	ULTRU	Unlatch Terminal U trip
112	ULTRW	Unlatch Terminal W trip
112	ULTRX	Unlatch Terminal X trip
112	ULTXFMR	Unlatch transformer trip
25	UR32G	Reverse ground fault Terminal U
32	UR32P	Reverse phase direction element asserted Terminal U
32	UR32Q	Reverse negative-sequence phase element asserted Terminal U
25	UR32QG	Negative-sequence ground element reverse Terminal U
25	UR32V	Zero-sequence ground element reverse Terminal U
119	VALARMV	Voltage alarm Terminal V
119	VALARMZ	Voltage alarm Terminal Z
119	VPOLV	Polarizing voltage available terminal V
119	VPOLZ	Polarizing voltage available terminal Z
26	W32QE	Negative-sequence phase element Terminal W enabled
26	W32QGE	Negative-sequence ground element Terminal W enabled
26	W32VE	Zero-sequence voltage directional element Terminal W enabled
26	W50GF	Zero-sequence current Terminal W above forward threshold
26	W50GR	Zero-sequence current Terminal W above reverse threshold

Table G.1 Alphabetic List of Relay Word Bits (Sheet 27 of 27)

Row	Relay Word	Description
26	W50QF	Negative-sequence current Terminal W above forward threshold
26	W50QR	Negative-sequence current Terminal W above reverse threshold
27	WF32G	Forward ground fault Terminal W
33	WF32P	Forward phase direction element asserted Terminal W
33	WF32Q	Forward negative-sequence phase element asserted Terminal W
26	WF32QG	Negative-sequence ground element forward Terminal W
27	WF32V	Zero-sequence ground element forward Terminal W
6	WFLTA	Windowed fault detector asserted A
6	WFLTB	Windowed fault detector asserted B
6	WFLTC	Windowed fault detector asserted C
27	WR32G	Reverse ground fault Terminal W
33	WR32P	Reverse phase direction element asserted Terminal W
33	WR32Q	Reverse negative-sequence phase element asserted Terminal W
27	WR32QG	Negative-sequence ground element reverse Terminal W
27	WR32V	Zero-sequence ground element reverse Terminal W
28	X32QE	Negative-sequence phase element Terminal X enabled
28	X32QGE	Negative-sequence ground element Terminal X enabled
28	X32VE	Zero-sequence voltage directional element Terminal X enabled
28	X50GF	Zero-sequence current Terminal X above forward threshold
28	X50GR	Zero-sequence current Terminal X above reverse threshold
28	X50QF	Negative-sequence current Terminal X above forward threshold
28	X50QR	Negative-sequence current Terminal X above reverse threshold
29	XF32G	Forward ground fault Terminal X
34	XF32P	Forward phase direction element asserted Terminal X
34	XF32Q	Forward negative-sequence phase element asserted Terminal X
28	XF32QG	Negative-sequence ground element forward Terminal X
29	XF32V	Zero-sequence ground element forward Terminal X
29	XR32G	Reverse ground fault Terminal X
34	XR32P	Reverse phase direction element asserted Terminal X
34	XR32Q	Reverse negative-sequence phase element asserted Terminal X
29	XR32QG	Negative-sequence ground element reverse Terminal X
29	XR32V	Zero-sequence ground element reverse Terminal X
348	YEAR1	IRIG B year information (add 1 years if bit asserted)
348	YEAR10	IRIG B year information (add 10 years if bit asserted)
348	YEAR2	IRIG B year information (add 2 years if bit asserted)
348	YEAR20	IRIG B year information (add 20 years if bit asserted)
348	YEAR4	IRIG B year information (add 4 years if bit asserted)
348	YEAR40	IRIG B year information (add 40 years if bit asserted)
348	YEAR8	IRIG B year information (add 8 years if bit asserted)
348	YEAR80	IRIG B year information (add 80 years if bit asserted)

Row List

Table G.2 Relay Word Bits: Enable and Tripping Bits

Row	Name	Description
0	EN	Enable LED on relay front panel
0	TRIPLED	Trip LED on front of relay front panel
1	TLED_1–TLED_8	Target LED 1–LED 8 on relay front panel
2	TLED_9–TLED_16	Target LED 9–LED 16 on relay front panel
3	TLED_17–TLED_24	Target LED 17–LED 24 on relay front panel

Table G.3 Relay Word Bits: Phase Differential Elements (Sheet 1 of 2)

Row	Name	Description
4	E87TS	Terminal S currents included in differential zone
4	E87TT	Terminal T currents included in differential zone
4	E87TU	Terminal U currents included in differential zone
4	E87TW	Terminal W currents included in differential zone
4	E87TX	Terminal X currents included in differential zone
5	CONA	External fault detected zone A
5	CONB	External fault detected zone B
5	CONC	External fault detected zone C
5	CON	Fault outside of transformer differential zone
6	GFLTA	Instantaneous fault detector asserted A
6	GFLTB	Instantaneous fault detector asserted B
6	GFLTC	Instantaneous fault detector asserted C
6	WFLTA	Windowed fault detector asserted A
6	WFLTB	Windowed fault detector asserted B
6	WFLTC	Windowed fault detector asserted C
7	IFLTA	Fault inside transformer differential zone A
7	IFLTB	Fault inside transformer differential zone B
7	IFLTC	Fault inside transformer differential zone C
8	87AHB	Harmonic blocking differential element picked up A
8	87BHB	Harmonic blocking differential element picked up B
8	87CHB	Harmonic blocking differential element picked up C
8	87AHR	Harmonic restraint differential element picked up A
8	87BHR	Harmonic restraint differential element picked up B
8	87CHR	Harmonic restraint differential element picked up C
9	87UA	Unrestrained element asserted zone A
9	87UB	Unrestrained element asserted zone B
9	87UC	Unrestrained element asserted zone C
9	87U	Unrestrained element operation
10	P87A	Differential element zone A picked up
10	P87B	Differential element zone B picked up

Table G.3 Relay Word Bits: Phase Differential Elements (Sheet 2 of 2)

Row	Name	Description
10	P87C	Differential element zone C picked up
10	87RA	Restrained Differential element operated phase A
10	87RB	Restrained Differential element operated phase B
10	87RC	Restrained Differential element operated phase C
10	87R	Restrained differential element operated
11	87ABK2	2nd and 4th harmonic blocking asserted zone A
11	87BBK2	2nd and 4th harmonic blocking asserted zone B
11	87CBK2	2nd and 4th harmonic blocking asserted zone C
11	87XBK2	Harmonic cross blocking picked up
11	87ABK5	5th harmonic blocking asserted zone A
11	87BBK5	5th harmonic blocking asserted zone B
11	87CBK5	5th harmonic blocking asserted zone C
11	87QB	Block negative and zero-sequence directional elements
12	TH5AP	Fifth harmonic content of operate current above pickup
12	TH5AD	Fifth harmonic operate current content timed out
12	CTUA	CT A in unsaturated state
12	CTUB	CT B in unsaturated state
12	CTUC	CT C in unsaturated state

Table G.4 Relay Word Bits: Negative-Sequence Differential Elements

Row	Name	Description
13	87Q	Negative-sequence differential element asserted (inter turn fault detected)

Table G.5 Relay Word Bits: Enable and Tripping Bits

Row	Name	Description
0	EN	Enable LED on relay front panel
0	TRIPLED	Trip LED on front of relay front panel
1	TLED_1–TLED_8	Target LED 1–LED 8 on relay front panel
2	TLED_9–TLED_16	Target LED 9–LED 16 on relay front panel
3	TLED_17–TLED_24	Target LED 17–LED 24 on relay front panel

Table G.6 Relay Word Bits: Phase Differential Elements (Sheet 1 of 2)

Row	Name	Description
4	E87TS	Terminal S currents included in differential zone
4	E87TT	Terminal T currents included in differential zone
4	E87TU	Terminal U currents included in differential zone
4	E87TW	Terminal W currents included in differential zone
4	E87TX	Terminal X currents included in differential zone
5	CONA	External fault detected zone A
5	CONB	External fault detected zone B
5	CONC	External fault detected zone C

Table G.6 Relay Word Bits: Phase Differential Elements (Sheet 2 of 2)

Row	Name	Description
5	CON	Fault outside of transformer differential zone
6	GFLTA	Instantaneous fault detector asserted A
6	GFLTB	Instantaneous fault detector asserted B
6	GFLTC	Instantaneous fault detector asserted C
6	WFLTA	Windowed fault detector asserted A
6	WFLTB	Windowed fault detector asserted B
6	WFLTC	Windowed fault detector asserted C
7	IFLTA	Fault inside transformer differential zone A
7	IFLTB	Fault inside transformer differential zone B
7	IFLTC	Fault inside transformer differential zone C
8	87AHB	Harmonic blocking differential element picked up A
8	87BHB	Harmonic blocking differential element picked up B
8	87CHB	Harmonic blocking differential element picked up C
8	87AHR	Harmonic restraint differential element picked up A
8	87BHR	Harmonic restraint differential element picked up B
8	87CHR	Harmonic restraint differential element picked up C
9	87UA	Unrestrained element asserted zone A
9	87UB	Unrestrained element asserted zone B
9	87UC	Unrestrained element asserted zone C
9	87U	Unrestrained element operation
10	P87A	Differential element zone A picked up
10	P87B	Differential element zone B picked up
10	P87C	Differential element zone C picked up
10	87RA	Restrained Differential element operated phase A
10	87RB	Restrained Differential element operated phase B
10	87RC	Restrained Differential element operated phase C
10	87R	Restrained differential element operated
11	87ABK2	2nd and 4th harmonic blocking asserted zone A
11	87BBK2	2nd and 4th harmonic blocking asserted zone B
11	87CBK2	2nd and 4th harmonic blocking asserted zone C
11	87XBK2	Harmonic cross blocking picked up
11	87ABK5	5th harmonic blocking asserted zone A
11	87BBK5	5th harmonic blocking asserted zone B
11	87CBK5	5th harmonic blocking asserted zone C
11	87QB	Block negative and zero-sequence directional elements
12	TH5AP	Fifth harmonic content of operate current above pickup
12	TH5AD	Fifth harmonic operate current content timed out
12	CTUA	CT A in unsaturated state
12	CTUB	CT B in unsaturated state
12	CTUC	CT C in unsaturated state

Table G.7 Relay Word Bits: Negative-Sequence Differential Elements

Row	Name	Description
13	87Q	Negative-sequence differential element asserted (inter turn fault detected)

Table G.8 Relay Word Bits: Restricted Earth Fault Elements

Row	Name	Description
14	TCREF1	REF element 1 enabled
14	NDREF1	Nondirectional REF element 1 enabled
14	REFF1	Earth fault inside restricted zone 1
14	REFR1	Earth fault outside restricted zone 1
14	REF501	Neutral (operating current) instantaneous over current element 1 picked up
14	REF50T1	Neutral Instantaneous overcurrent element 1 timed out
14	RF51TC1	Inverse time neutral overcurrent element 1 enabled
14	REF51T1	Inverse time neutral overcurrent element 1 picked up
15	REF51R1	Inverse time neutral overcurrent element 1 reset
16	TCREF2	REF element 2 enabled
16	NDREF2	Nondirectional REF element 2 enabled
16	REFF2	Earth fault inside restricted zone 2
16	REFR2	Earth fault outside restricted zone 2
16	REF502	Neutral (operating current) instantaneous over current element 2 picked up
16	REF50T2	Neutral Instantaneous overcurrent element 2 timed out
16	RF51TC2	Inverse time neutral overcurrent element 2 enabled
16	REF51T2	Inverse time neutral overcurrent element 2 picked up
17	REF51R2	Inverse time neutral overcurrent element 2 reset
18	TCREF3	REF element 3 enabled
18	NDREF3	Nondirectional REF element 3 enabled
18	REFF3	Earth fault inside restricted zone 3
18	REFR3	Earth fault outside restricted zone 3
18	REF503	Neutral (operating current) instantaneous over current element 3 picked up
18	REF50T3	Neutral Instantaneous overcurrent element 3 timed out
18	RF51TC3	Inverse time neutral overcurrent element 3 enabled
18	REF51T3	Inverse time neutral overcurrent element 3 picked up
19	REF51R3	Inverse time neutral overcurrent element 3 reset

Table G.9 Relay Word Bits: Ground Directional Elements (Sheet 1 of 3)

Row	Name	Description
20	S50QF	Negative-sequence current Terminal S above forward threshold
20	S50QR	Negative-sequence current Terminal S above reverse threshold
20	S32QE	Negative-sequence phase element Terminal S enabled
20	S32QGE	Negative-sequence ground element Terminal S enabled
20	S50GF	Zero-sequence current Terminal S above forward threshold
20	S50GR	Zero-sequence current Terminal S above reverse threshold
20	S32VE	Zero-sequence voltage directional element Terminal S enabled

Table G.9 Relay Word Bits: Ground Directional Elements (Sheet 2 of 3)

Row	Name	Description
20	SF32QG	Negative-sequence ground element forward Terminal S
21	SR32QG	Negative-sequence ground element reverse Terminal S
21	SF32V	Zero-sequence ground element forward Terminal S
21	SR32V	Zero-sequence ground element reverse Terminal S
21	SF32G	Forward ground fault Terminal S
21	SR32G	Reverse ground fault Terminal S
22	T50QF	Negative-sequence current Terminal T above forward threshold
22	T50QR	Negative-sequence current Terminal T above reverse threshold
22	T32QE	Negative-sequence phase element Terminal T enabled
22	T32QGE	Negative-sequence ground element Terminal T enabled
22	T50GF	Zero-sequence current Terminal T above forward threshold
22	T50GR	Zero-sequence current Terminal T above reverse threshold
22	T32VE	Zero-sequence voltage directional element Terminal T enabled
22	TF32QG	Negative-sequence ground element forward Terminal T
23	TR32QG	Negative-sequence ground element reverse Terminal T
23	TF32V	Zero-sequence ground element forward Terminal T
23	TR32V	Zero-sequence ground element reverse Terminal T
23	TF32G	Forward ground fault Terminal T
23	TR32G	Reverse ground fault Terminal T
24	U50QF	Negative-sequence current Terminal U above forward threshold
24	U50QR	Negative-sequence current Terminal U above reverse threshold
24	U32QE	Negative-sequence phase element Terminal U enabled
24	U32QGE	Negative-sequence ground element Terminal U enabled
24	U50GF	Zero-sequence current Terminal U above forward threshold
24	U50GR	Zero-sequence current Terminal U above reverse threshold
24	U32VE	Zero-sequence voltage directional element Terminal U enabled
24	UF32QG	Negative-sequence ground element forward Terminal U
25	UR32QG	Negative-sequence ground element reverse Terminal U
25	UF32V	Zero-sequence ground element forward Terminal U
25	UR32V	Zero-sequence ground element reverse Terminal U
25	UF32G	Forward ground fault Terminal U
25	UR32G	Reverse ground fault Terminal U
26	W50QF	Negative-sequence current Terminal W above forward threshold
26	W50QR	Negative-sequence current Terminal W above reverse threshold
26	W32QE	Negative-sequence phase element Terminal W enabled
26	W32QGE	Negative-sequence ground element Terminal W enabled
26	W50GF	Zero-sequence current Terminal W above forward threshold
26	W50GR	Zero-sequence current Terminal W above reverse threshold
26	W32VE	Zero-sequence voltage directional element Terminal W enabled
26	WF32QG	Negative-sequence ground element forward Terminal W
27	WR32QG	Negative-sequence ground element reverse Terminal W

Table G.9 Relay Word Bits: Ground Directional Elements (Sheet 3 of 3)

Row	Name	Description
27	WF32V	Zero-sequence ground element forward Terminal W
27	WR32V	Zero-sequence ground element reverse Terminal W
27	WF32G	Forward ground fault Terminal W
27	WR32G	Reverse ground fault Terminal W
28	X50QF	Negative-sequence current Terminal X above forward threshold
28	X50QR	Negative-sequence current Terminal X above reverse threshold
28	X32QE	Negative-sequence phase element Terminal X enabled
28	X32QGE	Negative-sequence ground element Terminal X enabled
28	X50GF	Zero-sequence current Terminal X above forward threshold
28	X50GR	Zero-sequence current Terminal X above reverse threshold
28	X32VE	Zero-sequence voltage directional element Terminal X enabled
28	XF32QG	Negative-sequence ground element forward Terminal X
29	XR32QG	Negative-sequence ground element reverse Terminal X
29	XF32V	Zero-sequence ground element forward Terminal X
29	XR32V	Zero-sequence ground element reverse Terminal X
29	XF32G	Forward ground fault Terminal X
29	XR32G	Reverse ground fault Terminal X

Table G.10 Relay Word Bits: Definite and Directional Overcurrent Elements

Row	Name	Description
30	SF32P	Forward phase direction element asserted Terminal S
30	SR32P	Reverse phase direction element asserted Terminal S
30	SF32Q	Forward negative-sequence phase element asserted Terminal S

Table G.11 Relay Word Bits: Phase Directional Elements (Sheet 1 of 2)

Row	Name	Description
30	SF32P	Forward phase direction element asserted Terminal S
30	SR32P	Reverse phase direction element asserted Terminal S
30	SF32Q	Forward negative-sequence phase element asserted Terminal S
30	SR32Q	Reverse negative-sequence phase element asserted Terminal S
31	TF32P	Forward phase direction element asserted Terminal T
31	TR32P	Reverse phase direction element asserted Terminal T
31	TF32Q	Forward negative-sequence phase element asserted Terminal T
31	TR32Q	Reverse negative-sequence phase element asserted Terminal T
32	UF32P	Forward phase direction element asserted Terminal U
32	UR32P	Reverse phase direction element asserted Terminal U
32	UF32Q	Forward negative-sequence phase element asserted Terminal U
32	UR32Q	Reverse negative-sequence phase element asserted Terminal U
33	WF32P	Forward phase direction element asserted Terminal W
33	WR32P	Reverse phase direction element asserted Terminal W
33	WF32Q	Forward negative-sequence phase element asserted Terminal W

Table G.11 Relay Word Bits: Phase Directional Elements (Sheet 2 of 2)

Row	Name	Description
33	WR32Q	Reverse negative-sequence phase element asserted Terminal W
34	XF32P	Forward phase direction element asserted Terminal X
34	XR32P	Reverse phase direction element asserted Terminal X
34	XF32Q	Forward negative-sequence phase element asserted Terminal X
34	XR32Q	Reverse negative-sequence phase element asserted Terminal X

Table G.12 Relay Word Bits: Definite and Directional Overcurrent Elements (Sheet 1 of 5)

Row	Name	Description
35	50SP1	Phase Definite time element 1 Terminal S asserted
35	67SP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal S
35	67SP1	Phase Directional/Torque controlled element 1 Terminal S picked up
35	67SP1T	Phase Directional/Torque controlled element 1 Terminal S timed out
35	50SP2	Phase Definite time element 2 Terminal S asserted
35	67SP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal S
35	67SP2	Phase Directional/Torque controlled element 2 Terminal S picked up
35	67SP2T	Phase Directional/Torque controlled element 2 Terminal S timed out
36	50SP3	Phase Definite time element 3 Terminal S asserted
36	67SP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal S
36	67SP3	Phase Directional/Torque controlled element 3 Terminal S picked up
36	67SP3T	Phase Directional/Torque controlled element 3 Terminal S timed out
37	50SQ1	Negative-sequence Definite time element 1 Terminal S asserted
37	67SQ1TC	Negative-sequence Directional/Torque Control enable definite time element 1 Terminal S
37	67SQ1	Negative-sequence Directional/Torque controlled element 1 Terminal S picked up
37	67SQ1T	Negative-sequence Directional/Torque controlled element 1 Terminal S timed out
37	50SQ2	Negative-sequence Definite time element 2 Terminal S asserted
37	67SQ2TC	Negative-sequence Directional/Torque Control enable definite time element 2 Terminal S
37	67SQ2	Negative-sequence Directional/Torque controlled element 2 Terminal S picked up
37	67SQ2T	Negative-sequence Directional/Torque controlled element 2 Terminal S timed out
38	50SQ3	Negative-sequence Definite time element 3 Terminal S asserted
38	67SQ3TC	Negative-sequence Directional/Torque Control enable definite time element 3 Terminal S
38	67SQ3	Negative-sequence Directional/Torque controlled element 3 Terminal S picked up
38	67SQ3T	Negative-sequence Directional/Torque controlled element 3 Terminal S timed out
39	50SG1	Residual Definite time element 1 Terminal S asserted
39	67SG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal S
39	67SG1	Residual Directional/Torque controlled element 1 Terminal S picked up
39	67SG1T	Residual Directional/Torque controlled element 1 Terminal S timed out
39	50SG2	Residual Definite time element 2 Terminal S asserted
39	67SG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal S
39	67SG2	Residual Directional/Torque controlled element 2 Terminal S picked up
39	67SG2T	Residual Directional/Torque controlled element 2 Terminal S timed out
40	50SG3	Residual Definite time element 3 Terminal S asserted

Table G.12 **Relay Word Bits: Definite and Directional Overcurrent Elements** (Sheet 2 of 5)

Row	Name	Description
40	67SG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal S
40	67SG3	Residual Directional/Torque controlled element 3 Terminal S picked up
40	67SG3T	Residual Directional/Torque controlled element 3 Terminal S timed out
41	50TP1	Phase Definite time element 1 Terminal T asserted
41	67TP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal T
41	67TP1	Phase Directional/Torque controlled element 1 Terminal T picked up
41	67TP1T	Phase Directional/Torque controlled element 1 Terminal T timed out
41	50TP2	Phase Definite time element 2 Terminal T asserted
41	67TP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal T
41	67TP2	Phase Directional/Torque controlled element 2 Terminal T picked up
41	67TP2T	Phase Directional/Torque controlled element 2 Terminal T timed out
42	50TP3	Phase Definite time element 3 Terminal T asserted
42	67TP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal T
42	67TP3	Phase Directional/Torque controlled element 3 Terminal T picked up
42	67TP3T	Phase Directional/Torque controlled element 3 Terminal T timed out
43	50TQ1	Negative-sequence Definite time element 1 Terminal T asserted
43	67TQ1TC	Negative-sequence Directional/Torque Control enable definite time element 1 Terminal T
43	67TQ1	Negative-sequence Directional/Torque controlled element 1 Terminal T picked up
43	67TQ1T	Negative-sequence Directional/Torque controlled element 1 Terminal T timed out
43	50TQ2	Negative-sequence Definite time element 2 Terminal T asserted
43	67TQ2TC	Negative-sequence Directional/Torque Control enable definite time element 2 Terminal T
43	67TQ2	Negative-sequence Directional/Torque controlled element 2 Terminal T picked up
43	67TQ2T	Negative-sequence Directional/Torque controlled element 2 Terminal T timed out
44	50TQ3	Negative-sequence Definite time element 3 Terminal T asserted
44	67TQ3TC	Negative-sequence Directional/Torque Control enable definite time element 3 Terminal T
44	67TQ3	Negative-sequence Directional/Torque controlled element 3 Terminal T picked up
44	67TQ3T	Negative-sequence Directional/Torque controlled element 3 Terminal T timed out
45	50TG1	Residual Definite time element 1 Terminal T asserted
45	67TG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal T
45	67TG1	Residual Directional/Torque controlled element 1 Terminal T picked up
45	67TG1T	Residual Directional/Torque controlled element 1 Terminal T timed out
45	50TG2	Residual Definite time element 2 Terminal T asserted
45	67TG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal T
45	67TG2	Residual Directional/Torque controlled element 2 Terminal T picked up
45	67TG2T	Residual Directional/Torque controlled element 2 Terminal T timed out
46	50TG3	Residual Definite time element 3 Terminal T asserted
46	67TG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal T
46	67TG3	Residual Directional/Torque controlled element 3 Terminal T picked up
46	67TG3T	Residual Directional/Torque controlled element 3 Terminal T timed out
47	50UP1	Phase Definite time element 1 Terminal U asserted
47	67UP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal U

Table G.12 Relay Word Bits: Definite and Directional Overcurrent Elements (Sheet 3 of 5)

Row	Name	Description
47	67UP1	Phase Directional/Torque controlled element 1 Terminal U picked up
47	67UP1T	Phase Directional/Torque controlled element 1 Terminal U timed out
47	50UP2	Phase Definite time element 2 Terminal U asserted
47	67UP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal U
47	67UP2	Phase Directional/Torque controlled element 2 Terminal U picked up
47	67UP2T	Phase Directional/Torque controlled element 2 Terminal U timed out
48	50UP3	Phase Definite time element 3 Terminal U asserted
48	67UP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal U
48	67UP3	Phase Directional/Torque controlled element 3 Terminal U picked up
48	67UP3T	Phase Directional/Torque controlled element 3 Terminal U timed out
49	50UQ1	Negative-sequence Definite time element 1 Terminal U asserted
49	67UQ1TC	Negative-sequence Directional/Torque Control enable definite time element 1 Terminal U
49	67UQ1	Negative-sequence Directional/Torque controlled element 1 Terminal U picked up
49	67UQ1T	Negative-sequence Directional/Torque controlled element 1 Terminal U timed out
49	50UQ2	Negative-sequence Definite time element 2 Terminal U asserted
49	67UQ2TC	Negative-sequence Directional/Torque Control enable definite time element 2 Terminal U
49	67UQ2	Negative-sequence Directional /Torque controlled element 2 Terminal U picked up
49	67UQ2T	Negative-sequence Directional/Torque controlled element 2 Terminal U timed out
50	50UQ3	Negative-sequence Definite time element 3 Terminal U asserted
50	67UQ3TC	Negative-sequence Directional/Torque Control enable definite time element 3 Terminal U
50	67UQ3	Negative-sequence Directional/Torque controlled element 3 Terminal U picked up
50	67UQ3T	Negative-sequence Directional/Torque controlled element 3 Terminal U timed out
51	50UG1	Residual Definite time element 1 Terminal U asserted
51	67UG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal U
51	67UG1	Residual Directional/Torque controlled element 1 Terminal U picked up
51	67UG1T	Residual Directional/Torque controlled element 1 Terminal U timed out
51	50UG2	Residual Definite time element 2 Terminal U asserted
51	67UG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal U
51	67UG2	Residual Directional/Torque controlled element 2 Terminal U picked up
51	67UG2T	Residual Directional/Torque controlled element 2 Terminal U timed out
52	50UG3	Residual Definite time element 3 Terminal U asserted
52	67UG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal U
52	67UG3	Residual Directional/Torque controlled element 3 Terminal U picked up
52	67UG3T	Residual Directional/Torque controlled element 3 Terminal U timed out
53	50WP1	Phase Definite time element 1 Terminal W asserted
53	67WP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal W
53	67WP1	Phase Directional/Torque controlled element 1 Terminal W picked up
53	67WP1T	Phase Directional/Torque controlled element 1 Terminal W timed out
53	50WP2	Phase Definite time element 2 Terminal W asserted
53	67WP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal W
53	67WP2	Phase Directional/Torque controlled element 2 Terminal W picked up

Table G.12 Relay Word Bits: Definite and Directional Overcurrent Elements (Sheet 4 of 5)

Row	Name	Description
53	67WP2T	Phase Directional/Torque controlled element 2 Terminal W timed out
54	50WP3	Phase Definite time element 3 Terminal W asserted
54	67WP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal W
54	67WP3	Phase Directional/Torque controlled element 3 Terminal W picked up
54	67WP3T	Phase Directional/Torque controlled element 3 Terminal W timed out
55	50WQ1	Negative-sequence Definite time element 1 Terminal W asserted
55	67WQ1TC	Negative-sequence Directional/Torque Control enable definite time element 1 Terminal W
55	67WQ1	Negative-sequence Directional/Torque controlled element 1 Terminal W picked up
55	67WQ1T	Negative-sequence Directional/Torque controlled element 1 Terminal W timed out
55	50WQ2	Negative-sequence Definite time element 2 Terminal W asserted
55	67WQ2TC	Negative-sequence Directional/Torque Control enable definite time element 2 Terminal W
55	67WQ2	Negative-sequence Directional/Torque controlled element 2 Terminal W picked up
55	67WQ2T	Negative-sequence Directional/Torque controlled element 2 Terminal W timed out
56	50WQ3	Negative-sequence Definite time element 3 Terminal W asserted
56	67WQ3TC	Negative-sequence Directional/Torque Control enable definite time element 3 Terminal W
56	67WQ3	Negative-sequence Directional/Torque controlled element 3 Terminal W picked up
56	67WQ3T	Negative-sequence Directional/Torque controlled element 3 Terminal W timed out
57	50WG1	Residual Definite time element 1 Terminal W asserted
57	67WG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal W
57	67WG1	Residual Directional/Torque controlled element 1 Terminal W picked up
57	67WG1T	Residual Directional/Torque controlled element 1 Terminal W timed out
57	50WG2	Residual Definite time element 2 Terminal W asserted
57	67WG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal W
57	67WG2	Residual Directional/Torque controlled element 2 Terminal W picked up
57	67WG2T	Residual Directional/Torque controlled element 2 Terminal W timed out
58	50WG3	Residual Definite time element 3 Terminal W asserted
58	67WG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal W
58	67WG3	Residual Directional/Torque controlled element 3 Terminal W picked up
58	67WG3T	Residual Directional/Torque controlled element 3 Terminal W timed out
59	50XP1	Phase Definite time element 1 Terminal X asserted
59	67XP1TC	Phase Directional/Torque Control enable definite time element 1 Terminal X
59	67XP1	Phase Directional/Torque controlled element 1 Terminal X picked up
59	67XP1T	Phase Directional/Torque controlled element 1 Terminal X timed out
59	50XP2	Phase Definite time element 2 Terminal X asserted
59	67XP2TC	Phase Directional/Torque Control enable definite time element 2 Terminal X
59	67XP2	Phase Directional/Torque controlled element 2 Terminal X picked up
59	67XP2T	Phase Directional/Torque controlled element 2 Terminal X timed out
60	50XP3	Phase Definite time element 3 Terminal X asserted
60	67XP3TC	Phase Directional/Torque Control enable definite time element 3 Terminal X
60	67XP3	Phase Directional/Torque controlled element 3 Terminal X picked up
60	67XP3T	Phase Directional/Torque controlled element 3 Terminal X timed out

Table G.12 Relay Word Bits: Definite and Directional Overcurrent Elements (Sheet 5 of 5)

Row	Name	Description
61	50XQ1	Negative-sequence Definite time element 1 Terminal X asserted
61	67XQ1TC	Negative-sequence Directional/Torque Control enable definite time element 1 Terminal X
61	67XQ1	Negative-sequence Directional/Torque controlled element 1 Terminal X picked up
61	67XQ1T	Negative-sequence Directional/Torque controlled element 1 Terminal X timed out
61	50XQ2	Negative-sequence Definite time element 2 Terminal X asserted
61	67XQ2TC	Negative-sequence Directional/Torque Control enable definite time element 2 Terminal X
61	67XQ2	Negative-sequence Directional/Torque controlled element 2 Terminal X picked up
61	67XQ2T	Negative-sequence Directional/Torque controlled element 2 Terminal X timed out
62	50XQ3	Negative-sequence Definite time element 3 Terminal X asserted
62	67XQ3TC	Negative-sequence Directional/Torque Control enable definite time element 3 Terminal X
62	67XQ3	Negative-sequence Directional/Torque controlled element 3 Terminal X picked up
62	67XQ3T	Negative-sequence Directional/Torque controlled element 3 Terminal X timed out
63	50XG1	Residual Definite time element 1 Terminal X asserted
63	67XG1TC	Residual Directional/Torque Control enable definite time element 1 Terminal X
63	67XG1	Residual Directional/Torque controlled element 1 Terminal X picked up
63	67XG1T	Residual Directional/Torque controlled element 1 Terminal X timed out
63	50XG2	Residual Definite time element 2 Terminal X asserted
63	67XG2TC	Residual Directional/Torque Control enable definite time element 2 Terminal X
63	67XG2	Residual Directional/Torque controlled element 2 Terminal X picked up
63	67XG2T	Residual Directional/Torque controlled element 2 Terminal X timed out
64	50XG3	Residual Definite time element 3 Terminal X asserted
64	67XG3TC	Residual Directional/Torque Control enable definite time element 3 Terminal X
64	67XG3	Residual Directional/Torque controlled element 3 Terminal X picked up
64	67XG3T	Residual Directional/Torque controlled element 3 Terminal X timed out

Table G.13 Relay Word Bits: Inverse Time Overcurrent Elements (Sheet 1 of 3)

Row	Name	Description
65	51TC01	Inverse time element 01 enabled
65	51S01	Inverse time element 01 picked up
65	51T01	Inverse time element 01 timed out
65	51R01	Inverse time element 01 reset
65	51MM01	Inverse time element 01 pickup setting outside of specified limits
65	51TM01	Inverse time element 01 time dial setting outside of specified limits
66	51TC02	Inverse time element 02 enabled
66	51S02	Inverse time element 02 picked up
66	51T02	Inverse time element 02 timed out
66	51R02	Inverse time element 02 reset
66	51MM02	Inverse time element 02 pickup setting outside of specified limits
66	51TM02	Inverse time element 02 time dial setting outside of specified limits
67	51TC03	Inverse time element 03 enabled
67	51S03	Inverse time element 03 picked up

Table G.13 Relay Word Bits: Inverse Time Overcurrent Elements (Sheet 2 of 3)

Row	Name	Description
67	51T03	Inverse time element 03 timed out
67	51R03	Inverse time element 03 reset
67	51MM03	Inverse time element 03 pickup setting outside of specified limits
67	51TM03	Inverse time element 03 time dial setting outside of specified limits
68	51TC04	Inverse time element 04 enabled
68	51S04	Inverse time element 04 picked up
68	51T04	Inverse time element 04 timed out
68	51R04	Inverse time element 04 reset
68	51MM04	Inverse time element 04 pickup setting outside of specified limits
68	51TM04	Inverse time element 04 time dial setting outside of specified limits
69	51TC05	Inverse time element 05 enabled
69	51S05	Inverse time element 05 picked up
69	51T05	Inverse time element 05 timed out
69	51R05	Inverse time element 05 reset
69	51MM05	Inverse time element 05 pickup setting outside of specified limits
69	51TM05	Inverse time element 05 time dial setting outside of specified limits
70	51TC06	Inverse time element 06 enabled
70	51S06	Inverse time element 06 picked up
70	51T06	Inverse time element 06 timed out
70	51R06	Inverse time element 06 reset
70	51MM06	Inverse time element 06 pickup setting outside of specified limits
70	51TM06	Inverse time element 06 time dial setting outside of specified limits
71	51TC07	Inverse time element 07 enabled
71	51S07	Inverse time element 07 picked up
71	51T07	Inverse time element 07 timed out
71	51R07	Inverse time element 07 reset
71	51MM07	Inverse time element 07 pickup setting outside of specified limits
71	51TM07	Inverse time element 07 time dial setting outside of specified limits
72	51TC08	Inverse time element 08 enabled
72	51S08	Inverse time element 08 picked up
72	51T08	Inverse time element 08 timed out
72	51R08	Inverse time element 08 reset
72	51MM08	Inverse time element 08 pickup setting outside of specified limits
72	51TM08	Inverse time element 08 time dial setting outside of specified limits
73	51TC09	Inverse time element 09 enabled
73	51S09	Inverse time element 09 picked up
73	51T09	Inverse time element 09 timed out
73	51R09	Inverse time element 09 reset
73	51MM09	Inverse time element 09 pickup setting outside of specified limits
73	51TM09	Inverse time element 09 time dial setting outside of specified limits
74	51TC10	Inverse time element 10 enabled

Table G.13 Relay Word Bits: Inverse Time Overcurrent Elements (Sheet 3 of 3)

Row	Name	Description
74	51S10	Inverse time element 10 picked up
74	51T10	Inverse time element 10 timed out
74	51R10	Inverse time element 10 reset
74	51MM10	Inverse time element 10 pickup setting outside of specified limits
74	51TM10	Inverse time element 10 time dial setting outside of specified limits

Table G.14 Relay Word Bits: Unbalance Logic

Row	Name	Description
85	46SP	Current unbalance detected Terminal S
85	46ST	Current unbalance Terminal S timed out
85	46TP	Current unbalance detected Terminal T
85	46TT	Current unbalance Terminal T timed out
85	46UP	Current unbalance detected Terminal U
85	46UT	Current unbalance Terminal U timed out
85	46WP	Current unbalance detected Terminal W
85	46WT	Current unbalance Terminal W timed out
86	46XP	Current unbalance detected Terminal X
86	46XT	Current unbalance Terminal X timed out

Table G.15 Relay Word Bits: Under/Over Voltage Elements (Sheet 1 of 2)

Row	Name	Description
87	271P1	Undervoltage element 1 level 1 asserted
87	271P1T	Undervoltage element 1 level 1 timed out
87	271P2	Undervoltage element 1 level 2 asserted
87	27TC1	Undervoltage element 1 Torque Control
87	272P1	Undervoltage element 2 level 1 asserted
87	272P1T	Undervoltage element 2 level 1 timed out
87	272P2	Undervoltage element 2 level 2 asserted
87	27TC2	Undervoltage element 2 Torque Control
88	273P1	Undervoltage element 3 level 1 asserted
88	273P1T	Undervoltage element 3 level 1 timed out
88	273P2	Undervoltage element 3 level 2 asserted
88	27TC3	Undervoltage element 3 Torque Control
88	274P1	Undervoltage element 4 level 1 asserted
88	274P1T	Undervoltage element 4 level 1 timed out
88	274P2	Undervoltage element 4 level 2 asserted
88	27TC4	Undervoltage element 4 Torque Control
89	275P1	Undervoltage element 5 level 1 asserted
89	275P1T	Undervoltage element 5 level 1 timed out
89	275P2	Undervoltage element 5 level 2 asserted
89	27TC5	Undervoltage element 5 Torque Control

Table G.15 **Relay Word Bits: Under/Over Voltage Elements** (Sheet 2 of 2)

Row	Name	Description
90	591P1	Overvoltage element 1 level 1 asserted
90	591P1T	Overvoltage element 1 level 1 timed out
90	591P2	Overvoltage element 1 level 2 asserted
90	59TC1	Overvoltage element 1 Torque Control
90	592P1	Overvoltage element 2 level 1 asserted
90	592P1T	Overvoltage element 2 level 1 timed out
90	592P2	Overvoltage element 2 level 2 asserted
90	59TC2	Overvoltage element 2 Torque Control
91	593P1	Overvoltage element 3 level 1 asserted
91	593P1T	Overvoltage element 3 level 1 timed out
91	593P2	Overvoltage element 3 level 2 asserted
91	59TC3	Overvoltage element 3 Torque Control
91	594P1	Overvoltage element 4 level 1 asserted
91	594P1T	Overvoltage element 4 level 1 timed out
91	594P2	Overvoltage element 4 level 2 asserted
91	59TC4	Overvoltage element 4 Torque Control
92	595P1	Overvoltage element 5 level 1 asserted
92	595P1T	Overvoltage element 5 level 1 timed out
92	595P2	Overvoltage element 5 level 2 asserted
92	59TC5	Overvoltage element 5 Torque Control

Table G.16 **Relay Word Bits: Under/Over Power Elements** (Sheet 1 of 2)

Row	Name	Description
93	E32OP01	Overpower element 01 enabled
93	32OP01	Overpower element 01 picked up
93	32OPT01	Overpower element 01 timed out
93	E32OP02	Overpower element 02 enabled
93	32OP02	Overpower element 02 picked up
93	32OPT02	Overpower element 02 timed out
94	E32OP03	Overpower element 03 enabled
94	32OP03	Overpower element 03 picked up
94	32OPT03	Overpower element 03 timed out
94	E32OP04	Overpower element 04 enabled
94	32OP04	Overpower element 04 picked up
94	32OPT04	Overpower element 04 timed out
95	E32OP05	Overpower element 05 enabled
95	32OP05	Overpower element 05 picked up
95	32OPT05	Overpower element 05 timed out
95	E32OP06	Overpower element 06 enabled
95	32OP06	Overpower element 06 picked up
95	32OPT06	Overpower element 06 timed out

Table G.16 Relay Word Bits: Under/Over Power Elements (Sheet 2 of 2)

Row	Name	Description
96	E32OP07	Overpower element 07 enabled
96	32OP07	Overpower element 07 picked up
96	32OPT07	Overpower element 07 timed out
96	E32OP08	Overpower element 08 enabled
96	32OP08	Overpower element 08 picked up
96	32OPT08	Overpower element 08 timed out
97	E32OP09	Overpower element 09 enabled
97	32OP09	Overpower element 09 picked up
97	32OPT09	Overpower element 09 timed out
97	E32OP10	Overpower element 10 enabled
97	32OP10	Overpower element 10 picked up
97	32OPT10	Overpower element 10 timed out
98	E32UP01	Underpower element 01 enabled
98	32UP01	Underpower element 01 picked up
98	32UPT01	Underpower element 01 timed out
98	E32UP02	Underpower element 02 enabled
98	32UP02	Underpower element 02 picked up
98	32UPT02	Underpower element 02 timed out
99	E32UP03	Underpower element 03 enabled
99	32UP03	Underpower element 03 picked up

Table G.17 Relay Word Bits: Under/Over Power Elements (Sheet 1 of 2)

Row	Name	Description
99	32UPT03	Underpower element 03 timed out
99	E32UP04	Underpower element 04 enabled
99	32UP04	Underpower element 04 picked up
99	32UPT04	Underpower element 04 timed out
100	E32UP05	Underpower element 05 enabled
100	32UP05	Underpower element 05 picked up
100	32UPT05	Underpower element 05 timed out
100	E32UP06	Underpower element 06 enabled
100	32UP06	Underpower element 06 picked up
100	32UPT06	Underpower element 06 timed out
101	E32UP07	Underpower element 07 enabled
101	32UP07	Underpower element 07 picked up
101	32UPT07	Underpower element 07 timed out
101	E32UP08	Underpower element 08 enabled
101	32UP08	Underpower element 08 picked up
101	32UPT08	Underpower element 08 timed out
102	E32UP09	Underpower element 09 enabled
102	32UP09	Underpower element 09 picked up

Table G.17 Relay Word Bits: Under/Over Power Elements (Sheet 2 of 2)

Row	Name	Description
102	32UPT09	Underpower element 09 timed out
102	E32UP10	Underpower element 10 enabled
102	32UP10	Underpower element 10 picked up
102	32UPT10	Underpower element 10 timed out

Table G.18 Relay Word Bits: Frequency Elements

Row	Name	Description
103	81D1OVR	Definite time Over Frequency level 1
103	81D1T	Definite time Over/Under Frequency Element Delay for level 1
103	81D1UDR	Definite time Under Frequency level 1
103	81D1	Definite time frequency element picked up level 1
103	81D2OVR	Definite time Over Frequency level 2
103	81D2T	Definite time Over/Under Frequency Element Delay for level 2
103	81D2UDR	Definite time Under Frequency level 2
103	81D2	Definite time frequency element picked up level 2
104	81D3OVR	Definite time Over Frequency level 3
104	81D3T	Definite time Over/Under Frequency Element Delay for level 3
104	81D3UDR	Definite time Under Frequency level 3
104	81D3	Definite time frequency element picked up level 3
104	81D4OVR	Definite time Over Frequency level 4
104	81D4T	Definite time Over/Under Frequency Element Delay for level 4
104	81D4UDR	Definite time Under Frequency level 4
104	81D4	Definite time frequency element picked up level 4
105	81D5OVR	Definite time Over Frequency level 5
105	81D5T	Definite time Over/Under Frequency Element Delay for level 5
105	81D5UDR	Definite time Under Frequency level 5
105	81D5	Definite time frequency element picked up level 5
105	81D6OVR	Definite time Over Frequency level 6
105	81D6T	Definite time Over/Under Frequency Element Delay for level 6
105	81D6UDR	Definite time Under Frequency level 6
105	81D6	Definite time frequency element picked up level 6
106	27B81	Frequency Elements blocked due to undervoltage

Table G.19 Relay Word Bits: Frequency Calculation

Row	Name	Description
107	FREQOK	Frequency Tracking OK
107	FREQFZ	Frequency Calculation Frozen

Table G.20 Relay Word Bits: Volts/Hertz

Row	Name	Description
108	24D1	Volts/Hertz Element level 1 asserted
108	24D1T	Volts/Hertz level 1 timed out
108	24D2T	Volts/Hertz level 2 timed out
108	24D2R	Volts/Hertz elements Level 2 reset
108	24TC	Volts/Hertz predefined element torque control
109	24U1T	User-defined Volts/Hertz curve 1 timed out
109	24U1R	User-defined Volts/Hertz curve 1 reset
109	24U1TC	User-defined Volts/Hertz curve 1 torque control
109	24U2T	User-defined Volts/Hertz curve 2 timed out
109	24U2R	User-defined Volts/Hertz curve 2 reset
109	24U2TC	User-defined Volts/Hertz curve 1 torque control

Table G.21 Relay Word Bits: Breaker Trip and Close Logic Elements (Sheet 1 of 2)

Row	Name	Description
110	TRXFMR	Transformer trip equation asserted
110	TRS	Terminal S trip equation asserted
110	TRT	Terminal T trip equation asserted
110	TRU	Terminal U trip equation asserted
110	TRW	Terminal W trip equation asserted
110	TRX	Terminal X trip equation asserted
111	TRPXFMR	Transformer trip output asserted
111	TRIPS	Terminal S trip output asserted
111	TRIPT	Terminal T trip output asserted
111	TRIPU	Terminal U trip output asserted
111	TRIPW	Terminal W trip output asserted
111	TRIPX	Terminal X trip output asserted
111	TRIP	Transformer or Terminal Trip signal asserted
112	ULTXFMR	Unlatch transformer trip
112	ULTRS	Unlatch Terminal S trip
112	ULTRT	Unlatch Terminal T trip
112	ULTRU	Unlatch Terminal U trip
112	ULTRW	Unlatch Terminal W trip
112	ULTRX	Unlatch Terminal X trip
113	CLS	Close breaker Terminal S equation
113	CLT	Close breaker Terminal T equation
113	CLU	Close breaker Terminal U equation
113	CLW	Close breaker Terminal W equation
113	CLX	Close breaker Terminal X equation
114	CLSS	Close breaker Terminal S output
114	CLST	Close breaker Terminal T output
114	CLSU	Close breaker Terminal U output

Table G.21 Relay Word Bits: Breaker Trip and Close Logic Elements (Sheet 2 of 2)

Row	Name	Description
114	CLSW	Close breaker Terminal W output
114	CLSX	Close breaker Terminal X output
115	ULCLS	Unlatch close Terminal S
115	ULCLT	Unlatch close Terminal T
115	ULCLU	Unlatch close Terminal U
115	ULCLW	Unlatch close Terminal W
115	ULCLX	Unlatch close Terminal X

Table G.22 Relay Word Bits: Open-Phase Detector

Row	Name	Description
116	OPHAS	Phase A Terminal S open
116	OPHBS	Phase B Terminal S open
116	OPHCS	Phase C Terminal S open
116	OPHS	Terminal S open
116	OPHAT	Phase A Terminal T open
116	OPHBT	Phase B Terminal T open
116	OPHCT	Phase C Terminal T open
116	OPHT	Terminal T open
117	OPHAU	Phase A Terminal U open
117	OPHBU	Phase B Terminal U open
117	OPHCU	Phase C Terminal U open
117	OPHU	Terminal U open
117	OPHAW	Phase A Terminal W open
117	OPHBW	Phase B Terminal W open
117	OPHCW	Phase C Terminal W open
117	OPHW	Terminal W open
118	OPHAX	Phase A Terminal X open
118	OPHBX	Phase B Terminal X open
118	OPHCX	Phase C Terminal X open
118	OPHX	Terminal X open

Table G.23 Relay Word Bits: Loss-of-Potential and Polarizing Voltage

Row	Name	Description
119	VALARMV	Voltage alarm Terminal V
119	LOPV	Loss of potential terminal V
119	VALARMZ	Voltage alarm Terminal Z
119	LOPZ	Loss of potential terminal Z
119	VPOLV	Polarizing voltage available terminal V
119	VPOLZ	Polarizing voltage available terminal Z

Table G.24 Relay Word Bits: Breaker Failure (Sheet 1 of 2)

Row	Name	Description
120	50FS	Phase or Neutral current above breaker failure pickup for Terminal S
120	BFITS	Breaker Failure Timer timed out Terminal S
120	RTS	Retrip Timer timed out/Retrip command issued Terminal S
120	EBFITS	Externally initiated breaker failure timer timed out Terminal S
120	BFIS	Breaker Failure initiated Terminal S
120	EXBFS	External breaker failure input initiated Terminal S
120	ATBFIS	Alternate breaker failure initiated Terminal S
120	ATBFTS	Alternate breaker failure timer timed out Terminal S
121	BFISPTS	Breaker Failure Seal in timer timed out Terminal S
121	ABFITS	Alternate breaker Failure Terminal S
121	ENINBFS	Neutral/residual breaker failure function enabled Terminal S
121	IASBF	A-Phase current above threshold Terminal S
121	IBSBF	B-Phase current above threshold Terminal S
121	ICSBF	C-Phase current above threshold Terminal S
121	INSBF	Neutral current above threshold Terminal S
121	FBFS	Breaker Failure asserted/initiated Terminal S
122	50FT	Phase or Neutral current above breaker failure pickup for Terminal T
122	BFITT	Breaker Failure Timer timed out Terminal T
122	RTT	Retrip Timer timed out/Retrip command issued Terminal T
122	EBFITT	Externally initiated breaker failure timer timed out Terminal T
122	BFIT	Breaker Failure initiated Terminal T
122	EXBFT	External breaker failure input initiated Terminal T
122	ATBFIT	Alternate breaker failure initiated Terminal T
122	ATBFTT	Alternate breaker failure timer timed out Terminal T
123	BFISPTT	Breaker Failure Seal in timer timed out Terminal T
123	ABFITT	Alternate breaker Failure Terminal T
123	ENINBFT	Neutral/residual breaker failure function enabled Terminal T
123	IATBF	A-Phase current above threshold Terminal T
123	IBTBF	B-Phase current above threshold Terminal T
123	ICTBF	C-Phase current above threshold Terminal T
123	INTBF	Neutral/Residual current exceeds pickup threshold Terminal T
123	FBFT	Breaker Failure asserted/initiated Terminal T
124	50FU	Phase or Neutral current above breaker failure pickup for Terminal U
124	BFITU	Breaker Failure Timer timed out Terminal U
124	RTU	Retrip Timer timed out/Retrip command issued Terminal U
124	EBFITU	Externally initiated breaker failure timer timed out Terminal U
124	BFIU	Breaker Failure initiated Terminal U
124	EXBFU	External breaker failure input initiated Terminal U
124	ATBFIU	Alternate breaker failure initiated Terminal U
124	ATBFTU	Alternate breaker failure timer timed out Terminal U
125	BFISPTU	Breaker Failure Seal in timer timed out Terminal U

Table G.24 Relay Word Bits: Breaker Failure (Sheet 2 of 2)

Row	Name	Description
125	ABFITU	Alternate breaker Failure Terminal U
125	ENINBFU	Neutral/residual breaker failure function enabled Terminal U
125	IAUBF	A-Phase current above threshold Terminal U
125	IBUBF	B-Phase current above threshold Terminal U
125	ICUBF	C-Phase current above threshold Terminal U
125	INUBF	Neutral/Residual current exceeds pickup threshold Terminal U
125	FBFU	Breaker Failure asserted/initiated Terminal U
126	50FW	Phase or Neutral current above breaker failure pickup for Terminal W
126	BFITW	Breaker Failure Timer timed out Terminal W
126	RTW	Retrip Timer timed out/ Retrip command issued Terminal W
126	EBFITW	Externally initiated breaker failure timer timed out Terminal W
126	BFIW	Breaker Failure initiated Terminal W
126	EXBFW	External breaker failure input initiated Terminal W
126	ATBFIW	Alternate breaker failure initiated Terminal W
126	ATBFTW	Alternate breaker failure timer timed out Terminal W
127	BFISPTW	Breaker Failure Seal in timer timed out Terminal W
127	ABFITW	Alternate breaker Failure Terminal W
127	ENINBFW	Neutral/residual breaker failure function enabled Terminal W
127	IAWBF	A-Phase current above threshold Terminal W
127	IBWBF	B-Phase current above threshold Terminal W
127	ICWBF	C-Phase current above threshold Terminal W
127	INWBF	Neutral/Residual current exceeds pickup threshold Terminal W
127	FBFW	Breaker Failure asserted/initiated Terminal W
128	50FX	Phase or Neutral current above breaker failure pickup for Terminal X
128	BFITX	Breaker Failure Timer timed out Terminal X
128	RTX	Retrip Timer timed out/Retrip command issued Terminal X
128	EBFITX	Externally initiated breaker failure timer timed out Terminal X
128	BFIX	Breaker Failure initiated Terminal X
128	EXBFX	External breaker failure input initiated Terminal X
128	ATBFIX	Alternate breaker failure initiated Terminal X
128	ATBFTX	Alternate breaker failure timer timed out Terminal X
129	BFISPTX	Breaker Failure Seal in timer timed out Terminal X
129	ABFITX	Alternate breaker Failure Terminal X
129	ENINBFX	Neutral/residual breaker failure function enabled Terminal X
129	IAXBF	A-Phase current above threshold Terminal X
129	IBXBF	B-Phase current above threshold Terminal X
129	ICXBF	C-Phase current above threshold Terminal X
129	INXBF	Neutral/Residual current exceeds pickup threshold Terminal X
129	FBFX	Breaker Failure asserted/initiated Terminal X

Table G.25 Relay Word Bits: 52 Status

Row	Name	Description
130	52CLS	Breaker Closed Terminal S
130	52ALS	Breaker Alarm Terminal S
130	52CLT	Breaker Closed Terminal T
130	52ALT	Breaker Alarm Terminal T
130	52CLU	Breaker Closed Terminal U
130	52ALU	Breaker Alarm Terminal U
130	52CLW	Breaker Closed Terminal W
130	52ALW	Breaker Alarm Terminal W
131	52CLX	Breaker Closed Terminal X
131	52ALX	Breaker Alarm Terminal X

Table G.26 Relay Word Bits: 89 Disconnect Switch Status

Row	Name	Description
132	89CL1–89CL8	Disconnect 1–8 Closed
133	89CLBZ1–89CLBZ8	Disconnect 1–8 Buszone contact closed
134	89OPN1–89OPN8	Disconnect 1–8 Open
135	89OIP1–89OIP8	Disconnect 1–8 Operation in progress
136	89AL1–89AL8	Disconnect 1–8 Alarm
137	89OIP	Disconnect operation in progress
137	89AL	Disconnect Alarm
138	89CLS1–89CLS8	Disconnect 1–8 Close Command
139	89CIMD1–89CIMD8	Disconnect 1–8 Close Immobility Timer timed out
140	89CSID1–89CSID8	Disconnect 1–8 Close Seal-in Timer timed out
141	89OPEN1–89OPEN8	Disconnect 1–8 Open Command
142	89OIMD1–89OIMD8	Disconnect 1–8 Open Immobility Timer timed out
143	89OSID1–89OSID8	Disconnect 1–8 Open Seal-in Timer timed out

Table G.27 Relay Word Bits: Breaker Monitor (Sheet 1 of 2)

Row	Name	Description
144	EBSMON	Breaker Monitoring Terminal S enabled
144	BSBCWAL	Breaker Contact Wear alarm Breaker S
144	BSESOAL	Slow Electrical Operate alarm Breaker S
144	BSBITAL	Inactivity Time Alarm Breaker S
144	BSKAIAL	Interrupted rms current alarm Breaker S
144	BSMSOAL	Mechanical Slow Operation Alarm Breaker S
144	BSMRTAL	Motor run time alarm Breaker S
145	EBTMON	Breaker Monitoring Terminal T enabled
145	BTBCWAL	Breaker Contact Wear alarm Breaker T
145	BTESOAL	Slow Electrical Operation Alarm Breaker T
145	BTBITAL	Inactivity Time Alarm Breaker T
145	BTKAIAL	Interrupted rms current alarm Breaker T

Table G.27 **Relay Word Bits: Breaker Monitor** (Sheet 2 of 2)

Row	Name	Description
145	BTMSOAL	Mechanical Slow Operation Alarm Breaker T
145	BTMRTAL	Motor run time alarm Breaker T
146	EBUMON	Breaker Monitoring Terminal U enabled
146	BUBCWAL	Breaker Contact Wear alarm Breaker U
146	BUESOAL	Slow Electrical Operation Alarm Breaker U
146	BUBITAL	Inactivity Time Alarm Breaker U
146	BUKAIAL	Interrupted rms current alarm Breaker U
146	BUMSOAL	Mechanical Slow Operation Alarm Breaker U
146	BUMRTAL	Motor run time alarm Breaker U
147	EBWMON	Breaker Monitoring Terminal W enabled
147	BWBCWAL	Breaker Contact Wear alarm Breaker W
147	BWESOAL	Slow Electrical Operation Alarm Breaker W
147	BWBITAL	Inactivity Time Alarm Breaker W
147	BWKAIAL	Interrupted rms current alarm Breaker W
147	BWMSOAL	Mechanical Slow Operation Alarm Breaker W
147	BWMRTAL	Motor run time alarm Breaker W
148	EBXMON	Breaker Monitoring Terminal X enabled
148	BXBCWAL	Breaker Contact Wear alarm Breaker X
148	BXESOAL	Slow Electrical Operation Alarm Breaker X
148	BXBITAL	Inactivity Time Alarm Breaker X
148	BXKAIAL	Interrupted rms current alarm Breaker X
148	BXMSOAL	Mechanical Slow Operation Alarm Breaker X
148	BXMRTAL	Motor run time alarm Breaker X

Table G.28 **Relay Word Bits: Thermal Element** (Sheet 1 of 2)

Row	Name	Description
149	TO1_1	Transformer 1 Top-oil temperature alarm level 1
149	TO2_1	Transformer 2 Top-oil temperature alarm level 1
149	TO3_1	Transformer 3 Top-oil temperature alarm level 1
149	TO1	Top-oil temperature Alarm level 1
149	TO1_2	Transformer 1 Top-oil temperature alarm level 2
149	TO2_2	Transformer 2 Top-oil temperature alarm level 2
149	TO3_2	Transformer 3 Top-oil temperature alarm level 2
149	TO2	Top-oil Temperature Alarm level 2
150	HS1_1	Transformer 1 hot spot temperature Alarm Level 1
150	HS2_1	Transformer 2 hot spot temperature Alarm Level 1
150	HS3_1	Transformer 3 hot spot temperature Alarm Level 1
150	HS1	Hot Spot alarm Level 1
150	HS1_2	Transformer 1 hot spot temperature Alarm Level 2
150	HS2_2	Transformer 2 hot spot temperature Alarm Level 2
150	HS3_2	Transformer 3 hot spot temperature Alarm Level 2

Table G.28 Relay Word Bits: Thermal Element (Sheet 2 of 2)

Row	Name	Description
150	HS2	Hot Spot alarm Level 2
151	FAA1_1	Transformer 1 aging insulation acceleration factor alarm Level 1
151	FAA2_1	Transformer 2 aging insulation acceleration factor alarm Level 1
151	FAA3_1	Transformer 3 aging insulation acceleration factor alarm Level 1
151	FAA1	aging insulation acceleration factor alarm level 1
151	FAA1_2	Transformer 1 aging insulation acceleration factor alarm Level 2
151	FAA2_2	Transformer 2 aging insulation acceleration factor alarm Level 2
151	FAA3_2	Transformer 3 aging insulation acceleration factor alarm Level 2
151	FAA2	Aging insulation acceleration factor alarm level 2
152	RLL_1	Transformer 1 rate of loss of life alarm
152	RLL_2	Transformer 2 rate of loss of life alarm
152	RLL_3	Transformer 3 rate of loss of life alarm
152	RLL	Rate of loss of life alarm
152	TLL_1	Transformer 1 total loss of life alarm
152	TLL_2	Transformer 2 total loss of life alarm
152	TLL_3	Transformer 3 total loss of life alarm
152	TLL	Total loss of life alarm
153	CSE_1	Transformer 1 Cooling stage efficiency alarm
153	CSE_2	Transformer 2 Cooling stage efficiency alarm
153	CSE_3	Transformer 3 Cooling stage efficiency alarm
153	CSE	Cooling stage efficiency alarm
153	CSCM_1	Transformer 1 Cooling coefficient or measurement alarm
153	CSCM_2	Transformer 2 Cooling coefficient or measurement alarm
153	CSCM_3	Transformer 3 Cooling coefficient or measurement alarm
153	CSCM	Cooling coefficient or measurement alarm
154	CSALRM	Cooling stage determination alarm
154	MAMB_OK	Ambient temperature measurement RTD healthy
154	MTO1_OK	Transformer 1 top-oil temperature measurement RTD healthy
154	MTO2_OK	Transformer 2 top-oil temperature measurement RTD healthy
154	MTO3_OK	Transformer 3 top-oil temperature measurement RTD healthy
155	TRDE	Transformer de-energize
155	T1CS2	Transformer 1 Cooling Stage 2
155	T1CS3	Transformer 1 Cooling Stage 3
155	T2CS2	Transformer 2 Cooling Stage 2
155	T2CS3	Transformer 2 Cooling Stage 3
155	T3CS2	Transformer 3 Cooling Stage 2
155	T3CS3	Transformer 3 Cooling Stage 3

Table G.29 Relay Word Bits: RTD Status Bits

Row	Name	Description
156	RTD01OK–RTD08OK	RTD01–RTD08 Healthy
157	RTD09OK–RTD12OK	RTD09–RTD12 Healthy
158	RTD01SC–RTD08SC	RTD01–RTD08 Short circuited
159	RTD09SC–RTD12SC	RTD09–RTD12 Short circuited
160	RTD01OC–RTD08OC	RTD01–RTD08 Open circuited
161	RTD09OC–RTD12OC	RTD09–RTD12 Open circuited
162	RTDCOMF	SEL-2600 Communication Failure
162	RTDFL	SEL-2600 RAM failure

Table G.30 Relay Word Bits: Through Fault Monitor

Row	Name	Description
163	ETHRFLT	Through Fault Element Enabled
163	TFLTALA	Through fault alarm phase A
163	TFLTALB	Through fault alarm phase B
163	TFLTALC	Through fault alarm phase C

Table G.31 Relay Word Bits: Battery Monitor

Row	Name	Description
164	DC1F	DC Channel 1 Failed
164	DC1W	DC Channel 1 Warning
164	DC1G	DC Channel 1 Ground Fault detected
164	DC1R	DC Channel 1 Excess Ripples detected

Table G.32 Relay Word Bits: Demand Metering

Row	Name	Description
165	EDM01–EDM04	Demand Metering element 01–04 enabled
165	DMP01–DMP04	Demand Metering element 01–04 asserted
166	EDM05–EDM08	Demand Metering element 05–08 enabled
166	DMP05–DMP08	Demand Metering element 05–08 asserted
167	EDM09	Demand Metering element 09 enabled
167	DMP09	Demand Metering element 09 asserted
167	EDM10	Demand Metering element 10 enabled
167	DMP10	Demand Metering element 10 asserted

Table G.33 Relay Word Bits: 52 Open and Close; 89 Open and Close (Sheet 1 of 2)

Row	Name	Description
168	CCW	Breaker Close Command Terminal W
168	OCW	Breaker Open Command Terminal W
168	CCU	Breaker Close Command Terminal U
168	OCU	Breaker Open Command Terminal U
168	CCT	Breaker Close Command Terminal T

Table G.33 Relay Word Bits: 52 Open and Close; 89 Open and Close (Sheet 2 of 2)

Row	Name	Description
168	OCT	Breaker Open Command Terminal T
168	CCS	Breaker Close Command Terminal S
168	OCS	Breaker Open Command Terminal S
169	CCX	Breaker Close Command Terminal X
169	OCX	Breaker Open Command Terminal X
170	89CC1–89CC4	Disconnect/Isolator 1–4 close command
170	89OC1–89OC4	Disconnect/Isolator 1–4 open command
171	89CC5–89CC8	Disconnect/Isolator 5–8 close command
171	89OC5–89OC8	Disconnect/Isolator 5–8 open command

Table G.34 Relay Word Bits: Local Bits

Row	Name	Description
172	LB01–LB08	Local Bit 01–Local Bit 08 asserted
173	LB09–LB16	Local Bit 09–Local Bit 16 asserted
174	LB17–LB24	Local Bit 17–Local Bit 24 asserted
175	LB25–LB32	Local Bit 25–Local Bit 32 asserted

Table G.35 Relay Word Bits: Local Control

Row	Name	Description
176	LB_SP01–LB_SP08	Local Bit 01–Local Bit 08 Supervision enabled
177	LB_SP09–LB_SP16	Local Bit 09–Local Bit 16 Supervision enabled
178	LB_SP17–LB_SP24	Local Bit 17–Local Bit 24 Supervision enabled
179	LB_SP25–LB_SP32	Local Bit 25–Local Bit 32 Supervision enabled
180	LB_DP01–LB_DP08	Local Bit 01–Local Bit 08 Status Display enabled
181	LB_DP09–LB_DP16	Local Bit 09–Local Bit 16 Status Display enabled
182	LB_DP17–LB_DP24	Local Bit 17–Local Bit 24 Status Display enabled
183	LB_DP25–LB_DP32	Local Bit 25–Local Bit 32 Status Display enabled

Table G.36 Relay Word Bits: Remote Bits

Row	Name	Description
184	RB25–RB32	Remote Bit 25–Remote Bit 32 asserted
185	RB17–RB24	Remote Bit 17–Remote Bit 24 asserted
186	RB09–RB16	Remote Bit 09–Remote Bit 16 asserted
187	RB01–RB08	Remote Bit 01–Remote Bit 08 asserted

Table G.37 Relay Word Bits: Setting Group Bits

Row	Name	Description
188	SG1–SG6	Setting Group 1–6 are active
188	CHSG	Settings Group Changed

Table G.38 Relay Word Bits: Inputs

Row	Name	Description
192	IN101–IN107	Input 101–Input 107 asserted
196	IN201–IN208	Input 201–Input 208 asserted
197	IN209–IN216	Input 209–Input 216 asserted
198	IN217–IN224	Input 217–Input 224 asserted
200	IN301–IN308	Input 301–Input 308 asserted
201	IN309–IN316	Input 309–Input 316 asserted
202	IN317–IN324	Input 317–Input 324 asserted

Table G.39 Relay Word Bits: Protection SELOGIC (Variables)

Row	Name	Description
204	PSV01–PSV08	Protection SELOGIC Variable 01–08 asserted
205	PSV09–PSV16	Protection SELOGIC Variable 09–16 asserted
206	PSV17–PSV24	Protection SELOGIC Variable17– 24 asserted
207	PSV25–PSV32	Protection SELOGIC Variable 25– 32 asserted
208	PSV33–PSV40	Protection SELOGIC Variable 33–40 asserted
209	PSV41–PSV48	Protection SELOGIC Variable 41–48 asserted
210	PSV49–PSV56	Protection SELOGIC Variable 49–56 asserted
211	PSV57–PSV64	Protection SELOGIC Variable 57–64 asserted

Table G.40 Relay Word Bits: Protection SELOGIC (Latches)

Row	Name	Description
212	PLT01–PLT08	Protection SELOGIC Latch 01–08 asserted
213	PLT09–PLT16	Protection SELOGIC Latch 09–16 asserted
214	PLT17–PLT24	Protection SELOGIC Latch 17–24 asserted
215	PLT25–PLT32	Protection SELOGIC Latch 25–32 asserted

Table G.41 Relay Word Bits: Protection SELOGIC (Conditioning Timers)

Row	Name	Description
216	PCT01Q–PCT08Q	Protection SELOGIC Conditioning Timer01– 08 asserted
217	PCT09Q–PCT16Q	Protection SELOGIC Conditioning Timer 09–16 asserted
218	PCT17Q–PCT24Q	Protection SELOGIC Conditioning Timer 17–24 asserted
219	PCT25Q–PCT32Q	Protection SELOGIC Conditioning Timer 25–32 asserted

Table G.42 Relay Word Bits: Protection SELOGIC (Sequencing Timers) (Sheet 1 of 2)

Row	Name	Description
220	PST01Q–PST08Q	Protection SELOGIC Sequencing Timer 01–08 asserted
221	PST09Q–PST16Q	Protection SELOGIC Sequencing Timer 09–16 asserted
222	PST17Q–PST24Q	Protection SELOGIC Sequencing Timer 17–24 asserted
223	PST25Q–PST32Q	Protection SELOGIC Sequencing Timer 25–32 asserted
224	PST01R–PST08R	Protection SELOGIC Sequencing Timer 01–08 reset
225	PST09R–PST16R	Protection SELOGIC Sequencing Timer 09–16 reset

Table G.42 Relay Word Bits: Protection SELOGIC (Sequencing Timers) (Sheet 2 of 2)

Row	Name	Description
226	PST17R–PST24R	Protection SELOGIC Sequencing Timer 17–24 reset
227	PST25R–PST32R	Protection SELOGIC Sequencing Timer 25–32 reset

Table G.43 Relay Word Bits: Protection SELOGIC (Counters)

Row	Name	Description
228	PCN01Q–PCN08Q	Protection SELOGIC Counter 01–08 asserted
229	PCN09Q–PCN16Q	Protection SELOGIC Counter 09–16 asserted
230	PCN17Q–PCN24Q	Protection SELOGIC Counter 17–24 asserted
231	PCN25Q–PCN32Q	Protection SELOGIC Counter 25–32 asserted
232	PCN01R–PCN08R	Protection SELOGIC Counter 01–08 reset
233	PCN09R–PCN16R	Protection SELOGIC Counter 09–16 reset
234	PCN17R–PCN24R	Protection SELOGIC Counter 17–24 reset
235	PCN25R–PCN32R	Protection SELOGIC Counter 25–32 reset

Table G.44 Relay Word Bits: Automation SELOGIC (Variables) (Sheet 1 of 2)

Row	Name	Description
236	ASV001–ASV008	Automation SELOGIC Variable 001–008 asserted
237	ASV009–ASV016	Automation SELOGIC Variable 009–016 asserted
238	ASV017–ASV024	Automation SELOGIC Variable 017–024 asserted
239	ASV025–ASV032	Automation SELOGIC Variable 025–032 asserted
240	ASV033–ASV040	Automation SELOGIC Variable 033–040 asserted
241	ASV041–ASV048	Automation SELOGIC Variable 041–048 asserted
242	ASV049–ASV056	Automation SELOGIC Variable 049–056 asserted
243	ASV057–ASV064	Automation SELOGIC Variable 057–064 asserted
244	ASV065–ASV072	Automation SELOGIC Variable 065–072 asserted
245	ASV073–ASV080	Automation SELOGIC Variable 073–080 asserted
246	ASV081–ASV088	Automation SELOGIC Variable 081–088 asserted
247	ASV089–ASV096	Automation SELOGIC Variable 089–096 asserted
248	ASV097–ASV104	Automation SELOGIC Variable 097–104 asserted
249	ASV105–ASV112	Automation SELOGIC Variable 105–112 asserted
250	ASV113–ASV120	Automation SELOGIC Variable 113–120 asserted
251	ASV121–ASV128	Automation SELOGIC Variable 121–128 asserted
252	ASV129–ASV136	Automation SELOGIC Variable 129–136 asserted
253	ASV137–ASV144	Automation SELOGIC Variable 137–144 asserted
254	ASV145–ASV152	Automation SELOGIC Variable 145–152 asserted
255	ASV153–ASV160	Automation SELOGIC Variable 153–160 asserted
256	ASV161–ASV168	Automation SELOGIC Variable 161–168 asserted
257	ASV169–ASV176	Automation SELOGIC Variable 169–176 asserted
258	ASV177–ASV184	Automation SELOGIC Variable 177–184 asserted
259	ASV185–ASV192	Automation SELOGIC Variable 185–192 asserted
260	ASV193–ASV200	Automation SELOGIC Variable 193–200 asserted

Table G.44 Relay Word Bits: Automation SELOGIC (Variables) (Sheet 2 of 2)

Row	Name	Description
261	ASV201–ASV208	Automation SELOGIC Variable 201–208 asserted
262	ASV209–ASV216	Automation SELOGIC Variable 209–216 asserted
263	ASV217–ASV224	Automation SELOGIC Variable 217–224 asserted
264	ASV225–ASV232	Automation SELOGIC Variable 225–232 asserted
265	ASV233–ASV240	Automation SELOGIC Variable 233–240 asserted
266	ASV241–ASV248	Automation SELOGIC Variable 241–248 asserted
267	ASV249–ASV256	Automation SELOGIC Variable 249–256 asserted

Table G.45 Relay Word Bits: Automation SELOGIC (Latches)

Row	Name	Description
268	ALT01–ALT08	Automation SELOGIC Latch 01–08 asserted
269	ALT09–ALT16	Automation SELOGIC Latch 09–16 asserted
270	ALT17–ALT24	Automation SELOGIC Latch 17–24 asserted
271	ALT25–ALT32	Automation SELOGIC Latch 25–32 asserted

Table G.46 Relay Word Bits: Automation SELOGIC (Sequencing Timers)

Row	Name	Description
272	AST01Q–AST08Q	Automation SELOGIC Sequencing Timer 01–08 asserted
273	AST09Q–AST16Q	Automation SELOGIC Sequencing Timer 09–16 asserted
274	AST17Q–AST24Q	Automation SELOGIC Sequencing Timer 17–24 asserted
275	AST25Q–AST32Q	Automation SELOGIC Sequencing Timer 25–32 asserted
276	AST01R–AST08R	Automation SELOGIC Sequencing Timer 01–08 reset
277	AST09R–AST16R	Automation SELOGIC Sequencing Timer 09–16 reset
278	AST17R–AST24R	Automation SELOGIC Sequencing Timer 17–24 reset
279	AST25R–AST32R	Automation SELOGIC Sequencing Timer 25–32 reset

Table G.47 Relay Word Bits: Automation SELOGIC (Counters)

Row	Name	Description
280	ACN01Q–ACN08Q	Automation SELOGIC Counter 01–08 asserted
281	ACN09Q–ACN16Q	Automation SELOGIC Counter 09–16 asserted
282	ACN17Q–ACN24Q	Automation SELOGIC Counter 17–24 asserted
283	ACN25Q–ACN32Q	Automation SELOGIC Counter 25–32 asserted
284	ACN01R–ACN08R	Automation SELOGIC Counter 01–08 reset
285	ACN09R–ACN16R	Automation SELOGIC Counter 09–16 reset
286	ACN17R–ACN24R	Automation SELOGIC Counter 17–24 reset
287	ACN25R–ACN32R	Automation SELOGIC Counter 25–32 reset

Table G.48 Relay Word Bits: SELOGIC Error and Status Reporting (Sheet 1 of 2)

Row	Name	Description
288	PUNRLBL	Protection SELOGIC control equation unresolved label
288	PFRTEX	Protection SELOGIC control equation first execution

Table G.48 Relay Word Bits: SELOGIC Error and Status Reporting (Sheet 2 of 2)

Row	Name	Description
288	MATHERR	SELOGIC control equation Math error
289	AUNRLBL	Automation SELOGIC control equation unresolved label
289	AFRTEXP	Automation SELOGIC control equation first execution after Protection settings change
289	AFRTEXA	Automation SELOGIC control equation first execution after Automation settings change

Table G.49 Relay Word Bits: Alarms

Row	Name	Description
290	SALARM	Software alarm
290	HALARM	Hardware alarm
290	BADPASS	Invalid password attempt alarm
290	CCALARM	Communication card status alarm

Table G.50 Relay Word Bits: Time and Date Management

Row	Name	Description
291	TIRIG	Time based on IRIG for both mark and value
291	TUPDH	Update source is a high-accuracy time source
291	TSYNCA	Time mark from time source not synchronized
291	TSOK	Time source accuracy meets synchrophasor requirement
291	PMDOK	Synchrophasor data acquisition functioning correctly

Table G.51 Relay Word Bits: Outputs

Row	Name	Description
292	OUT101–OUT108	Output 101–108 asserted
296	OUT201–OUT208	Output 201–208 asserted
297	OUT209–OUT216	Output 209–216 asserted
298	OUT301–OUT308	Output 301–308 asserted
299	OUT309–OUT316	Output 309–316 asserted

Table G.52 Relay Word Bits: Pushbuttons

Row	Name	Description
300	PB1–PB8	Pushbutton 01–08 asserted
301	PB9–PB12	Pushbutton 09–12 asserted
302	PB1_PUL–PB8_PUL	Pushbutton 01–08 pulsed for 1 processing interval
303	PB9_PUL–PB12PUL	Pushbutton 09–12 pulsed for 1 processing interval

Table G.53 Relay Word Bits: Pushbutton LED Bits

Row	Name	Description
304	PB1_LED–PB8_LED	PB01_ LED–PB08_ LED illuminated
305	PB9_LED–PB12LED	PB09_ LED–PB12_ LED illuminated

Table G.54 Relay Word Bits: Data Reset Bits

Row	Name	Description
306	RST_DEM	Reset Demand Metering
306	RST_PDM	Reset Peak Demand Metering
306	RST_ENE	Reset Energy metering
306	RST_BKS	Reset Breaker S monitoring
306	RST_BKT	Reset Breaker T monitoring
306	RST_BKU	Reset Breaker U monitoring
306	RST_BKW	Reset Breaker W monitoring
306	RST_BKX	Reset Breaker X monitoring
307	RST_BAT	Reset Battery monitoring
307	RSTTRGT	Reset Front Panel targets
307	RSTDNPE	Reset DNP fault summary data

Table G.55 Relay Word Bits: Target Logic Bits

Row	Name	Description
308	TRGTR	Target reset
308	PHASE_A	Faulted phase
308	PHASE_B	Faulted phase
308	PHASE_C	Faulted phase
308	ER	Event report triggered
308	FAULT	Fault detected

Table G.56 Relay Word Bits: MIRRORED BITS

Row	Name	Description
309	RMB1A–RMB8A	Received Mirrored bit 1–8 Channel A
310	TMB1A–TMB8A	Transmitted Mirrored bit 1–8 Channel A
311	RMB1B–RMB8B	Received Mirrored bit 1–8 Channel B
312	TMB1B–TMB8B	Transmitted Mirrored bit 1–8 Channel B
313	ROKA	Mirrored Bit Channel A normal status in non loopback mode
313	RBADA	Outage to large for normal mirrored bit communication channel A
313	CBADA	Unavailability threshold exceeded for normal mirrored bit communication channel A
313	LBOKA	Mirrored bit channel in loopback mode channel A
313	ANOKA	Analog transfer on mirrored bit channel A
313	DOKA	Mirrored bit channel A in normal mode
314	ROKB	Mirrored Bit channel B normal status in non loopback mode
314	RBADB	Outage to large for normal mirrored bit communication channel B
314	CBADB	Unavailability threshold exceeded for normal mirrored bit communication channel B
314	LBOKB	Mirrored bit channel in loopback mode channel B
314	ANOKB	Analog transfer on mirrored bit channel B
314	DOKB	Mirrored bit channel B in normal mode

Table G.57 Relay Word Bits: Test Bits

Row	Name	Description
315	TESTDNP	DNP test bit
315	TESTDB	Communication card database test bit
315	TESTFM	Fast Meter test bit
315	TESTPUL	Pulse test bit

Table G.58 Relay Word Bits: Communications Card Control Points

Row	Name	Description
316	CCIN121–CCIN128	Communication card input bit 121–128
317	CCIN113–CCIN120	Communication card input bit 113–120
318	CCIN105–CCIN112	Communication card input bit 105–112
319	CCIN097–CCIN104	Communication card input bit 097–104
320	CCIN089–CCIN096	Communication card input bit 089–096
321	CCIN081–CCIN088	Communication card input bit 081–088
322	CCIN073–CCIN080	Communication card input bit 073–080
323	CCIN065–CCIN072	Communication card input bit 065–072
324	CCIN057–CCIN064	Communication card input bit 057–064
325	CCIN049–CCIN056	Communication card input bit 049–056
326	CCIN041–CCIN048	Communication card input bit 041– 048
327	CCIN033–CCIN040	Communication card input bit 033–040
328	CCIN025–CCIN032	Communication card input bit 025–032
329	CCIN017–CCIN024	Communication card input bit 017–024
330	CCIN009–CCIN016	Communication card input bit 009–016
331	CCIN001–CCIN008	Communication card input bit 001–008
332	CCOUT25–CCOUT32	Communication card output point 25–32
333	CCOUT17–CCOUT24	Communication card output point 17–24
334	CCOUT09–CCOUT16	Communication card output point 09–16
335	CCOUT01–CCOUT08	Communication card output point 01–08

Table G.59 Relay Word Bits: Communications Card Status and Self-Test Bits

Row	Name	Description
336	CCSTA01–CCSTA08	Communication Card Status bit 01–Communication Card Status bit 08
337	CCSTA09–CCSTA16	Communication Card Status bit 09–Communication Card Status bit 16
338	CCSTA17–CCSTA24	Communication Card Self Test Register Status bit 17–24
339	CCSTA25–CCSTA32	Communication Card Self Test Register Status bit 25–32

Table G.60 Relay Word Bits: Fast SER Enable Bits

Row	Name	Description
340	FSERP1	Fast SER enabled for Port 1
340	FSERP2	Fast SER enabled for Port 2
340	FSERP3	Fast SER enabled for Port 3
340	FSERPF	Fast SER enabled for front port

Table G.61 Relay Word Bits: Synchrophasor SELOGIC Equations

Row	Name	Description
341	PMTRIG	Synchrophasor SELOGIC control equation trigger
341	TREA4	Synchrophasor SELOGIC control equation trigger reason 4
341	TREA3	Synchrophasor SELOGIC control equation trigger reason 3
341	TREA2	Synchrophasor SELOGIC control equation trigger reason 2
341	TREA1	Synchrophasor SELOGIC control equation trigger reason 1
341	FROKPM	Synchrophasor Frequency Measurement OK

Table G.62 Relay Word Bits: DNP Event Lock

Row	Bit Name	Description
342	EVELOCK	Lock DNP Events

Table G.63 Relay Word Bits: Synchrophasor Trigger SELOGIC Equations/RTC Synchrophasor Status Bits[a]

Row	Bit Name	Description
342	RTCCFGB	RTC Configuration Complete, Channel B
342	RTCCFGA	RTC Configuration Complete, Channel A
342	RTCSEQB	RTC Data In Sequence, Channel B
342	RTCSEQA	RTC Data In Sequence, Channel A
343	RTCDLYB	RTC Delay Exceeded, Channel B
343	RTCDLYA	RTC Delay Exceeded, Channel A
343	RTCROK	Valid Aligned RTC Data Available on All Enabled Channels
343	RTCROKB	Valid Aligned RTC Data Available on Channel B
343	RTCROKA	Valid Aligned RTC Data Available on Channel A
343	RTCENB	Valid Remote Synchrophasors Received on Channel B
343	RTCENA	Valid Remote Synchrophasors Received on Channel A

[a] These bits are sent as part of the IEEE C37.118 format synchrophasor data frame.

Table G.64 Relay Word Bits: RTC Remote Digital Status (Sheet 1 of 2)

Row	Bit Name	Description
344	RTCAD08	RTC Remote Data Bits, Channel A, bit 8
344	RTCAD07	RTC Remote Data Bits, Channel A, bit 7
344	RTCAD06	RTC Remote Data Bits, Channel A, bit 6
344	RTCAD05	RTC Remote Data Bits, Channel A, bit 5
344	RTCAD04	RTC Remote Data Bits, Channel A, bit 4
344	RTCAD03	RTC Remote Data Bits, Channel A, bit 3
344	RTCAD02	RTC Remote Data Bits, Channel A, bit 2
344	RTCAD01	RTC Remote Data Bits, Channel A, bit 1
345	RTCAD16	RTC Remote Data Bits, Channel A, bit 16
345	RTCAD15	RTC Remote Data Bits, Channel A, bit 15
345	RTCAD14	RTC Remote Data Bits, Channel A, bit 14
345	RTCAD13	RTC Remote Data Bits, Channel A, bit 13
345	RTCAD12	RTC Remote Data Bits, Channel A, bit 12

Table G.64 Relay Word Bits: RTC Remote Digital Status (Sheet 2 of 2)

Row	Bit Name	Description
345	RTCAD11	RTC Remote Data Bits, Channel A, bit 11
345	RTCAD10	RTC Remote Data Bits, Channel A, bit 10
345	RTCAD09	RTC Remote Data Bits, Channel A, bit 9
346	RTCBD08	RTC Remote Data Bits, Channel B, bit 8
346	RTCBD07	RTC Remote Data Bits, Channel B, bit 7
346	RTCBD06	RTC Remote Data Bits, Channel B, bit 6
346	RTCBD05	RTC Remote Data Bits, Channel B, bit 5
346	RTCBD04	RTC Remote Data Bits, Channel B, bit 4
346	RTCBD03	RTC Remote Data Bits, Channel B, bit 3
346	RTCBD02	RTC Remote Data Bits, Channel B, bit 2
346	RTCBD01	RTC Remote Data Bits, Channel B, bit 1
347	RTCBD16	RTC Remote Data Bits, Channel B, bit 16
347	RTCBD15	RTC Remote Data Bits, Channel B, bit 15
347	RTCBD14	RTC Remote Data Bits, Channel B, bit 14
347	RTCBD13	RTC Remote Data Bits, Channel B, bit 13
347	RTCBD12	RTC Remote Data Bits, Channel B, bit 12
347	RTCBD11	RTC Remote Data Bits, Channel B, bit 11
347	RTCBD10	RTC Remote Data Bits, Channel B, bit 10
347	RTCBD09	RTC Remote Data Bits, Channel B, bit 9

Table G.65 Relay Word Bits: IRIG-B Control Bits (Sheet 1 of 2)

Row	Name	Description
348	YEAR80	IRIG B year information (add 80 years if bit asserted)
348	YEAR40	IRIG B year information (add 40 years if bit asserted)
348	YEAR20	IRIG B year information (add 20 years if bit asserted)
348	YEAR10	IRIG B year information (add 10 years if bit asserted)
348	YEAR8	IRIG B year information (add 8 years if bit asserted)
348	YEAR4	IRIG B year information (add 4 years if bit asserted)
348	YEAR2	IRIG B year information (add 2 years if bit asserted)
348	YEAR1	IRIG B year information (add 1 years if bit asserted)
349	TUTCH	Offset half-hour from UTC time binary add 0.5 if asserted
349	TUTC8	Offset hours from UTC time binary add 8 if asserted
349	TUTC4	Offset hours from UTC time binary add 4 if asserted
349	TUTC2	Offset hours from UTC time binary add 2 if asserted
349	TUTC1	Offset hours from UTC time binary add 1 if asserted
349	TUTCS	Offset hours sign from UTC time subtract the UTC offset if TUTCS is asserted add otherwise
350	DST	Daylight Savings Time
350	DSTP	Daylight Savings Time Pending
350	LPSEC	Leap second is added
350	LPSECP	Leap second pending
350	TQUAL8	Time quality binary add 8 when asserted

Table G.65 Relay Word Bits: IRIG-B Control Bits (Sheet 2 of 2)

Row	Name	Description
350	TQUAL4	Time quality binary add 4 when asserted
350	TQUAL2	Time quality binary add 2 when asserted
350	TQUAL1	Time quality binary add 1 when asserted

Table G.66 Relay Word Bits: Signal Profiling

Row	Name	Description
353	SPEN	Signal Profiling enabled

Table G.67 Relay Word Bits: Fast Operate Transmit Bits (Sheet 1 of 4)

Row	Bit Name	Description
356	FOPF_08	Fast Operate Output Control Bits for Port F, bit 8
356	FOPF_07	Fast Operate Output Control Bits for Port F, bit 7
356	FOPF_06	Fast Operate Output Control Bits for Port F, bit 6
356	FOPF_05	Fast Operate Output Control Bits for Port F, bit 5
356	FOPF_04	Fast Operate Output Control Bits for Port F, bit 4
356	FOPF_03	Fast Operate Output Control Bits for Port F, bit 3
356	FOPF_02	Fast Operate Output Control Bits for Port F, bit 2
356	FOPF_01	Fast Operate Output Control Bits for Port F, bit 1
357	FOPF_16	Fast Operate Output Control Bits for Port F, bit 16
357	FOPF_15	Fast Operate Output Control Bits for Port F, bit 15
357	FOPF_14	Fast Operate Output Control Bits for Port F, bit 14
357	FOPF_13	Fast Operate Output Control Bits for Port F, bit 13
357	FOPF_12	Fast Operate Output Control Bits for Port F, bit 12
357	FOPF_11	Fast Operate Output Control Bits for Port F, bit 11
357	FOPF_10	Fast Operate Output Control Bits for Port F, bit 10
357	FOPF_09	Fast Operate Output Control Bits for Port F, bit 9
358	FOPF_24	Fast Operate Output Control Bits for Port F, bit 24
358	FOPF_23	Fast Operate Output Control Bits for Port F, bit 23
358	FOPF_22	Fast Operate Output Control Bits for Port F, bit 22
358	FOPF_21	Fast Operate Output Control Bits for Port F, bit 21
358	FOPF_20	Fast Operate Output Control Bits for Port F, bit 20
358	FOPF_19	Fast Operate Output Control Bits for Port F, bit 19
358	FOPF_18	Fast Operate Output Control Bits for Port F, bit 18
358	FOPF_17	Fast Operate Output Control Bits for Port F, bit 17
359	FOPF_32	Fast Operate Output Control Bits for Port F, bit 32
359	FOPF_31	Fast Operate Output Control Bits for Port F, bit 31
359	FOPF_30	Fast Operate Output Control Bits for Port F, bit 30
359	FOPF_29	Fast Operate Output Control Bits for Port F, bit 29
359	FOPF_28	Fast Operate Output Control Bits for Port F, bit 28
359	FOPF_27	Fast Operate Output Control Bits for Port F, bit 27
359	FOPF_26	Fast Operate Output Control Bits for Port F, bit 26

Table G.67 Relay Word Bits: Fast Operate Transmit Bits (Sheet 2 of 4)

Row	Bit Name	Description
359	FOPF_25	Fast Operate Output Control Bits for Port F, bit 25
360	FOP1_08	Fast Operate Output Control Bits for Port 1, bit 8
360	FOP1_07	Fast Operate Output Control Bits for Port 1, bit 7
360	FOP1_06	Fast Operate Output Control Bits for Port 1, bit 6
360	FOP1_05	Fast Operate Output Control Bits for Port 1, bit 5
360	FOP1_04	Fast Operate Output Control Bits for Port 1, bit 4
360	FOP1_03	Fast Operate Output Control Bits for Port 1, bit 3
360	FOP1_02	Fast Operate Output Control Bits for Port 1, bit 2
360	FOP1_01	Fast Operate Output Control Bits for Port 1, bit 1
361	FOP1_16	Fast Operate Output Control Bits for Port 1, bit 16
361	FOP1_15	Fast Operate Output Control Bits for Port 1, bit 15
361	FOP1_14	Fast Operate Output Control Bits for Port 1, bit 14
361	FOP1_13	Fast Operate Output Control Bits for Port 1, bit 13
361	FOP1_12	Fast Operate Output Control Bits for Port 1, bit 12
361	FOP1_11	Fast Operate Output Control Bits for Port 1, bit 11
361	FOP1_10	Fast Operate Output Control Bits for Port 1, bit 10
361	FOP1_09	Fast Operate Output Control Bits for Port 1, bit 9
362	FOP1_24	Fast Operate Output Control Bits for Port 1, bit 24
362	FOP1_23	Fast Operate Output Control Bits for Port 1, bit 23
362	FOP1_22	Fast Operate Output Control Bits for Port 1, bit 22
362	FOP1_21	Fast Operate Output Control Bits for Port 1, bit 21
362	FOP1_20	Fast Operate Output Control Bits for Port 1, bit 20
362	FOP1_19	Fast Operate Output Control Bits for Port 1, bit 19
362	FOP1_18	Fast Operate Output Control Bits for Port 1, bit 18
362	FOP1_17	Fast Operate Output Control Bits for Port 1, bit 17
363	FOP1_32	Fast Operate Output Control Bits for Port 1, bit 32
363	FOP1_31	Fast Operate Output Control Bits for Port 1, bit 31
363	FOP1_30	Fast Operate Output Control Bits for Port 1, bit 30
363	FOP1_29	Fast Operate Output Control Bits for Port 1, bit 29
363	FOP1_28	Fast Operate Output Control Bits for Port 1, bit 28
363	FOP1_27	Fast Operate Output Control Bits for Port 1, bit 27
363	FOP1_26	Fast Operate Output Control Bits for Port 1, bit 26
363	FOP1_25	Fast Operate Output Control Bits for Port 1, bit 25
364	FOP2_08	Fast Operate Output Control Bits for Port 2, bit 8
364	FOP2_07	Fast Operate Output Control Bits for Port 2, bit 7
364	FOP2_06	Fast Operate Output Control Bits for Port 2, bit 6
364	FOP2_05	Fast Operate Output Control Bits for Port 2, bit 5
364	FOP2_04	Fast Operate Output Control Bits for Port 2, bit 4
364	FOP2_03	Fast Operate Output Control Bits for Port 2, bit 3
364	FOP2_02	Fast Operate Output Control Bits for Port 2, bit 2
364	FOP2_01	Fast Operate Output Control Bits for Port 2, bit 1

Table G.67 Relay Word Bits: Fast Operate Transmit Bits (Sheet 3 of 4)

Row	Bit Name	Description
365	FOP2_16	Fast Operate Output Control Bits for Port 2, bit 16
365	FOP2_15	Fast Operate Output Control Bits for Port 2, bit 15
365	FOP2_14	Fast Operate Output Control Bits for Port 2, bit 14
365	FOP2_13	Fast Operate Output Control Bits for Port 2, bit 13
365	FOP2_12	Fast Operate Output Control Bits for Port 2, bit 12
365	FOP2_11	Fast Operate Output Control Bits for Port 2, bit 11
365	FOP2_10	Fast Operate Output Control Bits for Port 2, bit 10
365	FOP2_09	Fast Operate Output Control Bits for Port 2, bit 9
366	FOP2_24	Fast Operate Output Control Bits for Port 2, bit 24
366	FOP2_23	Fast Operate Output Control Bits for Port 2, bit 23
366	FOP2_22	Fast Operate Output Control Bits for Port 2, bit 22
366	FOP2_21	Fast Operate Output Control Bits for Port 2, bit 21
366	FOP2_20	Fast Operate Output Control Bits for Port 2, bit 20
366	FOP2_19	Fast Operate Output Control Bits for Port 2, bit 19
366	FOP2_18	Fast Operate Output Control Bits for Port 2, bit 18
366	FOP2_17	Fast Operate Output Control Bits for Port 2, bit 17
367	FOP2_32	Fast Operate Output Control Bits for Port 2, bit 32
367	FOP2_31	Fast Operate Output Control Bits for Port 2, bit 31
367	FOP2_30	Fast Operate Output Control Bits for Port 2, bit 30
367	FOP2_29	Fast Operate Output Control Bits for Port 2, bit 29
367	FOP2_28	Fast Operate Output Control Bits for Port 2, bit 28
367	FOP2_27	Fast Operate Output Control Bits for Port 2, bit 27
367	FOP2_26	Fast Operate Output Control Bits for Port 2, bit 26
367	FOP2_25	Fast Operate Output Control Bits for Port 2, bit 25
368	FOP3_08	Fast Operate Output Control Bits for Port 3, bit 8
368	FOP3_07	Fast Operate Output Control Bits for Port 3, bit 7
368	FOP3_06	Fast Operate Output Control Bits for Port 3, bit 6
368	FOP3_05	Fast Operate Output Control Bits for Port 3, bit 5
368	FOP3_04	Fast Operate Output Control Bits for Port 3, bit 4
368	FOP3_03	Fast Operate Output Control Bits for Port 3, bit 3
368	FOP3_02	Fast Operate Output Control Bits for Port 3, bit 2
368	FOP3_01	Fast Operate Output Control Bits for Port 3, bit 1
369	FOP3_16	Fast Operate Output Control Bits for Port 3, bit 16
369	FOP3_15	Fast Operate Output Control Bits for Port 3, bit 15
369	FOP3_14	Fast Operate Output Control Bits for Port 3, bit 14
369	FOP3_13	Fast Operate Output Control Bits for Port 3, bit 13
369	FOP3_12	Fast Operate Output Control Bits for Port 3, bit 12
369	FOP3_11	Fast Operate Output Control Bits for Port 3, bit 11
369	FOP3_10	Fast Operate Output Control Bits for Port 3, bit 10
369	FOP3_09	Fast Operate Output Control Bits for Port 3, bit 9
370	FOP3_24	Fast Operate Output Control Bits for Port 3, bit 24

Table G.67 Relay Word Bits: Fast Operate Transmit Bits (Sheet 4 of 4)

Row	Bit Name	Description
370	FOP3_23	Fast Operate Output Control Bits for Port 3, bit 23
370	FOP3_22	Fast Operate Output Control Bits for Port 3, bit 22
370	FOP3_21	Fast Operate Output Control Bits for Port 3, bit 21
370	FOP3_20	Fast Operate Output Control Bits for Port 3, bit 20
370	FOP3_19	Fast Operate Output Control Bits for Port 3, bit 19
370	FOP3_18	Fast Operate Output Control Bits for Port 3, bit 18
370	FOP3_17	Fast Operate Output Control Bits for Port 3, bit 17
371	FOP3_32	Fast Operate Output Control Bits for Port 3, bit 32
371	FOP3_31	Fast Operate Output Control Bits for Port 3, bit 31
371	FOP3_30	Fast Operate Output Control Bits for Port 3, bit 30
371	FOP3_29	Fast Operate Output Control Bits for Port 3, bit 29
371	FOP3_28	Fast Operate Output Control Bits for Port 3, bit 28
371	FOP3_27	Fast Operate Output Control Bits for Port 3, bit 27
371	FOP3_26	Fast Operate Output Control Bits for Port 3, bit 26
371	FOP3_25	Fast Operate Output Control Bits for Port 3, bit 25

Appendix H
Analog Quantities

Overview

This section contains a table of the analog quantities available within the SEL-487E Relay.

Use *Table H.2* as a reference for labels in this manual and as a resource for quantities you use in SELOGIC® control equation relay settings. *Table H.1* groups the analog quantities alphanumerically; *Table H.2* groups the analog quantities by function.

Quantities Listed Alphabetically

Use *Table H.2* as a reference for labels in this manual and as a resource for quantities you use in SELOGIC® control equation relay settings. *Table H.1* groups the analog quantities alphanumerically; *Table H.2* groups the analog quantities by function.

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 1 of 38)

Label	Description	Units
24Rpu	Volts/Hertz	(unitless - ratio)
3DPFS	3-Phase Displacement power factor, Terminal S	(unitless - ratio)
3DPFST	3-Phase Displacement power factor, Comb. Terminals ST	(unitless - ratio)
3DPFT	3-Phase Displacement power factor, Terminal T	(unitless - ratio)
3DPFTU	3-Phase Displacement power factor, Comb. Terminals TU	(unitless - ratio)
3DPFU	3-Phase Displacement power factor, Terminal U	(unitless - ratio)
3DPFUW	3-Phase Displacement power factor, Comb. Terminals UW	(unitless - ratio)
3DPFW	3-Phase Displacement power factor, Terminal W	(unitless - ratio)
3DPFWX	3-Phase Displacement power factor, Comb. Terminals WX	(unitless - ratio)
3DPFX	3-Phase Displacement power factor, Terminal X	(unitless - ratio)
3I0SA	Instantaneous zero-sequence current angle, Terminal S	Degrees [°] (±180°)
3I0SAC	1 cycle average zero-sequence current angle, Terminal S	Degrees [°] (±180°)
3I0SI	Instantaneous zero-sequence current, Imaginary component, Terminal S	Amps [A] (Secondary)
3I0SM	Instantaneous zero-sequence current magnitude, Terminal S	Amps [A] (Secondary)
3I0SMC	1 cycle average zero-sequence current magnitude, Terminal S	Amps [A] (primary)
3I0SMS	1 second average zero-sequence current magnitude, Terminal S	Amperes [A]
3I0SR	Instantaneous zero-sequence current, Real component, Terminal S	Amps [A] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 2 of 38)

Label	Description	Units
3I0STA	Instantaneous zero-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I0STAC	1 cycle average zero-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I0STI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals ST	Amps [A] (Secondary)
3I0STM	Instantaneous zero-sequence current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
3I0STMC	1 cycle average zero-sequence current magnitude, Comb. Terminals ST	Amps [A] (primary)
3I0STMS	1 second average zero-sequence current magnitude, Comb. Terminals ST	Amperes [A]
3I0STR	Instantaneous zero-sequence current, Real component, Comb. Terminals ST	Amps [A] (Secondary)
3I0TA	Instantaneous zero-sequence current angle, Terminal T	Degrees [°] (±180°)
3I0TAC	1 cycle average zero-sequence current angle, Terminal T	Degrees [°] (±180°)
3I0TI	Instantaneous zero-sequence current, Imaginary component, Terminal T	Amps [A] (Secondary)
3I0TM	Instantaneous zero-sequence current magnitude, Terminal T	Amps [A] (Secondary)
3I0TMC	1 cycle average zero-sequence current magnitude, Terminal T	Amps [A] (primary)
3I0TMS	1 second average zero-sequence current magnitude, Terminal T	Amperes [A]
3I0TR	Instantaneous zero-sequence current, Real component, Terminal T	Amps [A] (Secondary)
3I0TUA	Instantaneous zero-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I0TUAC	1 cycle average zero-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I0TUI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals TU	Amps [A] (Secondary)
3I0TUM	Instantaneous zero-sequence current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
3I0TUMC	1 cycle average zero-sequence current magnitude, Comb. Terminals TU	Amps [A] (primary)
3I0TUMS	1 second average zero-sequence current magnitude, Comb. Terminals TU	Amperes [A]
3I0TUR	Instantaneous zero-sequence current, Real component, Comb. Terminals TU	Amps [A] (Secondary)
3I0UA	Instantaneous zero-sequence current angle, Terminal U	Degrees [°] (±180°)
3I0UAC	1 cycle average zero-sequence current angle, Terminal U	Degrees [°] (±180°)
3I0UI	Instantaneous zero-sequence current, Imaginary component, Terminal U	Amps [A] (Secondary)
3I0UM	Instantaneous zero-sequence current magnitude, Terminal U	Amps [A] (Secondary)
3I0UMC	1 cycle average zero-sequence current magnitude, Terminal U	Amps [A] (primary)
3I0UMS	1 second average zero-sequence current magnitude, Terminal U	Amperes [A]
3I0UR	Instantaneous zero-sequence current, Real component, Terminal U	Amps [A] (Secondary)
3I0UWA	Instantaneous zero-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I0UWAC	1 cycle average zero-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I0UWI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals UW	Amps [A] (Secondary)
3I0UWM	Instantaneous zero-sequence current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
3I0UWMC	1 cycle average zero-sequence current magnitude, Comb. Terminals UW	Amps [A] (primary)
3I0UWMS	1 second average zero-sequence current magnitude, Comb. Terminals UW	Amperes [A]
3I0UWR	Instantaneous zero-sequence current, Real component, Comb. Terminals UW	Amps [A] (Secondary)
3I0WA	Instantaneous zero-sequence current angle, Terminal W	Degrees [°] (±180°)
3I0WAC	1 cycle average zero-sequence current angle, Terminal W	Degrees [°] (±180°)
3I0WI	Instantaneous zero-sequence current, Imaginary component, Terminal W	Amps [A] (Secondary)
3I0WM	Instantaneous zero-sequence current magnitude, Terminal W	Amps [A] (Secondary)
3I0WMC	1 cycle average zero-sequence current magnitude, Terminal W	Amps [A] (primary)
3I0WMS	1 second average zero-sequence current magnitude, Terminal W	Amperes [A]

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 3 of 38)

Label	Description	Units
3I0WR	Instantaneous zero-sequence current, Real component, Terminal W	Amps [A] (Secondary)
3I0WXA	Instantaneous zero-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I0WXAC	1 cycle average zero-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I0WXI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals WX	Amps [A] (Secondary)
3I0WXM	Instantaneous zero-sequence current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
3I0WXMC	1 cycle average zero-sequence current magnitude, Comb. Terminals WX	Amps [A] (primary)
3I0WXMS	1 second average zero-sequence current magnitude, Comb. Terminals WX	Amperes [A]
3I0WXR	Instantaneous zero-sequence current, Real component, Comb. Terminals WX	Amps [A] (Secondary)
3I0XA	Instantaneous zero-sequence current angle, Terminal X	Degrees [°] (±180°)
3I0XAC	1 cycle average zero-sequence current angle, Terminal X	Degrees [°] (±180°)
3I0XI	Instantaneous zero-sequence current, Imaginary component, Terminal X	Amps [A] (Secondary)
3I0XM	Instantaneous zero-sequence current magnitude, Terminal X	Amps [A] (Secondary)
3I0XMC	1 cycle average zero-sequence current magnitude, Terminal X	Amps [A] (primary)
3I0XMS	1 second average zero-sequence current magnitude, Terminal X	Amperes [A]
3I0XR	Instantaneous zero-sequence current, Real component, Terminal X	Amps [A] (Secondary)
3I2SA	Instantaneous negative-sequence current angle, Terminal S	Degrees [°] (±180°)
3I2SAC	1 cycle average negative-sequence current angle, Terminal S	Degrees [°] (±180°)
3I2SI	Instantaneous negative-sequence current, Imaginary component, Terminal S	Amps [A] (Secondary)
3I2SM	Instantaneous negative-sequence current magnitude, Terminal S	Amps [A] (Secondary)
3I2SMC	1 cycle average negative-sequence current magnitude, Terminal S	Amps [A] (primary)
3I2SMS	1 second average negative-sequence current magnitude, Terminal S	Amperes [A]
3I2SR	Instantaneous negative-sequence current, Real component, Terminal S	Amps [A] (Secondary)
3I2STA	Instantaneous negative-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I2STAC	1 cycle average negative-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I2STI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals ST	Amps [A] (Secondary)
3I2STM	Instantaneous negative-sequence current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
3I2STMC	1 cycle average negative-sequence current magnitude, Comb. Terminals ST	Amps [A] (primary)
3I2STMS	1 second average negative-sequence current magnitude, Comb. Terminals ST	Amperes [A]
3I2STR	Instantaneous negative-sequence current, Real component, Comb. Terminals ST	Amps [A] (Secondary)
3I2TA	Instantaneous negative-sequence current angle, Terminal T	Degrees [°] (±180°)
3I2TAC	1 cycle average negative-sequence current angle, Terminal T	Degrees [°] (±180°)
3I2TI	Instantaneous negative-sequence current, Imaginary component, Terminal T	Amps [A] (Secondary)
3I2TM	Instantaneous negative-sequence current magnitude, Terminal T	Amps [A] (Secondary)
3I2TMC	1 cycle average negative-sequence current magnitude, Terminal T	Amps [A] (primary)
3I2TMS	1 second average negative-sequence current magnitude, Terminal T	Amperes [A]
3I2TR	Instantaneous negative-sequence current, Real component, Terminal T	Amps [A] (Secondary)
3I2TUA	Instantaneous negative-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I2TUAC	1 cycle average negative-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I2TUI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals TU	Amps [A] (Secondary)
3I2TUM	Instantaneous negative-sequence current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
3I2TUMC	1 cycle average negative-sequence current magnitude, Comb. Terminals TU	Amps [A] (primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 4 of 38)

Label	Description	Units
3I2TUMS	1 second average negative-sequence current magnitude, Comb. Terminals TU	Amperes [A]
3I2TUR	Instantaneous negative-sequence current, Real component, Comb. Terminals TU	Amps [A] (Secondary)
3I2UA	Instantaneous negative-sequence current angle, Terminal U	Degrees [°] (±180°)
3I2UAC	1 cycle average negative-sequence current angle, Terminal U	Degrees [°] (±180°)
3I2UI	Instantaneous negative-sequence current, Imaginary component, Terminal U	Amps [A] (Secondary)
3I2UM	Instantaneous negative-sequence current magnitude, Terminal U	Amps [A] (Secondary)
3I2UMC	1 cycle average negative-sequence current magnitude, Terminal U	Amps [A] (primary)
3I2UMS	1 second average negative-sequence current magnitude, Terminal U	Amperes [A]
3I2UR	Instantaneous negative-sequence current, Real component, Terminal U	Amps [A] (Secondary)
3I2UWA	Instantaneous negative-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I2UWAC	1 cycle average negative-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I2UWI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals UW	Amps [A] (Secondary)
3I2UWM	Instantaneous negative-sequence current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
3I2UWMC	1 cycle average negative-sequence current magnitude, Comb. Terminals UW	Amps [A] (primary)
3I2UWMS	1 second average negative-sequence current magnitude, Comb. Terminals UW	Amperes [A]
3I2UWR	Instantaneous negative-sequence current, Real component, Comb. Terminals UW	Amps [A] (Secondary)
3I2WA	Instantaneous negative-sequence current angle, Terminal W	Degrees [°] (±180°)
3I2WAC	1 cycle average negative-sequence current angle, Terminal W	Degrees [°] (±180°)
3I2WI	Instantaneous negative-sequence current, Imaginary component, Terminal W	Amps [A] (Secondary)
3I2WM	Instantaneous negative-sequence current magnitude, Terminal W	Amps [A] (Secondary)
3I2WMC	1 cycle average negative-sequence current magnitude, Terminal W	Amps [A] (primary)
3I2WMS	1 second average negative-sequence current magnitude, Terminal W	Amperes [A]
3I2WR	Instantaneous negative-sequence current, Real component, Terminal W	Amps [A] (Secondary)
3I2WXA	Instantaneous negative-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I2WXAC	1 cycle average negative-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I2WXI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals WX	Amps [A] (Secondary)
3I2WXM	Instantaneous negative-sequence current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
3I2WXMC	1 cycle average negative-sequence current magnitude, Comb. Terminals WX	Amps [A] (primary)
3I2WXMS	1 second average negative-sequence current magnitude, Comb. Terminals WX	Amperes [A]
3I2WXR	Instantaneous negative-sequence current, Real component, Comb. Terminals WX	Amps [A] (Secondary)
3I2XA	Instantaneous negative-sequence current angle, Terminal X	Degrees [°] (±180°)
3I2XAC	1 cycle average negative-sequence current angle, Terminal X	Degrees [°] (±180°)
3I2XI	Instantaneous negative-sequence current, Imaginary component, Terminal X	Amps [A] (Secondary)
3I2XM	Instantaneous negative-sequence current magnitude, Terminal X	Amps [A] (Secondary)
3I2XMC	1 cycle average negative-sequence current magnitude, Terminal X	Amps [A] (primary)
3I2XMS	1 second average negative-sequence current magnitude, Terminal X	Amperes [A]
3I2XR	Instantaneous negative-sequence current, Real component, Terminal X	Amps [A] (Secondary)
3PSF	Instantaneous 3-phase fundamental active power, Terminal S	Watts [W] (Secondary)
3PSFC	1 cycle average 3-phase fundamental active power, Terminal S	Megawatts [MW] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 5 of 38)

Label	Description	Units
3PSMWhn	Three phase active energy imported, Terminal S	Megawatts hours [MWh] (Primary)
3PSMWhp	Three phase active energy exported, Terminal S	Megawatts hours [MWh] (Primary)
3PSMWhT	Total Three phase active energy, Terminal S	Megawatts hours [MWh] (Primary)
3PSTF	Instantaneous 3-phase fundamental active power, Comb. Terminals ST	Watts [W] (Secondary)
3PSTFC	1 cycle average 3-phase fundamental active power, Comb. Terminals ST	Megawatts [MW] (Primary)
3PSTWhn	Three phase active energy imported, Comb. Terminals ST	Megawatts hours [MWh] (Primary)
3PSTWhp	Three phase active energy exported, Comb. Terminals ST	Megawatts hours [MWh] (Primary)
3PSTWhT	Total Three phase active energy, Comb. Terminals ST	Megawatts hours [MWh] (Primary)
3PTF	Instantaneous 3-phase fundamental active power, Terminal T	Watts [W] (Secondary)
3PTFC	1 cycle average 3-phase fundamental active power, Terminal T	Megawatts [MW] (Primary)
3PTMWhn	Three phase active energy imported, Terminal T	Megawatts hours [MWh] (Primary)
3PTMWhp	Three phase active energy exported, Terminal T	Megawatts hours [MWh] (Primary)
3PTMWhT	Total Three phase active energy, Terminal T	Megawatts hours [MWh] (Primary)
3PTUF	Instantaneous 3-phase fundamental active power, Comb. Terminals TU	Watts [W] (Secondary)
3PTUFC	1 cycle average 3-phase fundamental active power, Comb. Terminals TU	Megawatts [MW] (Primary)
3PTUWhn	Three phase active energy imported, Comb. Terminals TU	Megawatts hours [MWh] (Primary)
3PTUWhp	Three phase active energy exported, Comb. Terminals TU	Megawatts hours [MWh] (Primary)
3PTUWhT	Total Three phase active energy, Comb. Terminals TU	Megawatts hours [MWh] (Primary)
3PUF	Instantaneous 3-phase fundamental active power, Terminal U	Watts [W] (Secondary)
3PUFC	1 cycle average 3-phase fundamental active power, Terminal U	Megawatts [MW] (Primary)
3PUMWhn	Three phase active energy imported, Terminal U	Megawatts hours [MWh] (Primary)
3PUMWhp	Three phase active energy exported, Terminal U	Megawatts hours [MWh] (Primary)
3PUMWhT	Total Three phase active energy, Terminal U	Megawatts hours [MWh] (Primary)
3PUWF	Instantaneous 3-phase fundamental active power, Comb. Terminals UW	Watts [W] (Secondary)
3PUWFC	1 cycle average 3-phase fundamental active power, Comb. Terminals UW	Megawatts [MW] (Primary)
3PUWWhn	Three phase active energy imported, Comb. Terminals UW	Megawatts hours [MWh] (Primary)
3PUWWhp	Three phase active energy exported, Comb. Terminals UW	Megawatts hours [MWh] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 6 of 38)

Label	Description	Units
3PUWWhT	Total Three phase active energy, Comb. Terminals UW	Megawatts hours [MWh] (Primary)
3PWF	Instantaneous 3-phase fundamental active power, Terminal W	Watts [W] (Secondary)
3PWFC	1 cycle average 3-phase fundamental active power, Terminal W	Megawatts [MW] (Primary)
3PWMWhn	Three phase active energy imported, Terminal W	Megawatts hours [MWh] (Primary)
3PWMWhp	Three phase active energy exported, Terminal W	Megawatts hours [MWh] (Primary)
3PWMWhT	Total Three phase active energy, Terminal W	Megawatts hours [MWh] (Primary)
3PWXF	Instantaneous 3-phase fundamental active power, Comb. Terminals WX	Watts [W] (Secondary)
3PWXFC	1 cycle average 3-phase fundamental active power, Comb. Terminals WX	Megawatts [MW] (Primary)
3PWXWhn	Three phase active energy imported, Comb. Terminals WX	Megawatts hours [MWh] (Primary)
3PWXWhp	Three phase active energy exported, Comb. Terminals WX	Megawatts hours [MWh] (Primary)
3PWXWhT	Total Three phase active energy, Comb. Terminals WX	Megawatts hours [MWh] (Primary)
3PXF	Instantaneous 3-phase fundamental active power, Terminal X	Watts [W] (Secondary)
3PXFC	1 cycle average 3-phase fundamental active power, Terminal X	Megawatts [MW] (Primary)
3PXMWhn	Three phase active energy imported, Terminal X	Megawatts hours [MWh] (Primary)
3PXMWhp	Three phase active energy exported, Terminal X	Megawatts hours [MWh] (Primary)
3PXMWhT	Total Three phase active energy, Terminal X	Megawatts hours [MWh] (Primary)
3QSF	Instantaneous 3-phase fundamental reactive power, Terminal S	VARS [Var] (Secondary)
3QSFC	1 cycle average 3-phase fundamental reactive power, Terminal S	Megavars [Mvar] (Primary)
3QSMVhn	Three phase reactive energy imported, Terminal S	Megavars hours [Mvarh] (Primary)
3QSMVhp	Three phase reactive energy exported, Terminal S	Megavars hours [Mvarh] (Primary)
3QSMVhT	Total Three phase reactive energy, Terminal S	Megavars hours [Mvarh] (Primary)
3QSTF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals ST	VARS [Var] (Secondary)
3QSTFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals ST	Megavars [Mvar] (Primary)
3QSTVhn	Three phase reactive energy imported, Comb. Terminals ST	Megavars hours [Mvarh] (Primary)
3QSTVhp	Three phase reactive energy exported, Comb. Terminals ST	Megavars hours [Mvarh] (Primary)
3QSTVhT	Total Three phase reactive energy, Comb. Terminals ST	Megavars hours [Mvarh] (Primary)
3QTF	Instantaneous 3-phase fundamental reactive power, Terminal T	VARS [Var] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 7 of 38)

Label	Description	Units
3QTFC	1 cycle average 3-phase fundamental reactive power, Terminal T	Megavars [Mvar] (Primary)
3QTMVhn	Three phase reactive energy imported, Terminal T	Megavars hours [Mvarh] (Primary)
3QTMVhp	Three phase reactive energy exported, Terminal T	Megavars hours [Mvarh] (Primary)
3QTMVhT	Total Three phase reactive energy, Terminal T	Megavars hours [Mvarh] (Primary)
3QTUF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals TU	VARS [Var] (Secondary)
3QTUFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals TU	Megavars [Mvar] (Primary)
3QTUVhn	Three phase reactive energy imported, Comb. Terminals TU	Megavars hours [Mvarh] (Primary)
3QTUVhp	Three phase reactive energy exported, Comb. Terminals TU	Megavars hours [Mvarh] (Primary)
3QTUVhT	Total Three phase reactive energy, Comb. Terminals TU	Megavars hours [Mvarh] (Primary)
3QUF	Instantaneous 3-phase fundamental reactive power, Terminal U	VARS [Var] (Secondary)
3QUFC	1 cycle average 3-phase fundamental reactive power, Terminal U	Megavars [Mvar] (Primary)
3QUMVhn	Three phase reactive energy imported, Terminal U	Megavars hours [Mvarh] (Primary)
3QUMVhp	Three phase reactive energy exported, Terminal U	Megavars hours [Mvarh] (Primary)
3QUMVhT	Total Three phase reactive energy, Terminal U	Megavars hours [Mvarh] (Primary)
3QUWF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals UW	VARS [Var] (Secondary)
3QUWFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals UW	Megavars [Mvar] (Primary)
3QUWVhn	Three phase reactive energy imported, Comb. Terminals UW	Megavars hours [Mvarh] (Primary)
3QUWVhp	Three phase reactive energy exported, Comb. Terminals UW	Megavars hours [Mvarh] (Primary)
3QUWVhT	Total Three phase reactive energy, Comb. Terminals UW	Megavars hours [Mvarh] (Primary)
3QWF	Instantaneous 3-phase fundamental reactive power, Terminal W	VARS [Var] (Secondary)
3QWFC	1 cycle average 3-phase fundamental reactive power, Terminal W	Megavars [Mvar] (Primary)
3QWMVhn	Three phase reactive energy imported, Terminal W	Megavars hours [Mvarh] (Primary)
3QWMVhp	Three phase reactive energy exported, Terminal W	Megavars hours [Mvarh] (Primary)
3QWMVhT	Total Three phase reactive energy, Terminal W	Megavars hours [Mvarh] (Primary)
3QWXF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals WX	VARS [Var] (Secondary)
3QWXFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals WX	Megavars [Mvar] (Primary)
3QWXVhn	Three phase reactive energy imported, Comb. Terminals WX	Megavars hours [Mvarh] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 8 of 38)

Label	Description	Units
3QWXVhp	Three phase reactive energy exported, Comb. Terminals WX	Megavars hours [Mvarh] (Primary)
3QWXVhT	Total Three phase reactive energy, Comb. Terminals WX	Megavars hours [Mvarh] (Primary)
3QXF	Instantaneous 3-phase fundamental reactive power, Terminal X	VARS [Var] (Secondary)
3QXFC	1 cycle average 3-phase fundamental reactive power, Terminal X	Megavars [Mvar] (Primary)
3QXMVhn	Three phase reactive energy imported, Terminal X	Megavars hours [Mvarh] (Primary)
3QXMVhp	Three phase reactive energy exported, Terminal X	Megavars hours [Mvarh] (Primary)
3QXMVhT	Total Three phase reactive energy, Terminal X	Megavars hours [Mvarh] (Primary)
3SSF	Instantaneous 3-phase fundamental apparent power, Terminal S	Voltamps [VA] (Secondary)
3SSFC	1 cycle average 3-phase fundamental apparent power, Terminal S	Mega Voltamps [MVA] (Primary)
3SSTF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals ST	Voltamps [VA] (Secondary)
3SSTFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)
3STF	Instantaneous 3-phase fundamental apparent power, Terminal T	Voltamps [VA] (Secondary)
3STFC	1 cycle average 3-phase fundamental apparent power, Terminal T	Mega Voltamps [MVA] (Primary)
3STUF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals TU	Voltamps [VA] (Secondary)
3STUFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)
3SUF	Instantaneous 3-phase fundamental apparent power, Terminal U	Voltamps [VA] (Secondary)
3SUFC	1 cycle average 3-phase fundamental apparent power, Terminal U	Mega Voltamps [MVA] (Primary)
3SUWF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals UW	Voltamps [VA] (Secondary)
3SUWFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
3SWF	Instantaneous 3-phase fundamental apparent power, Terminal W	Voltamps [VA] (Secondary)
3SWFC	1 cycle average 3-phase fundamental apparent power, Terminal W	Mega Voltamps [MVA] (Primary)
3SWXF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals WX	Voltamps [VA] (Secondary)
3SWXFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
3SXF	Instantaneous 3-phase fundamental apparent power, Terminal X	Voltamps [VA] (Secondary)
3SXFC	1 cycle average 3-phase fundamental apparent power, Terminal X	Mega Voltamps [MVA] (Primary)

Table H.1 **Analog Quantities Sorted Alphabetically** (Sheet 9 of 38)

Label	Description	Units
3V0VA	Instantaneous zero-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V0VAC	1 cycle average zero-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V0VI	Instantaneous zero-sequence Voltage, Imaginary component, Terminal V	Volts [V] (Secondary)
3V0VM	Instantaneous zero-sequence Voltage magnitude, Terminal V	Volts [V] (Secondary)
3V0VMC	1 cycle average zero-sequence Voltage magnitude, Terminal V	Kilovolts [kV] (primary)
3V0VR	Instantaneous zero-sequence Voltage, Real component, Terminal V	Volts [V] (Secondary)
3V0ZA	Instantaneous zero-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V0ZAC	1 cycle average zero-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V0ZI	Instantaneous zero-sequence Voltage, Imaginary component, Terminal Z	Volts [V] (Secondary)
3V0ZM	Instantaneous zero-sequence Voltage magnitude, Terminal Z	Volts [V] (Secondary)
3V0ZMC	1 cycle average zero-sequence Voltage magnitude, Terminal Z	Kilovolts [kV] (primary)
3V0ZR	Instantaneous zero-sequence Voltage, Real component, Terminal Z	Volts [V] (Secondary)
3V2VA	Instantaneous negative-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V2VAC	1 cycle average negative-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V2VI	Instantaneous negative-sequence Voltage, Imaginary component, Terminal V	Volts [V] (Secondary)
3V2VM	Instantaneous negative-sequence Voltage magnitude, Terminal V	Volts [V] (Secondary)
3V2VMC	1 cycle average negative-sequence Voltage magnitude, Terminal V	Kilovolts [kV] (primary)
3V2VR	Instantaneous negative-sequence Voltage, Real component, Terminal V	Volts [V] (Secondary)
3V2ZA	Instantaneous negative-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V2ZAC	1 cycle average negative-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V2ZI	Instantaneous negative-sequence Voltage, Imaginary component, Terminal Z	Volts [V] (Secondary)
3V2ZM	Instantaneous negative-sequence Voltage magnitude, Terminal Z	Volts [V] (Secondary)
3V2ZMC	1 cycle average negative-sequence Voltage magnitude, Terminal Z	Kilovolts [kV] (primary)
3V2ZR	Instantaneous negative-sequence Voltage, Real component, Terminal Z	Volts [V] (Secondary)
46AS	Current Unbalance Phase A, Terminal S	percent
46AT	Current Unbalance Phase A, Terminal T	percent
46AU	Current Unbalance Phase A, Terminal U	percent
46AW	Current Unbalance Phase A, Terminal W	percent
46AX	Current Unbalance Phase A, Terminal X	percent
46BS	Current Unbalance Phase B, Terminal S	percent
46BT	Current Unbalance Phase B, Terminal T	percent
46BU	Current Unbalance Phase B, Terminal U	percent
46BW	Current Unbalance Phase B, Terminal W	percent
46BX	Current Unbalance Phase B, Terminal X	percent
46CS	Current Unbalance Phase C, Terminal S	percent
46CT	Current Unbalance Phase C, Terminal T	percent
46CU	Current Unbalance Phase C, Terminal U	percent
46CW	Current Unbalance Phase C, Terminal W	percent
46CX	Current Unbalance Phase C, Terminal X	percent
51P01–51P10	51 element 01–10 pickup value	Amperes [A] (secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 10 of 38)

Label	Description	Units
51TD01–51TD10	51 element 01–10 Time dial setting	NA
87IOPAC	1 cycle average differential element operating current	Per Unit [p.u]
87IOPBC	1 cycle average differential element operating current	Per Unit [p.u]
87IOPCC	1 cycle average differential element operating current	Per Unit [p.u]
87IRTAC	1 cycle average differential element restraint current	Per Unit [p.u]
87IRTBC	1 cycle average differential element restraint current	Per Unit [p.u]
87IRTCC	1 cycle average differential element restraint current	Per Unit [p.u]
ACN01CV–ACN32PV	Automation SELOGIC Counter Current Value	unitless
ACTGRP	Active Group setting	
AMV001–AMV256	Automation SELOGIC Math Variable	Function dependent
AST01ET–AST32ET	Automation SELOGIC Sequencing Timer Elapsed Time	unitless
AST01PT–AST32PT	Automation SELOGIC Sequencing Timer Preset Time	unitless
BSBCWPA	Breaker S Breaker-Contact Wear for pole A	percent
BSBCWPB	Breaker S Breaker-Contact Wear for pole B	percent
BSBCWPC	Breaker S Breaker-Contact Wear for pole C	percent
BTBCWPA	Breaker T Breaker-Contact Wear for pole A	percent
BTBCWPB	Breaker T Breaker-Contact Wear for pole B	percent
BTBCWPC	Breaker T Breaker-Contact Wear for pole C	percent
BUBCWPA	Breaker U Breaker-Contact Wear for pole A	percent
BUBCWPB	Breaker U Breaker-Contact Wear for pole B	percent
BUBCWPC	Breaker U Breaker-Contact Wear for pole C	percent
BWBCWPA	Breaker W Breaker-Contact Wear for pole A	percent
BWBCWPB	Breaker W Breaker-Contact Wear for pole B	percent
BWBCWPC	Breaker W Breaker-Contact Wear for pole C	percent
BXBCWPA	Breaker X Breaker-Contact Wear for pole A	percent
BXBCWPB	Breaker X Breaker-Contact Wear for pole B	percent
BXBCWPC	Breaker X Breaker-Contact Wear for pole C	percent
DCMAX	Maximum DC 1 voltage	Volts [V]
DCMIN	Minimum DC 1 voltage	Volts [V]
DCNE	Average Negative to Ground DC 1 voltage	Volts [V]
DCPO	Average Positive to Ground DC 1 voltage	Volts [V]
DCRI	AC ripple of DC 1 voltage	Volts [V]
DDOM	Date	day
DDOW	Date	
DDOY	Date	day
DFDTPM	Rate-of-change of Frequency for Synchrophasor Data	Hertz/seconds [Hz/s]
DFDTPMD	Rate-of-change of Frequency for Synchrophasor Data, delayed for RTC alignment	Hertz/seconds [Hz/s]
DM01–DM10	Demand Metering value	Amps (A) (secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 11 of 38)

Label	Description	Units
DMM01–DMM10	Demand Metering maximum value	Amps (A) (secondary)
DMON	Date	month
DPFAS	Phase Displacement power factor, Phase A, Terminal S	(unitless - ratio)
DPFAST	Phase Displacement power factor, Phase A, Comb. Terminals ST	(unitless - ratio)
DPFAT	Phase Displacement power factor, Phase A, Terminal T	(unitless - ratio)
DPFATU	Phase Displacement power factor, Phase A, Comb. Terminals TU	(unitless - ratio)
DPFAU	Phase Displacement power factor, Phase A, Terminal U	(unitless - ratio)
DPFAUW	Phase Displacement power factor, Phase A, Comb. Terminals UW	(unitless - ratio)
DPFAW	Phase Displacement power factor, Phase A, Terminal W	(unitless - ratio)
DPFAWX	Phase Displacement power factor, Phase A, Comb. Terminals WX	(unitless - ratio)
DPFAX	Phase Displacement power factor, Phase A, Terminal X	(unitless - ratio)
DPFBS	Phase Displacement power factor, Phase B, Terminal S	(unitless - ratio)
DPFBST	Phase Displacement power factor, Phase B, Comb. Terminals ST	(unitless - ratio)
DPFBT	Phase Displacement power factor, Phase B, Terminal T	(unitless - ratio)
DPFBTU	Phase Displacement power factor, Phase B, Comb. Terminals TU	(unitless - ratio)
DPFBU	Phase Displacement power factor, Phase B, Terminal U	(unitless - ratio)
DPFBUW	Phase Displacement power factor, Phase B, Comb. Terminals UW	(unitless - ratio)
DPFBW	Phase Displacement power factor, Phase B, Terminal W	(unitless - ratio)
DPFBWX	Phase Displacement power factor, Phase B, Comb. Terminals WX	(unitless - ratio)
DPFBX	Phase Displacement power factor, Phase B, Terminal X	(unitless - ratio)
DPFCS	Phase Displacement power factor, Phase C, Terminal S	(unitless - ratio)
DPFCST	Phase Displacement power factor, Phase C, Comb. Terminals ST	(unitless - ratio)
DPFCT	Phase Displacement power factor, Phase C, Terminal T	(unitless - ratio)
DPFCTU	Phase Displacement power factor, Phase C, Comb. Terminals TU	(unitless - ratio)
DPFCU	Phase Displacement power factor, Phase C, Terminal U	(unitless - ratio)
DPFCUW	Phase Displacement power factor, Phase C, Comb. Terminals UW	(unitless - ratio)
DPFCW	Phase Displacement power factor, Phase C, Terminal W	(unitless - ratio)
DPFCWX	Phase Displacement power factor, Phase C, Comb. Terminals WX	(unitless - ratio)
DPFCX	Phase Displacement power factor, Phase C, Terminal X	(unitless - ratio)
DYEAR	Date	year
FOSPM	Fraction of Second of the Synchrophasor Data Packet	Seconds [s]
FOSPMD	Fraction of Second of the Synchrophasor Data Packet, delayed for RTC alignment	Seconds [s]
FREQ	Tracking frequency	Hz
FREQP	Frequency for Under/Over frequency elements	Hz
FREQPM	Frequency for Synchrophasor Data	Hertz [Hz]
FREQPMD	Frequency for Synchrophasor Data, delayed for RTC alignment	Hertz [Hz]
I1SA	Instantaneous positive-sequence current angle, Terminal S	Degrees [°] (±180°)
I1SAC	1 cycle average positive-sequence current angle, Terminal S	Degrees [°] (±180°)
I1SI	Instantaneous positive-sequence current, Imaginary component, Terminal S	Amps [A] (Secondary)
I1SM	Instantaneous positive-sequence current magnitude, Terminal S	Amps [A] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 12 of 38)

Label	Description	Units
I1SMC	1 cycle average positive-sequence current magnitude, Terminal S	Amps [A] (primary)
I1SPMA	Positive-sequence Synchrophasor current angle, Terminal S	Degrees [°] (±180°)
I1SPMAD	Positive-sequence Synchrophasor current angle, Terminal S, delayed for RTC alignment	Degrees [°] (±180°)
I1SPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal S	Amperes [A] (Primary)
I1SPMID	Positive-sequence Synchrophasor current Imaginary component, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
I1SPMM	Positive-sequence Synchrophasor current magnitude, Terminal S	Amperes [A] (Primary)
I1SPMMD	Positive-sequence Synchrophasor current magnitude, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
I1SPMR	Positive-sequence Synchrophasor current Real component, Terminal S	Amperes [A] (Primary)
I1SPMRD	Positive-sequence Synchrophasor current Real component, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
I1SR	Instantaneous positive-sequence current, Real component, Terminal S	Amps [A] (Secondary)
I1STA	Instantaneous positive-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
I1STAC	1 cycle average positive-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
I1STI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals ST	Amps [A] (Secondary)
I1STM	Instantaneous positive-sequence current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
I1STMC	1 cycle average positive-sequence current magnitude, Comb. Terminals ST	Amps [A] (primary)
I1STR	Instantaneous positive-sequence current, Real component, Comb. Terminals ST	Amps [A] (Secondary)
I1TA	Instantaneous positive-sequence current angle, Terminal T	Degrees [°] (±180°)
I1TAC	1 cycle average positive-sequence current angle, Terminal T	Degrees [°] (±180°)
I1TI	Instantaneous positive-sequence current, Imaginary component, Terminal T	Amps [A] (Secondary)
I1TM	Instantaneous positive-sequence current magnitude, Terminal T	Amps [A] (Secondary)
I1TMC	1 cycle average positive-sequence current magnitude, Terminal T	Amps [A] (primary)
I1TPMA	Positive-sequence Synchrophasor current angle, Terminal T	Degrees [°] (±180°)
I1TPMAD	Positive-sequence Synchrophasor current angle, Terminal T, delayed for RTC alignment	Degrees [°] (±180°)
I1TPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal T	Amperes [A] (Primary)
I1TPMID	Positive-sequence Synchrophasor current Imaginary component, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
I1TPMM	Positive-sequence Synchrophasor current magnitude, Terminal T	Amperes [A] (Primary)
I1TPMMD	Positive-sequence Synchrophasor current magnitude, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
I1TPMR	Positive-sequence Synchrophasor current Real component, Terminal T	Amperes [A] (Primary)
I1TPMRD	Positive-sequence Synchrophasor current Real component, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
I1TR	Instantaneous positive-sequence current, Real component, Terminal T	Amps [A] (Secondary)
I1TUA	Instantaneous positive-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
I1TUAC	1 cycle average positive-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
I1TUI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals TU	Amps [A] (Secondary)
I1TUM	Instantaneous positive-sequence current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
I1TUMC	1 cycle average positive-sequence current magnitude, Comb. Terminals TU	Amps [A] (primary)
I1TUR	Instantaneous positive-sequence current, Real component, Comb. Terminals TU	Amps [A] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 13 of 38)

Label	Description	Units
I1UA	Instantaneous positive-sequence current angle, Terminal U	Degrees [°] (±180°)
I1UAC	1 cycle average positive-sequence current angle, Terminal U	Degrees [°] (±180°)
I1UI	Instantaneous positive-sequence current, Imaginary component, Terminal U	Amps [A] (Secondary)
I1UM	Instantaneous positive-sequence current magnitude, Terminal U	Amps [A] (Secondary)
I1UMC	1 cycle average positive-sequence current magnitude, Terminal U	Amps [A] (primary)
I1UPMA	Positive-sequence Synchrophasor current angle, Terminal U	Degrees [°] (±180°)
I1UPMAD	Positive-sequence Synchrophasor current angle, Terminal U, delayed for RTC alignment	Degrees [°] (±180°)
I1UPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal U	Amperes [A] (Primary)
I1UPMID	Positive-sequence Synchrophasor current Imaginary component, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
I1UPMM	Positive-sequence Synchrophasor current magnitude, Terminal U	Amperes [A] (Primary)
I1UPMMD	Positive-sequence Synchrophasor current magnitude, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
I1UPMR	Positive-sequence Synchrophasor current Real component, Terminal U	Amperes [A] (Primary)
I1UPMRD	Positive-sequence Synchrophasor current Real component, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
I1UR	Instantaneous positive-sequence current, Real component, Terminal U	Amps [A] (Secondary)
I1UWA	Instantaneous positive-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
I1UWAC	1 cycle average positive-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
I1UWI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals UW	Amps [A] (Secondary)
I1UWM	Instantaneous positive-sequence current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
I1UWMC	1 cycle average positive-sequence current magnitude, Comb. Terminals UW	Amps [A] (primary)
I1UWR	Instantaneous positive-sequence current, Real component, Comb. Terminals UW	Amps [A] (Secondary)
I1WA	Instantaneous positive-sequence current angle, Terminal W	Degrees [°] (±180°)
I1WAC	1 cycle average positive-sequence current angle, Terminal W	Degrees [°] (±180°)
I1WI	Instantaneous positive-sequence current, Imaginary component, Terminal W	Amps [A] (Secondary)
I1WM	Instantaneous positive-sequence current magnitude, Terminal W	Amps [A] (Secondary)
I1WMC	1 cycle average positive-sequence current magnitude, Terminal W	Amps [A] (primary)
I1WPMA	Positive-sequence Synchrophasor current angle, Terminal W	Degrees [°] (±180°)
I1WPMAD	Positive-sequence Synchrophasor current angle, Terminal W, delayed for RTC alignment	Degrees [°] (±180°)
I1WPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal W	Amperes [A] (Primary)
I1WPMID	Positive-sequence Synchrophasor current Imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
I1WPMM	Positive-sequence Synchrophasor current magnitude, Terminal W	Amperes [A] (Primary)
I1WPMMD	Positive-sequence Synchrophasor current magnitude, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
I1WPMR	Positive-sequence Synchrophasor current Real component, Terminal W	Amperes [A] (Primary)
I1WPMRD	Positive-sequence Synchrophasor current Real component, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
I1WR	Instantaneous positive-sequence current, Real component, Terminal W	Amps [A] (Secondary)
I1WXA	Instantaneous positive-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
I1WXAC	1 cycle average positive-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 14 of 38)

Label	Description	Units
I1WXI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals WX	Amps [A] (Secondary)
I1WXM	Instantaneous positive-sequence current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
I1WXMC	1 cycle average positive-sequence current magnitude, Comb. Terminals WX	Amps [A] (primary)
I1WXR	Instantaneous positive-sequence current, Real component, Comb. Terminals WX	Amps [A] (Secondary)
I1XA	Instantaneous positive-sequence current angle, Terminal X	Degrees [°] (±180°)
I1XAC	1 cycle average positive-sequence current angle, Terminal X	Degrees [°] (±180°)
I1XI	Instantaneous positive-sequence current, Imaginary component, Terminal X	Amps [A] (Secondary)
I1XM	Instantaneous positive-sequence current magnitude, Terminal X	Amps [A] (Secondary)
I1XMC	1 cycle average positive-sequence current magnitude, Terminal X	Amps [A] (primary)
I1XPMA	Positive-sequence Synchrophasor current angle, Terminal X	Degrees [°] (±180°)
I1XPMAD	Positive-sequence Synchrophasor current angle, Terminal X, delayed for RTC alignment	Degrees [°] (±180°)
I1XPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal X	Amperes [A] (Primary)
I1XPMID	Positive-sequence Synchrophasor current Imaginary component, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
I1XPMM	Positive-sequence Synchrophasor current magnitude, Terminal X	Amperes [A] (Primary)
I1XPMMD	Positive-sequence Synchrophasor current magnitude, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
I1XPMR	Positive-sequence Synchrophasor current Real component, Terminal X	Amperes [A] (Primary)
I1XPMRD	Positive-sequence Synchrophasor current Real component, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
I1XR	Instantaneous positive-sequence current, Real component, Terminal X	Amps [A] (Secondary)
I1YPMA	Positive-sequence Synchrophasor current angle, Terminal Y	Degrees [°] (±180°)
I1YPMAD	Positive-sequence Synchrophasor current angle, Terminal Y, delayed for RTC alignment	Degrees [°] (±180°)
I1YPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal Y	Amperes [A] (Primary)
I1YPMID	Positive-sequence Synchrophasor current Imaginary component, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
I1YPMM	Positive-sequence Synchrophasor current magnitude, Terminal Y	Amperes [A] (Primary)
I1YPMMD	Positive-sequence Synchrophasor current magnitude, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
I1YPMR	Positive-sequence Synchrophasor current Real component, Terminal Y	Amperes [A] (Primary)
I1YPMRD	Positive-sequence Synchrophasor current Real component, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
IAM2	2nd Harmonic current content of operating current	Per Unit [p.u]
IAM4	4th Harmonic current content of operating current	Per Unit [p.u]
IAM5	5th Harmonic current content of operating current	Per Unit [p.u]
IASFA	Instantaneous Filtered phase current angle, Phase A, Terminal S	Degrees [°] (±180°)
IASFAC	1 cycle average filtered phase current angle, Phase A, Terminal S	Degrees [°] (±180°)
IASFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IASFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal S	Amps [A] (Secondary)
IASFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal S	Amps [A] (primary)
IASFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IASPMA	Synchrophasor current angle, Phase A, Terminal S	Degrees [°] (±180°)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 15 of 38)

Label	Description	Units
IASPMAD	Synchrophasor current angle, Phase A, Terminal S, delayed for RTC alignment	Degrees [°] (±180°)
IASPMI	Synchrophasor current Imaginary component, Phase A, Terminal S	Amperes [A] (Primary)
IASPMID	Synchrophasor current Imaginary component, Phase A, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
IASPMM	Synchrophasor current magnitude, Phase A, Terminal S	Amperes [A] (Primary)
IASPMMD	Synchrophasor current magnitude, Phase A, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
IASPMR	Synchrophasor current Real component, Phase A, Terminal S	Amperes [A] (Primary)
IASPMRD	Synchrophasor current Real component, Phase A, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
IASRC	1 cycle average RMS phase current, Phase A, Terminal S	Amps [A] (primary)
IASRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal S	Amps [A] (Secondary)
IASRS	1 second average RMS phase current, Phase A, Terminal S	Amperes [A]
IASTFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals ST	Degrees [°] (±180°)
IASTFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals ST	Degrees [°] (±180°)
IASTFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IASTFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals ST	Amps [A] (Secondary)
IASTFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals ST	Amps [A] (primary)
IASTFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IASTRC	1 cycle average RMS phase current, Phase A, Comb. Terminals ST	Amps [A] (primary)
IASTRMS	Instantaneous RMS phase current, Phase A, Comb. Terminals ST	Amps [A] (Secondary)
IASTRS	1 second average RMS phase current, Phase A, Comb. Terminals ST	Amperes [A]
IATFA	Instantaneous Filtered phase current angle, Phase A, Terminal T	Degrees [°] (±180°)
IATFAC	1 cycle average filtered phase current angle, Phase A, Terminal T	Degrees [°] (±180°)
IATFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IATFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal T	Amps [A] (Secondary)
IATFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal T	Amps [A] (primary)
IATFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IATPMA	Synchrophasor current angle, Phase A, Terminal T	Degrees [°] (±180°)
IATPMAD	Synchrophasor current angle, Phase A, Terminal T, delayed for RTC alignment	Degrees [°] (±180°)
IATPMI	Synchrophasor current Imaginary component, Phase A, Terminal T	Amperes [A] (Primary)
IATPMID	Synchrophasor current Imaginary component, Phase A, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
IATPMM	Synchrophasor current magnitude, Phase A, Terminal T	Amperes [A] (Primary)
IATPMMD	Synchrophasor current magnitude, Phase A, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
IATPMR	Synchrophasor current Real component, Phase A, Terminal T	Amperes [A] (Primary)
IATPMRD	Synchrophasor current Real component, Phase A, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
IATRC	1 cycle average RMS phase current, Phase A, Terminal T	Amps [A] (primary)
IATRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal T	Amps [A] (Secondary)
IATRS	1 second average RMS phase current, Phase A, Terminal T	Amperes [A]
IATUFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals TU	Degrees [°] (±180°)
IATUFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals TU	Degrees [°] (±180°)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 16 of 38)

Label	Description	Units
IATUFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IATUFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals TU	Amps [A] (Secondary)
IATUFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals TU	Amps [A] (primary)
IATUFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IATURC	1 cycle average RMS phase current, Phase A, Comb. Terminals TU	Amps [A] (primary)
IATURMS	Instantaneous RMS phase current, Phase A, Comb. Terminals TU	Amps [A] (Secondary)
IATURS	1 second average RMS phase current, Phase A, Comb. Terminals TU	Amperes [A]
IAUFA	Instantaneous Filtered phase current angle, Phase A, Terminal U	Degrees [°] (±180°)
IAUFAC	1 cycle average filtered phase current angle, Phase A, Terminal U	Degrees [°] (±180°)
IAUFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IAUFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal U	Amps [A] (Secondary)
IAUFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal U	Amps [A] (primary)
IAUFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IAUPMA	Synchrophasor current angle, Phase A, Terminal U	Degrees [°] (±180°)
IAUPMAD	Synchrophasor current angle, Phase A, Terminal U, delayed for RTC alignment	Degrees [°] (±180°)
IAUPMI	Synchrophasor current Imaginary component, Phase A, Terminal U	Amperes [A] (Primary)
IAUPMID	Synchrophasor current Imaginary component, Phase A, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
IAUPMM	Synchrophasor current magnitude, Phase A, Terminal U	Amperes [A] (Primary)
IAUPMMD	Synchrophasor current magnitude, Phase A, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
IAUPMR	Synchrophasor current Real component, Phase A, Terminal U	Amperes [A] (Primary)
IAUPMRD	Synchrophasor current Real component, Phase A, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
IAURC	1 cycle average RMS phase current, Phase A, Terminal U	Amps [A] (primary)
IAURMS	Instantaneous RMS phase current magnitude, Phase A, Terminal U	Amps [A] (Secondary)
IAURS	1 second average RMS phase current, Phase A, Terminal U	Amperes [A]
IAUWFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals UW	Degrees [°] (±180°)
IAUWFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals UW	Degrees [°] (±180°)
IAUWFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IAUWFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals UW	Amps [A] (Secondary)
IAUWFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals UW	Amps [A] (primary)
IAUWFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IAUWRC	1 cycle average RMS phase current, Phase A, Comb. Terminals UW	Amps [A] (primary)
IAUWRMS	Instantaneous RMS phase current, Phase A, Comb. Terminals UW	Amps [A] (Secondary)
IAUWRS	1 second average RMS phase current, Phase A, Comb. Terminals UW	Amperes [A]
IAWFA	Instantaneous Filtered phase current angle, Phase A, Terminal W	Degrees [°] (±180°)
IAWFAC	1 cycle average filtered phase current angle, Phase A, Terminal W	Degrees [°] (±180°)
IAWFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IAWFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal W	Amps [A] (Secondary)
IAWFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal W	Amps [A] (primary)
IAWFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IAWPMA	Synchrophasor current angle, Phase A, Terminal W	Degrees [°] (±180°)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 17 of 38)

Label	Description	Units
IAWPMAD	Synchrophasor current angle, Phase A, Terminal W, delayed for RTC alignment	Degrees [°] (±180°)
IAWPMI	Synchrophasor current Imaginary component, Phase A, Terminal W	Amperes [A] (Primary)
IAWPMID	Synchrophasor current Imaginary component, Phase A, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
IAWPMM	Synchrophasor current magnitude, Phase A, Terminal W	Amperes [A] (Primary)
IAWPMMD	Synchrophasor current magnitude, Phase A, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
IAWPMR	Synchrophasor current Real component, Phase A, Terminal W	Amperes [A] (Primary)
IAWPMRD	Synchrophasor current Real component, Phase A, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
IAWRC	1 cycle average RMS phase current, Phase A, Terminal W	Amps [A] (primary)
IAWRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal W	Amps [A] (Secondary)
IAWRS	1 second average RMS phase current, Phase A, Terminal W	Amperes [A]
IAWXFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals WX	Degrees [°] (±180°)
IAWXFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals WX	Degrees [°] (±180°)
IAWXFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IAWXFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals WX	Amps [A] (Secondary)
IAWXFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals WX	Amps [A] (primary)
IAWXFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IAWXRC	1 cycle average RMS phase current, Phase A, Comb. Terminals WX	Amps [A] (primary)
IAWXRMS	Instantaneous RMS phase current, Phase A, Comb. Terminals WX	Amps [A] (Secondary)
IAWXRS	1 second average RMS phase current, Phase A, Comb. Terminals WX	Amperes [A]
IAXFA	Instantaneous Filtered phase current angle, Phase A, Terminal X	Degrees [°] (±180°)
IAXFAC	1 cycle average filtered phase current angle, Phase A, Terminal X	Degrees [°] (±180°)
IAXFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IAXFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal X	Amps [A] (Secondary)
IAXFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal X	Amps [A] (primary)
IAXFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IAXPMA	Synchrophasor current angle, Phase A, Terminal X	Degrees [°] (±180°)
IAXPMAD	Synchrophasor current angle, Phase A, Terminal X, delayed for RTC alignment	Degrees [°] (±180°)
IAXPMI	Synchrophasor current Imaginary component, Phase A, Terminal X	Amperes [A] (Primary)
IAXPMID	Synchrophasor current Imaginary component, Phase A, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
IAXPMM	Synchrophasor current magnitude, Phase A, Terminal X	Amperes [A] (Primary)
IAXPMMD	Synchrophasor current magnitude, Phase A, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
IAXPMR	Synchrophasor current Real component, Phase A, Terminal X	Amperes [A] (Primary)
IAXPMRD	Synchrophasor current Real component, Phase A, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
IAXRC	1 cycle average RMS phase current, Phase A, Terminal X	Amps [A] (primary)
IAXRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal X	Amps [A] (Secondary)
IAXRS	1 second average RMS phase current, Phase A, Terminal X	Amperes [A]
IAYPMA	Synchrophasor current angle, Phase A, Terminal Y	Degrees [°] (±180°)
IAYPMAD	Synchrophasor current angle, Phase A, Terminal Y, delayed for RTC alignment	Degrees [°] (±180°)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 18 of 38)

Label	Description	Units
IAYPMI	Synchrophasor current Imaginary component, Phase A, Terminal Y	Amperes [A] (Primary)
IAYPMID	Synchrophasor current Imaginary component, Phase A, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
IAYPMM	Synchrophasor current magnitude, Phase A, Terminal Y	Amperes [A] (Primary)
IAYPMMD	Synchrophasor current magnitude, Phase A, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
IAYPMR	Synchrophasor current Real component, Phase A, Terminal Y	Amperes [A] (Primary)
IAYPMRD	Synchrophasor current Real component, Phase A, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
IBM2	2nd Harmonic current content of operating current	Per Unit [p.u]
IBM4	4th Harmonic current content of operating current	Per Unit [p.u]
IBM5	5th Harmonic current content of operating current	Per Unit [p.u]
IBSFA	Instantaneous Filtered phase current angle, Phase B, Terminal S	Degrees [°] (±180°)
IBSFAC	1 cycle average filtered phase current angle, Phase B, Terminal S	Degrees [°] (±180°)
IBSFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
IBSFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal S	Amps [A] (Secondary)
IBSFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal S	Amps [A] (primary)
IBSFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBSPMA	Synchrophasor current angle, Phase B, Terminal S	Degrees [°] (±180°)
IBSPMAD	Synchrophasor current angle, Phase B, Terminal S, delayed for RTC alignment	Degrees [°] (±180°)
IBSPMI	Synchrophasor current Imaginary component, Phase B, Terminal S	Amperes [A] (Primary)
IBSPMID	Synchrophasor current Imaginary component, Phase B, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
IBSPMM	Synchrophasor current magnitude, Phase B, Terminal S	Amperes [A] (Primary)
IBSPMMD	Synchrophasor current magnitude, Phase B, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
IBSPMR	Synchrophasor current Real component, Phase B, Terminal S	Amperes [A] (Primary)
IBSPMRD	Synchrophasor current Real component, Phase B, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
IBSRC	1 cycle average RMS phase current, Phase B, Terminal S	Amps [A] (primary)
IBSRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal S	Amps [A] (Secondary)
IBSRS	1 second average RMS phase current, Phase B, Terminal S	Amperes [A]
IBSTFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals ST	Degrees [°] (±180°)
IBSTFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals ST	Degrees [°] (±180°)
IBSTFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
IBSTFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals ST	Amps [A] (Secondary)
IBSTFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals ST	Amps [A] (primary)
IBSTFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBSTRC	1 cycle average RMS phase current, Phase B, Comb. Terminals ST	Amps [A] (primary)
IBSTRMS	Instantaneous RMS phase current, Phase B, Comb. Terminals ST	Amps [A] (Secondary)
IBSTRS	1 second average RMS phase current, Phase B, Comb. Terminals ST	Amperes [A]
IBTFA	Instantaneous Filtered phase current angle, Phase B, Terminal T	Degrees [°] (±180°)
IBTFAC	1 cycle average filtered phase current angle, Phase B, Terminal T	Degrees [°] (±180°)
IBTFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 19 of 38)

Label	Description	Units
IBTFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal T	Amps [A] (Secondary)
IBTFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal T	Amps [A] (primary)
IBTFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBTPMA	Synchrophasor current angle, Phase B, Terminal T	Degrees [°] (±180°)
IBTPMAD	Synchrophasor current angle, Phase B, Terminal T, delayed for RTC alignment	Degrees [°] (±180°)
IBTPMI	Synchrophasor current Imaginary component, Phase B, Terminal T	Amperes [A] (Primary)
IBTPMID	Synchrophasor current Imaginary component, Phase B, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
IBTPMM	Synchrophasor current magnitude, Phase B, Terminal T	Amperes [A] (Primary)
IBTPMMD	Synchrophasor current magnitude, Phase B, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
IBTPMR	Synchrophasor current Real component, Phase B, Terminal T	Amperes [A] (Primary)
IBTPMRD	Synchrophasor current Real component, Phase B, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
IBTRC	1 cycle average RMS phase current, Phase B, Terminal T	Amps [A] (primary)
IBTRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal T	Amps [A] (Secondary)
IBTRS	1 second average RMS phase current, Phase B, Terminal T	Amperes [A]
IBTUFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals TU	Degrees [°] (±180°)
IBTUFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals TU	Degrees [°] (±180°)
IBTUFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
IBTUFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals TU	Amps [A] (Secondary)
IBTUFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals TU	Amps [A] (primary)
IBTUFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBTURC	1 cycle average RMS phase current, Phase B, Comb. Terminals TU	Amps [A] (primary)
IBTURMS	Instantaneous RMS phase current, Phase B, Comb. Terminals TU	Amps [A] (Secondary)
IBTURS	1 second average RMS phase current, Phase B, Comb. Terminals TU	Amperes [A]
IBUFA	Instantaneous Filtered phase current angle, Phase B, Terminal U	Degrees [°] (±180°)
IBUFAC	1 cycle average filtered phase current angle, Phase B, Terminal U	Degrees [°] (±180°)
IBUFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
IBUFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal U	Amps [A] (Secondary)
IBUFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal U	Amps [A] (primary)
IBUFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBUPMA	Synchrophasor current angle, Phase B, Terminal U	Degrees [°] (±180°)
IBUPMAD	Synchrophasor current angle, Phase B, Terminal U, delayed for RTC alignment	Degrees [°] (±180°)
IBUPMI	Synchrophasor current Imaginary component, Phase B, Terminal U	Amperes [A] (Primary)
IBUPMID	Synchrophasor current Imaginary component, Phase B, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
IBUPMM	Synchrophasor current magnitude, Phase B, Terminal U	Amperes [A] (Primary)
IBUPMMD	Synchrophasor current magnitude, Phase B, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
IBUPMR	Synchrophasor current Real component, Phase B, Terminal U	Amperes [A] (Primary)
IBUPMRD	Synchrophasor current Real component, Phase B, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
IBURC	1 cycle average RMS phase current, Phase B, Terminal U	Amps [A] (primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 20 of 38)

Label	Description	Units
IBURMS	Instantaneous RMS phase current magnitude, Phase B, Terminal U	Amps [A] (Secondary)
IBURS	1 second average RMS phase current, Phase B, Terminal U	Amperes [A]
IBUWFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals UW	Degrees [°] (±180°)
IBUWFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals UW	Degrees [°] (±180°)
IBUWFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
IBUWFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals UW	Amps [A] (Secondary)
IBUWFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals UW	Amps [A] (primary)
IBUWFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBUWRC	1 cycle average RMS phase current, Phase B, Comb. Terminals UW	Amps [A] (primary)
IBUWRMS	Instantaneous RMS phase current, Phase B, Comb. Terminals UW	Amps [A] (Secondary)
IBUWRS	1 second average RMS phase current, Phase B, Comb. Terminals UW	Amperes [A]
IBWFA	Instantaneous Filtered phase current angle, Phase B, Terminal W	Degrees [°] (±180°)
IBWFAC	1 cycle average filtered phase current angle, Phase B, Terminal W	Degrees [°] (±180°)
IBWFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
IBWFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal W	Amps [A] (Secondary)
IBWFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal W	Amps [A] (primary)
IBWFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBWPMA	Synchrophasor current angle, Phase B, Terminal W	Degrees [°] (±180°)
IBWPMAD	Synchrophasor current angle, Phase B, Terminal W, delayed for RTC alignment	Degrees [°] (±180°)
IBWPMI	Synchrophasor current Imaginary component, Phase B, Terminal W	Amperes [A] (Primary)
IBWPMID	Synchrophasor current Imaginary component, Phase B, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
IBWPMM	Synchrophasor current magnitude, Phase B, Terminal W	Amperes [A] (Primary)
IBWPMMD	Synchrophasor current magnitude, Phase B, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
IBWPMR	Synchrophasor current Real component, Phase B, Terminal W	Amperes [A] (Primary)
IBWPMRD	Synchrophasor current Real component, Phase B, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
IBWRC	1 cycle average RMS phase current, Phase B, Terminal W	Amps [A] (primary)
IBWRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal W	Amps [A] (Secondary)
IBWRS	1 second average RMS phase current, Phase B, Terminal W	Amperes [A]
IBWXFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals WX	Degrees [°] (±180°)
IBWXFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals WX	Degrees [°] (±180°)
IBWXFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
IBWXFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals WX	Amps [A] (Secondary)
IBWXFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals WX	Amps [A] (primary)
IBWXFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBWXRC	1 cycle average RMS phase current, Phase B, Comb. Terminals WX	Amps [A] (primary)
IBWXRMS	Instantaneous RMS phase current, Phase B, Comb. Terminals WX	Amps [A] (Secondary)
IBWXRS	1 second average RMS phase current, Phase B, Comb. Terminals WX	Amperes [A]
IBXFA	Instantaneous Filtered phase current angle, Phase B, Terminal X	Degrees [°] (±180°)
IBXFAC	1 cycle average filtered phase current angle, Phase B, Terminal X	Degrees [°] (±180°)
IBXFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 21 of 38)

Label	Description	Units
IBXFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal X	Amps [A] (Secondary)
IBXFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal X	Amps [A] (primary)
IBXFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
IBXPMA	Synchrophasor current angle, Phase B, Terminal X	Degrees [°] (±180°)
IBXPMAD	Synchrophasor current angle, Phase B, Terminal X, delayed for RTC alignment	Degrees [°] (±180°)
IBXPMI	Synchrophasor current Imaginary component, Phase B, Terminal X	Amperes [A] (Primary)
IBXPMID	Synchrophasor current Imaginary component, Phase B, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
IBXPMM	Synchrophasor current magnitude, Phase B, Terminal X	Amperes [A] (Primary)
IBXPMMD	Synchrophasor current magnitude, Phase B, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
IBXPMR	Synchrophasor current Real component, Phase B, Terminal X	Amperes [A] (Primary)
IBXPMRD	Synchrophasor current Real component, Phase B, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
IBXRC	1 cycle average RMS phase current, Phase B, Terminal X	Amps [A] (primary)
IBXRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal X	Amps [A] (Secondary)
IBXRS	1 second average RMS phase current, Phase B, Terminal X	Amperes [A]
IBYPMA	Synchrophasor current angle, Phase B, Terminal Y	Degrees [°] (±180°)
IBYPMAD	Synchrophasor current angle, Phase B, Terminal Y, delayed for RTC alignment	Degrees [°] (±180°)
IBYPMI	Synchrophasor current Imaginary component, Phase B, Terminal Y	Amperes [A] (Primary)
IBYPMID	Synchrophasor current Imaginary component, Phase B, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
IBYPMM	Synchrophasor current magnitude, Phase B, Terminal Y	Amperes [A] (Primary)
IBYPMMD	Synchrophasor current magnitude, Phase B, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
IBYPMR	Synchrophasor current Real component, Phase B, Terminal Y	Amperes [A] (Primary)
IBYPMRD	Synchrophasor current Real component, Phase B, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
ICM2	2nd Harmonic current content of operating current	Per Unit [p.u]
ICM4	4th Harmonic current content of operating current	Per Unit [p.u]
ICM5	5th Harmonic current content of operating current	Per Unit [p.u]
ICSFA	Instantaneous Filtered phase current angle, Phase C, Terminal S	Degrees [°] (±180°)
ICSFAC	1 cycle average filtered phase current angle, Phase C, Terminal S	Degrees [°] (±180°)
ICSFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICSFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal S	Amps [A] (Secondary)
ICSFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal S	Amps [A] (primary)
ICSFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICSPMA	Synchrophasor current angle, Phase C, Terminal S	Degrees [°] (±180°)
ICSPMAD	Synchrophasor current angle, Phase C, Terminal S, delayed for RTC alignment	Degrees [°] (±180°)
ICSPMI	Synchrophasor current Imaginary component, Phase C, Terminal S	Amperes [A] (Primary)
ICSPMID	Synchrophasor current Imaginary component, Phase C, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
ICSPMM	Synchrophasor current magnitude, Phase C, Terminal S	Amperes [A] (Primary)
ICSPMMD	Synchrophasor current magnitude, Phase C, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
ICSPMR	Synchrophasor current Real component, Phase C, Terminal S	Amperes [A] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 22 of 38)

Label	Description	Units
ICSPMRD	Synchrophasor current Real component, Phase C, Terminal S, delayed for RTC alignment	Amperes [A] (Primary)
ICSRC	1 cycle average RMS phase current, Phase C, Terminal S	Amps [A] (primary)
ICSRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal S	Amps [A] (Secondary)
ICSRS	1 second average RMS phase current, Phase C, Terminal S	Amperes [A]
ICSTFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals ST	Degrees [°] (±180°)
ICSTFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals ST	Degrees [°] (±180°)
ICSTFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICSTFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals ST	Amps [A] (Secondary)
ICSTFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals ST	Amps [A] (primary)
ICSTFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICSTRC	1 cycle average RMS phase current, Phase C, Comb. Terminals ST	Amps [A] (primary)
ICSTRMS	Instantaneous RMS phase current, Phase C, Comb. Terminals ST	Amps [A] (Secondary)
ICSTRS	1 second average RMS phase current, Phase C, Comb. Terminals ST	Amperes [A]
ICTFA	Instantaneous Filtered phase current angle, Phase C, Terminal T	Degrees [°] (±180°)
ICTFAC	1 cycle average filtered phase current angle, Phase C, Terminal T	Degrees [°] (±180°)
ICTFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICTFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal T	Amps [A] (Secondary)
ICTFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal T	Amps [A] (primary)
ICTFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICTPMA	Synchrophasor current angle, Phase C, Terminal T	Degrees [°] (±180°)
ICTPMAD	Synchrophasor current angle, Phase C, Terminal T, delayed for RTC alignment	Degrees [°] (±180°)
ICTPMI	Synchrophasor current Imaginary component, Phase C, Terminal T	Amperes [A] (Primary)
ICTPMID	Synchrophasor current Imaginary component, Phase C, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
ICTPMM	Synchrophasor current magnitude, Phase C, Terminal T	Amperes [A] (Primary)
ICTPMMD	Synchrophasor current magnitude, Phase C, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
ICTPMR	Synchrophasor current Real component, Phase C, Terminal T	Amperes [A] (Primary)
ICTPMRD	Synchrophasor current Real component, Phase C, Terminal T, delayed for RTC alignment	Amperes [A] (Primary)
ICTRC	1 cycle average RMS phase current, Phase C, Terminal T	Amps [A] (primary)
ICTRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal T	Amps [A] (Secondary)
ICTRS	1 second average RMS phase current, Phase C, Terminal T	Amperes [A]
ICTUFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals TU	Degrees [°] (±180°)
ICTUFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals TU	Degrees [°] (±180°)
ICTUFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICTUFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals TU	Amps [A] (Secondary)
ICTUFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals TU	Amps [A] (primary)
ICTUFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICTURC	1 cycle average RMS phase current, Phase C, Comb. Terminals TU	Amps [A] (primary)
ICTURMS	Instantaneous RMS phase current, Phase C, Comb. Terminals TU	Amps [A] (Secondary)
ICTURS	1 second average RMS phase current, Phase C, Comb. Terminals TU	Amperes [A]

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 23 of 38)

Label	Description	Units
ICUFA	Instantaneous Filtered phase current angle, Phase C, Terminal U	Degrees [°] (±180°)
ICUFAC	1 cycle average filtered phase current angle, Phase C, Terminal U	Degrees [°] (±180°)
ICUFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICUFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal U	Amps [A] (Secondary)
ICUFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal U	Amps [A] (primary)
ICUFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICUPMA	Synchrophasor current angle, Phase C, Terminal U	Degrees [°] (±180°)
ICUPMAD	Synchrophasor current angle, Phase C, Terminal U, delayed for RTC alignment	Degrees [°] (±180°)
ICUPMI	Synchrophasor current Imaginary component, Phase C, Terminal U	Amperes [A] (Primary)
ICUPMID	Synchrophasor current Imaginary component, Phase C, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
ICUPMM	Synchrophasor current magnitude, Phase C, Terminal U	Amperes [A] (Primary)
ICUPMMD	Synchrophasor current magnitude, Phase C, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
ICUPMR	Synchrophasor current Real component, Phase C, Terminal U	Amperes [A] (Primary)
ICUPMRD	Synchrophasor current Real component, Phase C, Terminal U, delayed for RTC alignment	Amperes [A] (Primary)
ICURC	1 cycle average RMS phase current, Phase C, Terminal U	Amps [A] (primary)
ICURMS	Instantaneous RMS phase current magnitude, Phase C, Terminal U	Amps [A] (Secondary)
ICURS	1 second average RMS phase current, Phase C, Terminal U	Amperes [A]
ICUWFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals UW	Degrees [°] (±180°)
ICUWFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals UW	Degrees [°] (±180°)
ICUWFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICUWFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals UW	Amps [A] (Secondary)
ICUWFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals UW	Amps [A] (primary)
ICUWFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICUWRC	1 cycle average RMS phase current, Phase C, Comb. Terminals UW	Amps [A] (primary)
ICUWRMS	Instantaneous RMS phase current, Phase C, Comb. Terminals UW	Amps [A] (Secondary)
ICUWRS	1 second average RMS phase current, Phase C, Comb. Terminals UW	Amperes [A]
ICWFA	Instantaneous Filtered phase current angle, Phase C, Terminal W	Degrees [°] (±180°)
ICWFAC	1 cycle average filtered phase current angle, Phase C, Terminal W	Degrees [°] (±180°)
ICWFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICWFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal W	Amps [A] (Secondary)
ICWFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal W	Amps [A] (primary)
ICWFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICWPMA	Synchrophasor current angle, Phase C, Terminal W	Degrees [°] (±180°)
ICWPMAD	Synchrophasor current angle, Phase C, Terminal W, delayed for RTC alignment	Degrees [°] (±180°)
ICWPMI	Synchrophasor current Imaginary component, Phase C, Terminal W	Amperes [A] (Primary)
ICWPMID	Synchrophasor current Imaginary component, Phase C, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
ICWPMM	Synchrophasor current magnitude, Phase C, Terminal W	Amperes [A] (Primary)
ICWPMMD	Synchrophasor current magnitude, Phase C, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
ICWPMR	Synchrophasor current Real component, Phase C, Terminal W	Amperes [A] (Primary)

Table H.1 **Analog Quantities Sorted Alphabetically** (Sheet 24 of 38)

Label	Description	Units
ICWPMRD	Synchrophasor current Real component, Phase C, Terminal W, delayed for RTC alignment	Amperes [A] (Primary)
ICWRC	1 cycle average RMS phase current, Phase C, Terminal W	Amps [A] (primary)
ICWRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal W	Amps [A] (Secondary)
ICWRS	1 second average RMS phase current, Phase C, Terminal W	Amperes [A]
ICWXFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals WX	Degrees [°] (±180°)
ICWXFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals WX	Degrees [°] (±180°)
ICWXFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICWXFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals WX	Amps [A] (Secondary)
ICWXFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals WX	Amps [A] (primary)
ICWXFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICWXRC	1 cycle average RMS phase current, Phase C, Comb. Terminals WX	Amps [A] (primary)
ICWXRMS	Instantaneous RMS phase current, Phase C, Comb. Terminals WX	Amps [A] (Secondary)
ICWXRS	1 second average RMS phase current, Phase C, Comb. Terminals WX	Amperes [A]
ICXFA	Instantaneous Filtered phase current angle, Phase C, Terminal X	Degrees [°] (±180°)
ICXFAC	1 cycle average filtered phase current angle, Phase C, Terminal X	Degrees [°] (±180°)
ICXFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
ICXFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal X	Amps [A] (Secondary)
ICXFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal X	Amps [A] (primary)
ICXFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
ICXPMA	Synchrophasor current angle, Phase C, Terminal X	Degrees [°] (±180°)
ICXPMAD	Synchrophasor current angle, Phase C, Terminal X, delayed for RTC alignment	Degrees [°] (±180°)
ICXPMI	Synchrophasor current Imaginary component, Phase C, Terminal X	Amperes [A] (Primary)
ICXPMID	Synchrophasor current Imaginary component, Phase C, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
ICXPMM	Synchrophasor current magnitude, Phase C, Terminal X	Amperes [A] (Primary)
ICXPMMD	Synchrophasor current magnitude, Phase C, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
ICXPMR	Synchrophasor current Real component, Phase C, Terminal X	Amperes [A] (Primary)
ICXPMRD	Synchrophasor current Real component, Phase C, Terminal X, delayed for RTC alignment	Amperes [A] (Primary)
ICXRC	1 cycle average RMS phase current, Phase C, Terminal X	Amps [A] (primary)
ICXRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal X	Amps [A] (Secondary)
ICXRS	1 second average RMS phase current, Phase C, Terminal X	Amperes [A]
ICYPMA	Synchrophasor current angle, Phase C, Terminal Y	Degrees [°] (±180°)
ICYPMAD	Synchrophasor current angle, Phase C, Terminal Y, delayed for RTC alignment	Degrees [°] (±180°)
ICYPMI	Synchrophasor current Imaginary component, Phase C, Terminal Y	Amperes [A] (Primary)
ICYPMID	Synchrophasor current Imaginary component, Phase C, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
ICYPMM	Synchrophasor current magnitude, Phase C, Terminal Y	Amperes [A] (Primary)
ICYPMMD	Synchrophasor current magnitude, Phase C, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)
ICYPMR	Synchrophasor current Real component, Phase C, Terminal Y	Amperes [A] (Primary)
ICYPMRD	Synchrophasor current Real component, Phase C, Terminal Y, delayed for RTC alignment	Amperes [A] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 25 of 38)

Label	Description	Units
IMAXSF	Instantaneous Filtered Maximum phase current magnitude, Terminal S	Amps [A] (Secondary)
IMAXSR	Instantaneous RMS Maximum phase current, Terminal S	Amps [A] (Secondary)
IMAXSTF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
IMAXSTR	Instantaneous RMS Maximum phase current, Comb. Terminals ST	Amps [A] (Secondary)
IMAXTF	Instantaneous Filtered Maximum phase current magnitude, Terminal T	Amps [A] (Secondary)
IMAXTR	Instantaneous RMS Maximum phase current, Terminal T	Amps [A] (Secondary)
IMAXTUF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
IMAXTUR	Instantaneous RMS Maximum phase current, Comb. Terminals TU	Amps [A] (Secondary)
IMAXUF	Instantaneous Filtered Maximum phase current magnitude, Terminal U	Amps [A] (Secondary)
IMAXUR	Instantaneous RMS Maximum phase current, Terminal U	Amps [A] (Secondary)
IMAXUWF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
IMAXUWR	Instantaneous RMS Maximum phase current, Comb. Terminals UW	Amps [A] (Secondary)
IMAXWF	Instantaneous Filtered Maximum phase current magnitude, Terminal W	Amps [A] (Secondary)
IMAXWR	Instantaneous RMS Maximum phase current, Terminal W	Amps [A] (Secondary)
IMAXWXF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
IMAXWXR	Instantaneous RMS Maximum phase current, Comb. Terminals WX	Amps [A] (Secondary)
IMAXXF	Instantaneous Filtered Maximum phase current magnitude, Terminal X	Amps [A] (Secondary)
IMAXXR	Instantaneous RMS Maximum phase current, Terminal X	Amps [A] (Secondary)
IMINSF	Instantaneous Filtered Minimum phase-current magnitude, Terminal S	Amps [A] (Secondary)
IMINSR	Instantaneous RMS Minimum phase current, Terminal S	Amps [A] (Secondary)
IMINSTF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
IMINSTR	Instantaneous RMS Minimum phase current, Comb. Terminals ST	Amps [A] (Secondary)
IMINTF	Instantaneous Filtered Minimum phase-current magnitude, Terminal T	Amps [A] (Secondary)
IMINTR	Instantaneous RMS Minimum phase current, Terminal T	Amps [A] (Secondary)
IMINTUF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
IMINTUR	Instantaneous RMS Minimum phase current, Comb. Terminals TU	Amps [A] (Secondary)
IMINUF	Instantaneous Filtered Minimum phase-current magnitude, Terminal U	Amps [A] (Secondary)
IMINUR	Instantaneous RMS Minimum phase current, Terminal U	Amps [A] (Secondary)
IMINUWF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
IMINUWR	Instantaneous RMS Minimum phase current, Comb. Terminals UW	Amps [A] (Secondary)
IMINWF	Instantaneous Filtered Minimum phase-current magnitude, Terminal W	Amps [A] (Secondary)
IMINWR	Instantaneous RMS Minimum phase current, Terminal W	Amps [A] (Secondary)
IMINWXF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
IMINWXR	Instantaneous RMS Minimum phase current, Comb. Terminals WX	Amps [A] (Secondary)
IMINXF	Instantaneous Filtered Minimum phase-current magnitude, Terminal X	Amps [A] (Secondary)
IMINXR	Instantaneous RMS Minimum phase current, Terminal X	Amps [A] (Secondary)
IMXSRS	1 second average Maximum RMS phase current, Terminal S, Amperes [A]	Amperes [A]
IMXSTRS	1 second average Maximum RMS phase current, Comb. Terminals ST	Amperes [A]
IMXTRS	1 second average Maximum RMS phase current, Terminal T, Amperes [A]	Amperes [A]
IMXTURS	1 second average Maximum RMS phase current, Comb. Terminals TU	Amperes [A]
IMXURS	1 second average Maximum RMS phase current, Terminal U, Amperes [A]	Amperes [A]

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 26 of 38)

Label	Description	Units
IMXUWRS	1 second average Maximum RMS phase current, Comb. Terminals UW	Amperes [A]
IMXWRS	1 second average Maximum RMS phase current, Terminal W, Amperes [A]	Amperes [A]
IMXWXRS	1 second average Maximum RMS phase current, Comb. Terminals WX	Amperes [A]
IMXXRS	1 second average Maximum RMS phase current, Terminal X, Amperes [A]	Amperes [A]
IOPA	Instantaneous operating current	Per Unit [p.u]
IOPB	Instantaneous operating current	Per Unit [p.u]
IOPC	Instantaneous operating current	Per Unit [p.u]
IRTA	Instantaneous restraint current	Per Unit [p.u]
IRTB	Instantaneous restraint current	Per Unit [p.u]
IRTC	Instantaneous restraint current	Per Unit [p.u]
IRTKA	Biased Instantaneous restraint current, Phase A	Per Unit [p.u]
IRTKB	Biased Instantaneous restraint current, Phase B	Per Unit [p.u]
IRTKC	Biased Instantaneous restraint current, Phase C	Per Unit [p.u]
IRTHRA	Instantaneous Harmonic restraint current, Phase A	Per Unit [p.u]
IRTHRB	Instantaneous Harmonic restraint current, Phase B	Per Unit [p.u]
IRTHRC	Instantaneous Harmonic restraint current, Phase B	Per Unit [p.u]
IY1FAC–IY3FAC	1 cycle average filtered current angle, channel 1, Terminal Y	Degrees [°] (±180°)
IY1FA–IY3FA	Instantaneous Filtered current angle, channels 1–3, Terminal Y	Degrees [°] (±180°)
IY1FI–IY3FI	Instantaneous Filtered current, Real component, Channels 1–3	Amps [A] (Secondary)
IY1FMC–IY3FMC	1 cycle average filtered current magnitude, Channel 1, Terminal Y	Amps [A] (primary)
IY1FM–IY3FM	Instantaneous Filtered current magnitude, Channels 1–3, Terminal Y	Amps [A] (Secondary)
IY1FR–IY3FR	Instantaneous Filtered current, Real component, Channels 1–3	Amps [A] (Secondary)
MAMBT	Measured ambient temperature	°C (degrees Celsius)
MB1A–MB7B	A Channel Received Mirrored Bit Analog Values	Function of selection
MTOIL1–MTOIL3	Measured top oil temperature	°C (degrees Celsius)
PASF	Instantaneous phase fundamental active power, Phase A, Terminal S	Watts [W] (Secondary)
PASFC	1 cycle average phase fundamental active power, Phase A, Terminal S	Megawatts [MW] (Primary)
PASTF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals ST	Watts [W] (Secondary)
PASTFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals ST	Megawatts [MW] (Primary)
PATF	Instantaneous phase fundamental active power, Phase A, Terminal T	Watts [W] (Secondary)
PATFC	1 cycle average phase fundamental active power, Phase A, Terminal T	Megawatts [MW] (Primary)
PATUF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals TU	Watts [W] (Secondary)
PATUFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals TU	Megawatts [MW] (Primary)
PAUF	Instantaneous phase fundamental active power, Phase A, Terminal U	Watts [W] (Secondary)
PAUFC	1 cycle average phase fundamental active power, Phase A, Terminal U	Megawatts [MW] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 27 of 38)

Label	Description	Units
PAUWF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals UW	Watts [W] (Secondary)
PAUWFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals UW	Megawatts [MW] (Primary)
PAWF	Instantaneous phase fundamental active power, Phase A, Terminal W	Watts [W] (Secondary)
PAWFC	1 cycle average phase fundamental active power, Phase A, Terminal W	Megawatts [MW] (Primary)
PAWXF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals WX	Watts [W] (Secondary)
PAWXFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals WX	Megawatts [MW] (Primary)
PAXF	Instantaneous phase fundamental active power, Phase A, Terminal X	Watts [W] (Secondary)
PAXFC	1 cycle average phase fundamental active power, Phase A, Terminal X	Megawatts [MW] (Primary)
PBSF	Instantaneous phase fundamental active power, Phase B, Terminal S	Watts [W] (Secondary)
PBSFC	1 cycle average phase fundamental active power, Phase B, Terminal S	Megawatts [MW] (Primary)
PBSTF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals ST	Watts [W] (Secondary)
PBSTFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals ST	Megawatts [MW] (Primary)
PBTF	Instantaneous phase fundamental active power, Phase B, Terminal T	Watts [W] (Secondary)
PBTFC	1 cycle average phase fundamental active power, Phase B, Terminal T	Megawatts [MW] (Primary)
PBTUF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals TU	Watts [W] (Secondary)
PBTUFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals TU	Megawatts [MW] (Primary)
PBUF	Instantaneous phase fundamental active power, Phase B, Terminal U	Watts [W] (Secondary)
PBUFC	1 cycle average phase fundamental active power, Phase B, Terminal U	Megawatts [MW] (Primary)
PBUWF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals UW	Watts [W] (Secondary)
PBUWFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals UW	Megawatts [MW] (Primary)
PBWF	Instantaneous phase fundamental active power, Phase B, Terminal W	Watts [W] (Secondary)
PBWFC	1 cycle average phase fundamental active power, Phase B, Terminal W	Megawatts [MW] (Primary)
PBWXF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals WX	Watts [W] (Secondary)
PBWXFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals WX	Megawatts [MW] (Primary)
PBXF	Instantaneous phase fundamental active power, Phase B, Terminal X	Watts [W] (Secondary)
PBXFC	1 cycle average phase fundamental active power, Phase B, Terminal X	Megawatts [MW] (Primary)
PCN01CV–PCN32CV	Protection SELOGIC Counter Current Value	unitless
PCN01PV–PCN32PV	Protection SELOGIC Counter Preset Value	unitless
PCSF	Instantaneous phase fundamental active power, Phase C, Terminal S	Watts [W] (Secondary)
PCSFC	1 cycle average phase fundamental active power, Phase C, Terminal S	Megawatts [MW] (Primary)
PCSTF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals ST	Watts [W] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 28 of 38)

Label	Description	Units
PCSTFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals ST	Megawatts [MW] (Primary)
PCT01DO–PCT32DO	Protection SELOGIC Conditioning Timer Dropout Time	unitless
PCT01PU–PCT32PU	Protection SELOGIC Conditioning Timer Pickup Time	unitless
PCTF	Instantaneous phase fundamental active power, Phase C, Terminal T	Watts [W] (Secondary)
PCTFC	1 cycle average phase fundamental active power, Phase C, Terminal T	Megawatts [MW] (Primary)
PCTUF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals TU	Watts [W] (Secondary)
PCTUFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals TU	Megawatts [MW] (Primary)
PCUF	Instantaneous phase fundamental active power, Phase C, Terminal U	Watts [W] (Secondary)
PCUFC	1 cycle average phase fundamental active power, Phase C, Terminal U	Megawatts [MW] (Primary)
PCUWF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals UW	Watts [W] (Secondary)
PCUWFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals UW	Megawatts [MW] (Primary)
PCWF	Instantaneous phase fundamental active power, Phase C, Terminal W	Watts [W] (Secondary)
PCWFC	1 cycle average phase fundamental active power, Phase C, Terminal W	Megawatts [MW] (Primary)
PCWXF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals WX	Watts [W] (Secondary)
PCWXFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals WX	Megawatts [MW] (Primary)
PCXF	Instantaneous phase fundamental active power, Phase C, Terminal X	Watts [W] (Secondary)
PCXFC	1 cycle average phase fundamental active power, Phase C, Terminal X	Megawatts [MW] (Primary)
PMV01–PMV64	Protection SELOGIC Math Variable	
PST01ET–PST32ET	Protection SELOGIC Sequencing Timer Elapsed Time	unitless
PST01PT–PST32PT	Protection SELOGIC Sequencing Timer Preset Time	unitless
QASF	Instantaneous phase fundamental reactive power, Phase A, Terminal S	VARS [Var] (Secondary)
QASFC	1 cycle average phase fundamental reactive power, Phase A, Terminal S	Megavars [Mvar] (Primary)
QASTF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals ST	VARS [Var] (Secondary)
QASTFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals ST	Megavars [Mvar] (Primary)
QATF	Instantaneous phase fundamental reactive power, Phase A, Terminal T	VARS [Var] (Secondary)
QATFC	1 cycle average phase fundamental reactive power, Phase A, Terminal T	Megavars [Mvar] (Primary)
QATUF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals TU	VARS [Var] (Secondary)
QATUFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals TU	Megavars [Mvar] (Primary)
QAUF	Instantaneous phase fundamental reactive power, Phase A, Terminal U	VARS [Var] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 29 of 38)

Label	Description	Units
QAUFC	1 cycle average phase fundamental reactive power, Phase A, Terminal U	Megavars [Mvar] (Primary)
QAUWF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals UW	VARS [Var] (Secondary)
QAUWFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals UW	Megavars [Mvar] (Primary)
QAWF	Instantaneous phase fundamental reactive power, Phase A, Terminal W	VARS [Var] (Secondary)
QAWFC	1 cycle average phase fundamental reactive power, Phase A, Terminal W	Megavars [Mvar] (Primary)
QAWXF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals WX	VARS [Var] (Secondary)
QAWXFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals WX	Megavars [Mvar] (Primary)
QAXF	Instantaneous phase fundamental reactive power, Phase A, Terminal X	VARS [Var] (Secondary)
QAXFC	1 cycle average phase fundamental reactive power, Phase A, Terminal X	Megavars [Mvar] (Primary)
QBSF	Instantaneous phase fundamental reactive power, Phase B, Terminal S	VARS [Var] (Secondary)
QBSFC	1 cycle average phase fundamental reactive power, Phase B, Terminal S	Megavars [Mvar] (Primary)
QBSTF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals ST	VARS [Var] (Secondary)
QBSTFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals ST	Megavars [Mvar] (Primary)
QBTF	Instantaneous phase fundamental reactive power, Phase B, Terminal T	VARS [Var] (Secondary)
QBTFC	1 cycle average phase fundamental reactive power, Phase B, Terminal T	Megavars [Mvar] (Primary)
QBTUF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals TU	VARS [Var] (Secondary)
QBTUFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals TU	Megavars [Mvar] (Primary)
QBUF	Instantaneous phase fundamental reactive power, Phase B, Terminal U	VARS [Var] (Secondary)
QBUFC	1 cycle average phase fundamental reactive power, Phase B, Terminal U	Megavars [Mvar] (Primary)
QBUWF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals UW	VARS [Var] (Secondary)
QBUWFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals UW	Megavars [Mvar] (Primary)
QBWF	Instantaneous phase fundamental reactive power, Phase B, Terminal W	VARS [Var] (Secondary)
QBWFC	1 cycle average phase fundamental reactive power, Phase B, Terminal W	Megavars [Mvar] (Primary)
QBWXF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals WX	VARS [Var] (Secondary)
QBWXFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals WX	Megavars [Mvar] (Primary)
QBXF	Instantaneous phase fundamental reactive power, Phase B, Terminal X	VARS [Var] (Secondary)
QBXFC	1 cycle average phase fundamental reactive power, Phase B, Terminal X	Megavars [Mvar] (Primary)
QCSF	Instantaneous phase fundamental reactive power, Phase C, Terminal S	VARS [Var] (Secondary)
QCSFC	1 cycle average phase fundamental reactive power, Phase C, Terminal S	Megavars [Mvar] (Primary)
QCSTF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals ST	VARS [Var] (Secondary)
QCSTFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals ST	Megavars [Mvar] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 30 of 38)

Label	Description	Units
QCTF	Instantaneous phase fundamental reactive power, Phase C, Terminal T	VARS [Var] (Secondary)
QCTFC	1 cycle average phase fundamental reactive power, Phase C, Terminal T	Megavars [Mvar] (Primary)
QCTUF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals TU	VARS [Var] (Secondary)
QCTUFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals TU	Megavars [Mvar] (Primary)
QCUF	Instantaneous phase fundamental reactive power, Phase C, Terminal U	VARS [Var] (Secondary)
QCUFC	1 cycle average phase fundamental reactive power, Phase C, Terminal U	Megavars [Mvar] (Primary)
QCUWF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals UW	VARS [Var] (Secondary)
QCUWFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals UW	Megavars [Mvar] (Primary)
QCWF	Instantaneous phase fundamental reactive power, Phase C, Terminal W	VARS [Var] (Secondary)
QCWFC	1 cycle average phase fundamental reactive power, Phase C, Terminal W	Megavars [Mvar] (Primary)
QCWXF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals WX	VARS [Var] (Secondary)
QCWXFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals WX	Megavars [Mvar] (Primary)
QCXF	Instantaneous phase fundamental reactive power, Phase C, Terminal X	VARS [Var] (Secondary)
QCXFC	1 cycle average phase fundamental reactive power, Phase C, Terminal X	Megavars [Mvar] (Primary)
RA001–RA256	Remote analogs from 27XX card	Function dependent
REFTQ1–REFTQ3	Restricted Earth Fault Element 1 Torque quantity	Amps secondary
RLYTEMP	Relay temperature (temperature of the box)	°C (degrees Celsius)
RTCAA01–RTCAA08	RTC Remote Analog Values, Channel A	
RTCAP01–RTCAP32	RTC Remote Phasor Values, Channel A	
RTCBA01–RTCBA08	RTC Remote Analog Values, Channel B	
RTCBP01–RTCBP32	RTC Remote Phasor Values, Channel B	
RTCDFA	RTC Remote Frequency Rate of Change, Channel A	Hertz.seconds [Hz/s]
RTCDFB	RTC Remote Frequency Rate of Change, Channel B	Hertz.seconds [Hz/s]
RTCFA	RTC Remote Frequency, Channel A	Hertz [Hz]
RTCFB	RTC Remote Frequency, Channel B	Hertz [Hz]
RTD01TV–RTD12TV	RTD temperature value	°C (degrees Celsius)
SASF	Instantaneous phase fundamental apparent power, Phase A, Terminal S	Voltamps [VA] (Secondary)
SASFC	1 cycle average phase fundamental apparent power, Phase A, Terminal S	Mega Voltamps [MVA] (Primary)
SASTF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals ST	Voltamps [VA] (Secondary)
SASTFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 31 of 38)

Label	Description	Units
SATF	Instantaneous phase fundamental apparent power, Phase A, Terminal T	Voltamps [VA] (Secondary)
SATFC	1 cycle average phase fundamental apparent power, Phase A, Terminal T	Mega Voltamps [MVA] (Primary)
SATUF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals TU	Voltamps [VA] (Secondary)
SATUFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)
SAUF	Instantaneous phase fundamental apparent power, Phase A, Terminal U	Voltamps [VA] (Secondary)
SAUFC	1 cycle average phase fundamental apparent power, Phase A, Terminal U	Mega Voltamps [MVA] (Primary)
SAUWF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals UW	Voltamps [VA] (Secondary)
SAUWFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
SAWF	Instantaneous phase fundamental apparent power, Phase A, Terminal W	Voltamps [VA] (Secondary)
SAWFC	1 cycle average phase fundamental apparent power, Phase A, Terminal W	Mega Voltamps [MVA] (Primary)
SAWXF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals WX	Voltamps [VA] (Secondary)
SAWXFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
SAXF	Instantaneous phase fundamental apparent power, Phase A, Terminal X	Voltamps [VA] (Secondary)
SAXFC	1 cycle average phase fundamental apparent power, Phase A, Terminal X	Mega Voltamps [MVA] (Primary)
SBSF	Instantaneous phase fundamental apparent power, Phase B, Terminal S	Voltamps [VA] (Secondary)
SBSFC	1 cycle average phase fundamental apparent power, Phase B, Terminal S	Mega Voltamps [MVA] (Primary)
SBSTF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals ST	Voltamps [VA] (Secondary)
SBSTFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)
SBTF	Instantaneous phase fundamental apparent power, Phase B, Terminal T	Voltamps [VA] (Secondary)
SBTFC	1 cycle average phase fundamental apparent power, Phase B, Terminal T	Mega Voltamps [MVA] (Primary)
SBTUF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals TU	Voltamps [VA] (Secondary)
SBTUFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)
SBUF	Instantaneous phase fundamental apparent power, Phase B, Terminal U	Voltamps [VA] (Secondary)
SBUFC	1 cycle average phase fundamental apparent power, Phase B, Terminal U	Mega Voltamps [MVA] (Primary)
SBUWF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals UW	Voltamps [VA] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 32 of 38)

Label	Description	Units
SBUWFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
SBWF	Instantaneous phase fundamental apparent power, Phase B, Terminal W	Voltamps [VA] (Secondary)
SBWFC	1 cycle average phase fundamental apparent power, Phase B, Terminal W	Mega Voltamps [MVA] (Primary)
SBWXF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals WX	Voltamps [VA] (Secondary)
SBWXFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
SBXF	Instantaneous phase fundamental apparent power, Phase B, Terminal X	Voltamps [VA] (Secondary)
SBXFC	1 cycle average phase fundamental apparent power, Phase B, Terminal X	Mega Voltamps [MVA] (Primary)
SCSF	Instantaneous phase fundamental apparent power, Phase C, Terminal S	Voltamps [VA] (Secondary)
SCSFC	1 cycle average phase fundamental apparent power, Phase C, Terminal S	Mega Voltamps [MVA] (Primary)
SCSTF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals ST	Voltamps [VA] (Secondary)
SCSTFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)
SCTF	Instantaneous phase fundamental apparent power, Phase C, Terminal T	Voltamps [VA] (Secondary)
SCTFC	1 cycle average phase fundamental apparent power, Phase C, Terminal T	Mega Voltamps [MVA] (Primary)
SCTUF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals TU	Voltamps [VA] (Secondary)
SCTUFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)
SCUF	Instantaneous phase fundamental apparent power, Phase C, Terminal U	Voltamps [VA] (Secondary)
SCUFC	1 cycle average phase fundamental apparent power, Phase C, Terminal U	Mega Voltamps [MVA] (Primary)
SCUWF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals UW	Voltamps [VA] (Secondary)
SCUWFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
SCWF	Instantaneous phase fundamental apparent power, Phase C, Terminal W	Voltamps [VA] (Secondary)
SCWFC	1 cycle average phase fundamental apparent power, Phase C, Terminal W	Mega Voltamps [MVA] (Primary)
SCWXF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals WX	Voltamps [VA] (Secondary)
SCWXFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
SCXF	Instantaneous phase fundamental apparent power, Phase C, Terminal X	Voltamps [VA] (Secondary)
SCXFC	1 cycle average phase fundamental apparent power, Phase C, Terminal X	Mega Voltamps [MVA] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 33 of 38)

Label	Description	Units
SODPM	Second of Day of the Synchrophasor Data Packet	Seconds [s]
SODPMD	Second of Day of the Synchrophasor Data Packet, delayed for RTC alignment	Seconds [s]
T1FAA–T3FAA	Insulation Aging Acceleration Factor	unitless
T1HS–T3HS	Calculated Hot spot temperature	°C (degrees Celsius)
T1LOAD–T3LOAD	Percentage of full load	percent
T1OILC–T3OILC	Calculated transformer top oil temperature	°C (degrees Celsius)
T1RLOL–T3RLOL	Rate of Loss-of-Life	percent
T1TLL–T3TLL	Time to Total Loss-of-Life Alarm	hrs (hours)
T1TLOL–T3TLOL	Total Loss-of-Life	percent
TEC1–TEC3	Thermal element Condition	unitless
THR	Time	hour
TMIN	Time	minute
TMSEC	Time	millisecond
TNSEC	Time	nanosecond
TODMS	Time of Day	millisecond
TQUAL	Worst case IRIG-B clock time error	second
TSEC	Time	second
TUTC	Offset from IRIG-B time to UTC time	hour
V1VA	Instantaneous positive-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
V1VAC	1 cycle average positive-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
V1VI	Instantaneous positive-sequence Voltage, Imaginary component, Terminal V	Volts [V] (Secondary)
V1VM	Instantaneous positive-sequence Voltage magnitude, Terminal V	Volts [V] (Secondary)
V1VMC	1 cycle average positive-sequence Voltage magnitude, Terminal V	Kilovolts [kV] (primary)
V1VPMA	Positive-sequence Synchrophasor Voltage angle, Terminal V	Degrees [°] (±180°)
V1VPMAD	Positive-sequence Synchrophasor Voltage angle, Terminal V, delayed for RTC alignment	Degrees [°] (±180°)
V1VPMI	Positive-sequence Synchrophasor Voltage Imaginary component, Terminal V	Kilovolts [kV] (Primary)
V1VPMID	Positive-sequence Synchrophasor Voltage Imaginary component, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
V1VPMM	Positive-sequence Synchrophasor Voltage magnitude, Terminal V	Kilovolts [kV] (Primary)
V1VPMMD	Positive-sequence Synchrophasor Voltage magnitude, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
V1VPMR	Positive-sequence Synchrophasor Voltage Real component, Terminal V	Kilovolts [kV] (Primary)
V1VPMRD	Positive-sequence Synchrophasor Voltage Real component, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
V1VR	Instantaneous positive-sequence Voltage, Real component, Terminal V	Volts [V] (Secondary)
V1ZA	Instantaneous positive-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
V1ZAC	1 cycle average positive-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
V1ZI	Instantaneous positive-sequence Voltage, Imaginary component, Terminal Z	Volts [V] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 34 of 38)

Label	Description	Units
V1ZM	Instantaneous positive-sequence Voltage magnitude, Terminal Z	Volts [V] (Secondary)
V1ZMC	1 cycle average positive-sequence Voltage magnitude, Terminal Z	Kilovolts [kV] (primary)
V1ZPMA	Positive-sequence Synchrophasor Voltage angle, Terminal Z	Degrees [°] (±180°)
V1ZPMAD	Positive-sequence Synchrophasor Voltage angle, Terminal Z, delayed for RTC alignment	Degrees [°] (±180°)
V1ZPMI	Positive-sequence Synchrophasor Voltage Imaginary component, Terminal Z	Kilovolts [kV] (Primary)
V1ZPMID	Positive-sequence Synchrophasor Voltage Imaginary component, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
V1ZPMM	Positive-sequence Synchrophasor Voltage magnitude, Terminal Z	Kilovolts [kV] (Primary)
V1ZPMMD	Positive-sequence Synchrophasor Voltage magnitude, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
V1ZPMR	Positive-sequence Synchrophasor Voltage Real component, Terminal Z	Kilovolts [kV] (Primary)
V1ZPMRD	Positive-sequence Synchrophasor Voltage Real component, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
V1ZR	Instantaneous positive-sequence Voltage, Real component, Terminal Z	Volts [V] (Secondary)
VABVFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases AB, Terminal V	Degrees [°] (±180°)
VABVFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases AB, Terminal V	Degrees [°] (±180°)
VABVFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases AB	Volts [V] (Secondary)
VABVFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases AB, Terminal V	Volts [V] (Secondary)
VABVFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases AB, Terminal V	Kilovolts [V] (primary)
VABVFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases AB	Volts [V] (Secondary)
VABVRC	1 cycle average RMS phase-to-phase Voltage, Phases AB, Terminal V	Kilovolts [kV] (primary)
VABVRMS	Instantaneous RMS phase-to-phase voltage Phases AB, Terminal V	Volts [V] (Secondary)
VABZFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases AB, Terminal Z	Degrees [°] (±180°)
VABZFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases AB, Terminal Z	Degrees [°] (±180°)
VABZFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases AB	Volts [V] (Secondary)
VABZFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases AB, Terminal Z	Volts [V] (Secondary)
VABZFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases AB, Terminal Z	Kilovolts [V] (primary)
VABZFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases AB	Volts [V] (Secondary)
VABZRC	1 cycle average RMS phase-to-phase Voltage, Phases AB, Terminal Z	Kilovolts [kV] (primary)
VABZRMS	Instantaneous RMS phase-to-phase voltage Phases AB, Terminal Z	Volts [V] (Secondary)
VAVFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase A, Terminal V	Degrees [°] (±180°)
VAVFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase A, Terminal V	Degrees [°] (±180°)
VAVFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase A	Volts [V] (Secondary)
VAVFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase A, Terminal V	Volts [V] (Secondary)
VAVFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase A, Terminal V	Kilovolts [kV] (primary)
VAVFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase A	Volts [V] (Secondary)
VAVPMA	Synchrophasor Voltage angle, Phase A, Terminal V	Degrees [°] (±180°)
VAVPMAD	Synchrophasor Voltage angle, Phase A, Terminal V, delayed for RTC alignment	Degrees [°] (±180°)
VAVPMI	Synchrophasor Voltage Imaginary component, Phase A, Terminal V	Kilovolts [kV] (Primary)
VAVPMID	Synchrophasor Voltage Imaginary component, Phase A, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VAVPMM	Synchrophasor Voltage magnitude, Phase A, Terminal V	Kilovolts [kV] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 35 of 38)

Label	Description	Units
VAVPMMD	Synchrophasor Voltage magnitude, Phase A, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VAVPMR	Synchrophasor Voltage Real component, Phase A, Terminal V	Kilovolts [kV] (Primary)
VAVPMRD	Synchrophasor Voltage Real component, Phase A, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VAVRC	1 cycle average RMS phase-to-neutral Voltage, Phase A, Terminal V	Kilovolts [kV] (primary)
VAVRMS	Instantaneous RMS phase to neutral voltage, Phase A, Terminal V	Volts [V] (Secondary)
VAZFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase A, Terminal Z	Degrees [°] (±180°)
VAZFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase A, Terminal Z	Degrees [°] (±180°)
VAZFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase A	Volts [V] (Secondary)
VAZFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase A, Terminal Z	Volts [V] (Secondary)
VAZFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase A, Terminal Z	Kilovolts [kV] (primary)
VAZFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase A	Volts [V] (Secondary)
VAZPMA	Synchrophasor Voltage angle, Phase A, Terminal Z	Degrees [°] (±180°)
VAZPMAD	Synchrophasor Voltage angle, Phase A, Terminal Z, delayed for RTC alignment	Degrees [°] (±180°)
VAZPMI	Synchrophasor Voltage Imaginary component, Phase A, Terminal Z	Kilovolts [kV] (Primary)
VAZPMID	Synchrophasor Voltage Imaginary component, Phase A, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VAZPMM	Synchrophasor Voltage magnitude, Phase A, Terminal Z	Kilovolts [kV] (Primary)
VAZPMMD	Synchrophasor Voltage magnitude, Phase A, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VAZPMR	Synchrophasor Voltage Real component, Phase A, Terminal Z	Kilovolts [kV] (Primary)
VAZPMRD	Synchrophasor Voltage Real component, Phase A, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VAZRC	1 cycle average RMS phase-to-neutral Voltage, Phase A, Terminal Z	Kilovolts [kV] (primary)
VAZRMS	Instantaneous RMS phase to neutral voltage, Phase A, Terminal Z	Volts [V] (Secondary)
VBCVFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases BC, Terminal V	Degrees [°] (±180°)
VBCVFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases BC, Terminal V	Degrees [°] (±180°)
VBCVFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases BC	Volts [V] (Secondary)
VBCVFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases BC, Terminal V	Volts [V] (Secondary)
VBCVFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases BC, Terminal V	Kilovolts [V] (primary)
VBCVFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases BC	Volts [V] (Secondary)
VBCVRC	1 cycle average RMS phase-to-phase Voltage, Phases BC, Terminal V	Kilovolts [kV] (primary)
VBCVRMS	Instantaneous RMS phase-to-phase voltage Phases BC, Terminal V	Volts [V] (Secondary)
VBCZFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases BC, Terminal Z	Degrees [°] (±180°)
VBCZFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases BC, Terminal Z	Degrees [°] (±180°)
VBCZFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases BC	Volts [V] (Secondary)
VBCZFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases BC, Terminal Z	Volts [V] (Secondary)
VBCZFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases BC, Terminal Z	Kilovolts [V] (primary)
VBCZFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases BC	Volts [V] (Secondary)
VBCZRC	1 cycle average RMS phase-to-phase Voltage, Phases BC, Terminal Z	Kilovolts [kV] (primary)
VBCZRMS	Instantaneous RMS phase-to-phase voltage Phases BC, Terminal Z	Volts [V] (Secondary)
VBVFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase B, Terminal V	Degrees [°] (±180°)
VBVFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase B, Terminal V	Degrees [°] (±180°)

Table H.1 **Analog Quantities Sorted Alphabetically** (Sheet 36 of 38)

Label	Description	Units
VBVFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase B	Volts [V] (Secondary)
VBVFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase B, Terminal V	Volts [V] (Secondary)
VBVFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase B, Terminal V	Kilovolts [kV] (primary)
VBVFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase B	Volts [V] (Secondary)
VBVPMA	Synchrophasor Voltage angle, Phase B, Terminal V	Degrees [°] (±180°)
VBVPMAD	Synchrophasor Voltage angle, Phase B, Terminal V, delayed for RTC alignment	Degrees [°] (±180°)
VBVPMI	Synchrophasor Voltage Imaginary component, Phase B, Terminal V	Kilovolts [kV] (Primary)
VBVPMID	Synchrophasor Voltage Imaginary component, Phase B, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VBVPMM	Synchrophasor Voltage magnitude, Phase B, Terminal V	Kilovolts [kV] (Primary)
VBVPMMD	Synchrophasor Voltage magnitude, Phase B, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VBVPMR	Synchrophasor Voltage Real component, Phase B, Terminal V	Kilovolts [kV] (Primary)
VBVPMRD	Synchrophasor Voltage Real component, Phase B, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VBVRC	1 cycle average RMS phase-to-neutral Voltage, Phase B, Terminal V	Kilovolts [kV] (primary)
VBVRMS	Instantaneous RMS phase to neutral voltage, Phase B, Terminal V	Volts [V] (Secondary)
VBZFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase B, Terminal Z	Degrees [°] (±180°)
VBZFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase B, Terminal Z	Degrees [°] (±180°)
VBZFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase B	Volts [V] (Secondary)
VBZFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase B, Terminal Z	Volts [V] (Secondary)
VBZFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase B, Terminal Z	Kilovolts [kV] (primary)
VBZFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase B	Volts [V] (Secondary)
VBZPMA	Synchrophasor Voltage angle, Phase B, Terminal Z	Degrees [°] (±180°)
VBZPMAD	Synchrophasor Voltage angle, Phase B, Terminal Z, delayed for RTC alignment	Degrees [°] (±180°)
VBZPMI	Synchrophasor Voltage Imaginary component, Phase B, Terminal Z	Kilovolts [kV] (Primary)
VBZPMID	Synchrophasor Voltage Imaginary component, Phase B, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VBZPMM	Synchrophasor Voltage magnitude, Phase B, Terminal Z	Kilovolts [kV] (Primary)
VBZPMMD	Synchrophasor Voltage magnitude, Phase B, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VBZPMR	Synchrophasor Voltage Real component, Phase B, Terminal Z	Kilovolts [kV] (Primary)
VBZPMRD	Synchrophasor Voltage Real component, Phase B, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VBZRC	1 cycle average RMS phase-to-neutral Voltage, Phase B, Terminal Z	Kilovolts [kV] (primary)
VBZRMS	Instantaneous RMS phase to neutral voltage, Phase B, Terminal Z	Volts [V] (Secondary)
VCAVFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases CA, Terminal V	Degrees [°] (±180°)
VCAVFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases CA, Terminal V	Degrees [°] (±180°)
VCAVFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases CA	Volts [V] (Secondary)
VCAVFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases CA, Terminal V	Volts [V] (Secondary)
VCAVFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases CA, Terminal V	Kilovolts [V] (primary)
VCAVFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases CA	Volts [V] (Secondary)
VCAVRC	1 cycle average RMS phase-to-phase Voltage, Phases CA, Terminal V	Kilovolts [kV] (primary)
VCAVRMS	Instantaneous RMS phase-to-phase voltage Phases CA, Terminal V	Volts [V] (Secondary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 37 of 38)

Label	Description	Units
VCAZFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases CA, Terminal Z	Degrees [°] (±180°)
VCAZFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases CA, Terminal Z	Degrees [°] (±180°)
VCAZFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases CA	Volts [V] (Secondary)
VCAZFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases CA, Terminal Z	Volts [V] (Secondary)
VCAZFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases CA, Terminal Z	Kilovolts [V] (primary)
VCAZFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases CA	Volts [V] (Secondary)
VCAZRC	1 cycle average RMS phase-to-phase Voltage, Phases CA, Terminal Z	Kilovolts [kV] (primary)
VCAZRMS	Instantaneous RMS phase-to-phase voltage Phases CA, Terminal Z	Volts [V] (Secondary)
VCVFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase C, Terminal V	Degrees [°] (±180°)
VCVFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase C, Terminal V	Degrees [°] (±180°)
VCVFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase C	Volts [V] (Secondary)
VCVFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase C, Terminal V	Volts [V] (Secondary)
VCVFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase C, Terminal V	Kilovolts [kV] (primary)
VCVFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase C	Volts [V] (Secondary)
VCVPMA	Synchrophasor Voltage angle, Phase C, Terminal V	Degrees [°] (±180°)
VCVPMAD	Synchrophasor Voltage angle, Phase C, Terminal V, delayed for RTC alignment	Degrees [°] (±180°)
VCVPMI	Synchrophasor Voltage Imaginary component, Phase C, Terminal V	Kilovolts [kV] (Primary)
VCVPMID	Synchrophasor Voltage Imaginary component, Phase C, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VCVPMM	Synchrophasor Voltage magnitude, Phase C, Terminal V	Kilovolts [kV] (Primary)
VCVPMMD	Synchrophasor Voltage magnitude, Phase C, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VCVPMR	Synchrophasor Voltage Real component, Phase C, Terminal V	Kilovolts [kV] (Primary)
VCVPMRD	Synchrophasor Voltage Real component, Phase C, Terminal V, delayed for RTC alignment	Kilovolts [kV] (Primary)
VCVRC	1 cycle average RMS phase-to-neutral Voltage, Phase C, Terminal V	Kilovolts [kV] (primary)
VCVRMS	Instantaneous RMS phase to neutral voltage, Phase C, Terminal V	Volts [V] (Secondary)
VCZFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase C, Terminal Z	Degrees [°] (±180°)
VCZFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase C, Terminal Z	Degrees [°] (±180°)
VCZFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase C	Volts [V] (Secondary)
VCZFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase C, Terminal Z	Volts [V] (Secondary)
VCZFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase C, Terminal Z	Kilovolts [kV] (primary)
VCZFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase C	Volts [V] (Secondary)
VCZPMA	Synchrophasor Voltage angle, Phase C, Terminal Z	Degrees [°] (±180°)
VCZPMAD	Synchrophasor Voltage angle, Phase C, Terminal Z, delayed for RTC alignment	Degrees [°] (±180°)
VCZPMI	Synchrophasor Voltage Imaginary component, Phase C, Terminal Z	Kilovolts [kV] (Primary)
VCZPMID	Synchrophasor Voltage Imaginary component, Phase C, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VCZPMM	Synchrophasor Voltage magnitude, Phase C, Terminal Z	Kilovolts [kV] (Primary)
VCZPMMD	Synchrophasor Voltage magnitude, Phase C, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)
VCZPMR	Synchrophasor Voltage Real component, Phase C, Terminal Z	Kilovolts [kV] (Primary)
VCZPMRD	Synchrophasor Voltage Real component, Phase C, Terminal Z, delayed for RTC alignment	Kilovolts [kV] (Primary)

Table H.1 Analog Quantities Sorted Alphabetically (Sheet 38 of 38)

Label	Description	Units
VCZRC	1 cycle average RMS phase-to-neutral Voltage, Phase C, Terminal Z	Kilovolts [kV] (primary)
VCZRMS	Instantaneous RMS phase to neutral voltage, Phase C, Terminal Z	Volts [V] (Secondary)
VDC	Station Battery 1 DC voltage	Volts [V]
VNMAXVF	Instantaneous Filtered Maximum phase-to-neutral voltage magnitude, Terminal V	Volts [V] (Secondary)
VNMAXVR	Instantaneous RMS Maximum phase-to-neutral voltage, Terminal V	Volts [V] (Secondary)
VNMAXZF	Instantaneous Filtered Maximum phase-to-neutral voltage magnitude, Terminal Z	Volts [V] (Secondary)
VNMAXZR	Instantaneous RMS Maximum phase-to-neutral voltage, Terminal Z	Volts [V] (Secondary)
VNMINVF	Instantaneous Filtered Minimum phase-to-neutral voltage magnitude, Terminal V	Volts [V] (Secondary)
VNMINVR	Instantaneous RMS Minimum phase-to-neutral voltage, Terminal V	Volts [V] (Secondary)
VNMINZF	Instantaneous Filtered Minimum phase-to-neutral voltage magnitude, Terminal Z	Volts [V] (Secondary)
VNMINZR	Instantaneous RMS Minimum phase-to-neutral voltage, Terminal Z	Volts [V] (Secondary)
VPMAXVF	Instantaneous Filtered Maximum phase-to-phase voltage magnitude, Terminal V	Volts [V] (Secondary)
VPMAXVR	Instantaneous RMS Maximum phase-to-phase voltage, Terminal V	Volts [V] (Secondary)
VPMAXZF	Instantaneous Filtered Maximum phase-to-phase voltage magnitude, Terminal Z	Volts [V] (Secondary)
VPMAXZR	Instantaneous RMS Maximum phase-to-phase voltage, Terminal Z	Volts [V] (Secondary)
VPMINVF	Instantaneous Filtered Minimum phase-to-phase voltage magnitude, Terminal V	Volts [V] (Secondary)
VPMINVR	Instantaneous RMS Minimum phase-to-phase voltage, Terminal V	Volts [V] (Secondary)
VPMINZF	Instantaneous Filtered Minimum phase-to-phase voltage magnitude, Terminal Z	Volts [V] (Secondary)
VPMINZR	Instantaneous RMS Minimum phase-to-phase voltage, Terminal Z	Volts [V] (Secondary)
Z1AS	Positive-sequence Impedance Angle, Terminal S	Degrees [°] (±180°)
Z1AT	Positive-sequence Impedance Angle, Terminal T	Degrees [°] (±180°)
Z1AU	Positive-sequence Impedance Angle, Terminal U	Degrees [°] (±180°)
Z1AW	Positive-sequence Impedance Angle, Terminal W	Degrees [°] (±180°)
Z1AX	Positive-sequence Impedance Angle, Terminal X	Degrees [°] (±180°)
Z1MS	Positive-sequence Impedance Magnitude, Terminal S	Ohms Secondary
Z1MT	Positive-sequence Impedance Magnitude, Terminal T	Ohms Secondary
Z1MU	Positive-sequence Impedance Magnitude, Terminal U	Ohms Secondary
Z1MW	Positive-sequence Impedance Magnitude, Terminal W	Ohms Secondary
Z1MX	Positive-sequence Impedance Magnitude, Terminal X	Ohms Secondary

Quantities Listed by Function

Table H.2 Analog Quantities Sorted By Function (Sheet 1 of 40)

Label	Description	Units
Instantaneous Filtered Voltage		
VAVFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase A, Terminal V	Volts [V] (Secondary)
VBVFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase B, Terminal V	Volts [V] (Secondary)
VCVFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase C, Terminal V	Volts [V] (Secondary)
VAZFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase A, Terminal Z	Volts [V] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 2 of 40)

Label	Description	Units
VBZFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase B, Terminal Z	Volts [V] (Secondary)
VCZFM	Instantaneous Filtered phase-to-neutral Voltage magnitude, Phase C, Terminal Z	Volts [V] (Secondary)
VAVFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase A, Terminal V	Degrees [°] (±180°)
VBVFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase B, Terminal V	Degrees [°] (±180°)
VCVFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase C, Terminal V	Degrees [°] (±180°)
VAZFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase A, Terminal Z	Degrees [°] (±180°)
VBZFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase B, Terminal Z	Degrees [°] (±180°)
VCZFA	Instantaneous Filtered phase-to-neutral Voltage angle, Phase C, Terminal Z	Degrees [°] (±180°)
VAVFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase A	Volts [V] (Secondary)
VBVFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase B	Volts [V] (Secondary)
VCVFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase C	Volts [V] (Secondary)
VAZFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase A	Volts [V] (Secondary)
VBZFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase B	Volts [V] (Secondary)
VCZFR	Instantaneous Filtered phase-to-neutral Voltage, Real component, Phase C	Volts [V] (Secondary)
VAVFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase A	Volts [V] (Secondary)
VBVFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase B	Volts [V] (Secondary)
VCVFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase C	Volts [V] (Secondary)
VAZFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase A	Volts [V] (Secondary)
VBZFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase B	Volts [V] (Secondary)
VCZFI	Instantaneous Filtered phase-to-neutral Voltage, Imaginary component, Phase C	Volts [V] (Secondary)
VABVFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases AB, Terminal V	Volts [V] (Secondary)
VBCVFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases BC, Terminal V	Volts [V] (Secondary)
VCAVFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases CA, Terminal V	Volts [V] (Secondary)
VABZFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases AB, Terminal Z	Volts [V] (Secondary)
VBCZFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases BC, Terminal Z	Volts [V] (Secondary)
VCAZFM	Instantaneous Filtered phase-to-phase Voltage magnitude, Phases CA, Terminal Z	Volts [V] (Secondary)
VABVFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases AB, Terminal V	Degrees [°] (±180°)
VBCVFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases BC, Terminal V	Degrees [°] (±180°)
VCAVFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases CA, Terminal V	Degrees [°] (±180°)
VABZFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases AB, Terminal Z	Degrees [°] (±180°)
VBCZFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases BC, Terminal Z	Degrees [°] (±180°)
VCAZFA	Instantaneous Filtered phase-to-phase Voltage angle, Phases CA, Terminal Z	Degrees [°] (±180°)
VABVFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases AB	Volts [V] (Secondary)
VBCVFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases BC	Volts [V] (Secondary)
VCAVFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases CA	Volts [V] (Secondary)
VABZFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases AB	Volts [V] (Secondary)
VBCZFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases BC	Volts [V] (Secondary)
VCAZFR	Instantaneous Filtered phase-to-phase Voltage, Real component, Phases CA	Volts [V] (Secondary)
VABVFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases AB	Volts [V] (Secondary)
VBCVFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases BC	Volts [V] (Secondary)
VCAVFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases CA	Volts [V] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 3 of 40)

Label	Description	Units
VABZFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases AB	Volts [V] (Secondary)
VBCZFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases BC	Volts [V] (Secondary)
VCAZFI	Instantaneous Filtered phase-to-phase Voltage, Imaginary component, Phases CA	Volts [V] (Secondary)
VNMAXVF	Instantaneous Filtered Maximum phase-to-neutral voltage magnitude, Terminal V	Volts [V] (Secondary)
VNMAXZF	Instantaneous Filtered Maximum phase-to-neutral voltage magnitude, Terminal Z	Volts [V] (Secondary)
VNMINVF	Instantaneous Filtered Minimum phase-to-neutral voltage magnitude, Terminal V	Volts [V] (Secondary)
VNMINZF	Instantaneous Filtered Minimum phase-to-neutral voltage magnitude, Terminal Z	Volts [V] (Secondary)
VPMAXVF	Instantaneous Filtered Maximum phase-to-phase voltage magnitude, Terminal V	Volts [V] (Secondary)
VPMAXZF	Instantaneous Filtered Maximum phase-to-phase voltage magnitude, Terminal Z	Volts [V] (Secondary)
VPMINVF	Instantaneous Filtered Minimum phase-to-phase voltage magnitude, Terminal V	Volts [V] (Secondary)
VPMINZF	Instantaneous Filtered Minimum phase-to-phase voltage magnitude, Terminal Z	Volts [V] (Secondary)
V1VM	Instantaneous positive-sequence Voltage magnitude, Terminal V	Volts [V] (Secondary)
V1ZM	Instantaneous positive-sequence Voltage magnitude, Terminal Z	Volts [V] (Secondary)
V1VA	Instantaneous positive-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
V1ZA	Instantaneous positive-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
V1VR	Instantaneous positive-sequence Voltage, Real component, Terminal V	Volts [V] (Secondary)
V1ZR	Instantaneous positive-sequence Voltage, Real component, Terminal Z	Volts [V] (Secondary)
V1VI	Instantaneous positive-sequence Voltage, Imaginary component, Terminal V	Volts [V] (Secondary)
V1ZI	Instantaneous positive-sequence Voltage, Imaginary component, Terminal Z	Volts [V] (Secondary)
3V2VM	Instantaneous negative-sequence Voltage magnitude, Terminal V	Volts [V] (Secondary)
3V2ZM	Instantaneous negative-sequence Voltage magnitude, Terminal Z	Volts [V] (Secondary)
3V2VA	Instantaneous negative-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V2ZA	Instantaneous negative-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V2VR	Instantaneous negative-sequence Voltage, Real component, Terminal V	Volts [V] (Secondary)
3V2ZR	Instantaneous negative-sequence Voltage, Real component, Terminal Z	Volts [V] (Secondary)
3V2VI	Instantaneous negative-sequence Voltage, Imaginary component, Terminal V	Volts [V] (Secondary)
3V2ZI	Instantaneous negative-sequence Voltage, Imaginary component, Terminal Z	Volts [V] (Secondary)
3V0VM	Instantaneous zero-sequence Voltage magnitude, Terminal V	Volts [V] (Secondary)
3V0ZM	Instantaneous zero-sequence Voltage magnitude, Terminal Z	Volts [V] (Secondary)
3V0VA	Instantaneous zero-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V0ZA	Instantaneous zero-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V0VR	Instantaneous zero-sequence Voltage, Real component, Terminal V	Volts [V] (Secondary)
3V0ZR	Instantaneous zero-sequence Voltage, Real component, Terminal Z	Volts [V] (Secondary)
3V0VI	Instantaneous zero-sequence Voltage, Imaginary component, Terminal V	Volts [V] (Secondary)
3V0ZI	Instantaneous zero-sequence Voltage, Imaginary component, Terminal Z	Volts [V] (Secondary)
Instantaneous Filtered Currents		
IASFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal S	Amps [A] (Secondary)
IBSFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal S	Amps [A] (Secondary)
ICSFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal S	Amps [A] (Secondary)
IATFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal T	Amps [A] (Secondary)
IBTFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal T	Amps [A] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 4 of 40)

Label	Description	Units
ICTFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal T	Amps [A] (Secondary)
IAUFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal U	Amps [A] (Secondary)
IBUFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal U	Amps [A] (Secondary)
ICUFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal U	Amps [A] (Secondary)
IAWFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal W	Amps [A] (Secondary)
IBWFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal W	Amps [A] (Secondary)
ICWFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal W	Amps [A] (Secondary)
IAXFM	Instantaneous Filtered phase current magnitude, Phase A, Terminal X	Amps [A] (Secondary)
IBXFM	Instantaneous Filtered phase current magnitude, Phase B, Terminal X	Amps [A] (Secondary)
ICXFM	Instantaneous Filtered phase current magnitude, Phase C, Terminal X	Amps [A] (Secondary)
IASFA	Instantaneous Filtered phase current angle, Phase A, Terminal S	Degrees [°] (±180°)
IBSFA	Instantaneous Filtered phase current angle, Phase B, Terminal S	Degrees [°] (±180°)
ICSFA	Instantaneous Filtered phase current angle, Phase C, Terminal S	Degrees [°] (±180°)
IATFA	Instantaneous Filtered phase current angle, Phase A, Terminal T	Degrees [°] (±180°)
IBTFA	Instantaneous Filtered phase current angle, Phase B, Terminal T	Degrees [°] (±180°)
ICTFA	Instantaneous Filtered phase current angle, Phase C, Terminal T	Degrees [°] (±180°)
IAUFA	Instantaneous Filtered phase current angle, Phase A, Terminal U	Degrees [°] (±180°)
IBUFA	Instantaneous Filtered phase current angle, Phase B, Terminal U	Degrees [°] (±180°)
ICUFA	Instantaneous Filtered phase current angle, Phase C, Terminal U	Degrees [°] (±180°)
IAWFA	Instantaneous Filtered phase current angle, Phase A, Terminal W	Degrees [°] (±180°)
IBWFA	Instantaneous Filtered phase current angle, Phase B, Terminal W	Degrees [°] (±180°)
ICWFA	Instantaneous Filtered phase current angle, Phase C, Terminal W	Degrees [°] (±180°)
IAXFA	Instantaneous Filtered phase current angle, Phase A, Terminal X	Degrees [°] (±180°)
IBXFA	Instantaneous Filtered phase current angle, Phase B, Terminal X	Degrees [°] (±180°)
ICXFA	Instantaneous Filtered phase current angle, Phase C, Terminal X	Degrees [°] (±180°)
IASFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBSFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICSFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IATFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBTFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICTFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IAUFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBUFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICUFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IAWFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBWFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICWFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IAXFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBXFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICXFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IASFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)

Table H.2 **Analog Quantities Sorted By Function** (Sheet 5 of 40)

Label	Description	Units
IBSFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICSFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IATFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBTFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICTFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IAUFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBUFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICUFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IAWFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBWFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICWFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IAXFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBXFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICXFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IY1FM–IY3FM	Instantaneous Filtered current magnitude, Channels 1–3, Terminal Y	Amps [A] (Secondary)
IY1FA–IY3FA	Instantaneous Filtered current angle, channels 1–3, Terminal Y	Degrees [°] (±180°)
IY1FR–IY3FR	Instantaneous Filtered current, Real component, Channels 1–3	Amps [A] (Secondary)
IY1FI–IY3FI	Instantaneous Filtered current, Real component, Channels 1–3	Amps [A] (Secondary)
IASTFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals ST	Amps [A] (Secondary)
IBSTFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals ST	Amps [A] (Secondary)
ICSTFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals ST	Amps [A] (Secondary)
IATUFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals TU	Amps [A] (Secondary)
IBTUFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals TU	Amps [A] (Secondary)
ICTUFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals TU	Amps [A] (Secondary)
IAUWFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals UW	Amps [A] (Secondary)
IBUWFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals UW	Amps [A] (Secondary)
ICUWFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals UW	Amps [A] (Secondary)
IAWXFM	Instantaneous Filtered phase current magnitude, Phase A, Comb. Terminals WX	Amps [A] (Secondary)
IBWXFM	Instantaneous Filtered phase current magnitude, Phase B, Comb. Terminals WX	Amps [A] (Secondary)
ICWXFM	Instantaneous Filtered phase current magnitude, Phase C, Comb. Terminals WX	Amps [A] (Secondary)
IASTFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals ST	Degrees [°] (±180°)
IBSTFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals ST	Degrees [°] (±180°)
ICSTFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals ST	Degrees [°] (±180°)
IATUFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals TU	Degrees [°] (±180°)
IBTUFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals TU	Degrees [°] (±180°)
ICTUFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals TU	Degrees [°] (±180°)
IAUWFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals UW	Degrees [°] (±180°)
IBUWFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals UW	Degrees [°] (±180°)
ICUWFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals UW	Degrees [°] (±180°)
IAWXFA	Instantaneous Filtered phase current angle, Phase A, Comb. Terminals WX	Degrees [°] (±180°)

Table H.2 Analog Quantities Sorted By Function (Sheet 6 of 40)

Label	Description	Units
IBWXFA	Instantaneous Filtered phase current angle, Phase B, Comb. Terminals WX	Degrees [°] (±180°)
ICWXFA	Instantaneous Filtered phase current angle, Phase C, Comb. Terminals WX	Degrees [°] (±180°)
IASTFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBSTFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICSTFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IATUFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBTUFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICTUFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IAUWFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBUWFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICUWFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IAWXFR	Instantaneous Filtered phase current, Real component, Phase A	Amps [A] (Secondary)
IBWXFR	Instantaneous Filtered phase current, Real component, Phase B	Amps [A] (Secondary)
ICWXFR	Instantaneous Filtered phase current, Real component, Phase C	Amps [A] (Secondary)
IASTFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBSTFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICSTFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IATUFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBTUFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICTUFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IAUWFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBUWFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICUWFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IAWXFI	Instantaneous Filtered phase current, Imaginary component, Phase A	Amps [A] (Secondary)
IBWXFI	Instantaneous Filtered phase current, Imaginary component, Phase B	Amps [A] (Secondary)
ICWXFI	Instantaneous Filtered phase current, Imaginary component, Phase C	Amps [A] (Secondary)
IMAXSF	Instantaneous Filtered Maximum phase current magnitude, Terminal S	Amps [A] (Secondary)
IMAXTF	Instantaneous Filtered Maximum phase current magnitude, Terminal T	Amps [A] (Secondary)
IMAXUF	Instantaneous Filtered Maximum phase current magnitude, Terminal U	Amps [A] (Secondary)
IMAXWF	Instantaneous Filtered Maximum phase current magnitude, Terminal W	Amps [A] (Secondary)
IMAXXF	Instantaneous Filtered Maximum phase current magnitude, Terminal X	Amps [A] (Secondary)
IMINSF	Instantaneous Filtered Minimum phase-current magnitude, Terminal S	Amps [A] (Secondary)
IMINTF	Instantaneous Filtered Minimum phase-current magnitude, Terminal T	Amps [A] (Secondary)
IMINUF	Instantaneous Filtered Minimum phase-current magnitude, Terminal U	Amps [A] (Secondary)
IMINWF	Instantaneous Filtered Minimum phase-current magnitude, Terminal W	Amps [A] (Secondary)
IMINXF	Instantaneous Filtered Minimum phase-current magnitude, Terminal X	Amps [A] (Secondary)
IMAXSTF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
IMAXTUF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
IMAXUWF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
IMAXWXF	Instantaneous Filtered Maximum phase current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
IMINSTF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals ST	Amps [A] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 7 of 40)

Label	Description	Units
IMINTUF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
IMINUWF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
IMINWXF	Instantaneous Filtered Minimum phase current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
I1SM	Instantaneous positive-sequence current magnitude, Terminal S	Amps [A] (Secondary)
I1TM	Instantaneous positive-sequence current magnitude, Terminal T	Amps [A] (Secondary)
I1UM	Instantaneous positive-sequence current magnitude, Terminal U	Amps [A] (Secondary)
I1WM	Instantaneous positive-sequence current magnitude, Terminal W	Amps [A] (Secondary)
I1XM	Instantaneous positive-sequence current magnitude, Terminal X	Amps [A] (Secondary)
I1SA	Instantaneous positive-sequence current angle, Terminal S	Degrees [°] (±180°)
I1TA	Instantaneous positive-sequence current angle, Terminal T	Degrees [°] (±180°)
I1UA	Instantaneous positive-sequence current angle, Terminal U	Degrees [°] (±180°)
I1WA	Instantaneous positive-sequence current angle, Terminal W	Degrees [°] (±180°)
I1XA	Instantaneous positive-sequence current angle, Terminal X	Degrees [°] (±180°)
I1SR	Instantaneous positive-sequence current, Real component, Terminal S	Amps [A] (Secondary)
I1TR	Instantaneous positive-sequence current, Real component, Terminal T	Amps [A] (Secondary)
I1UR	Instantaneous positive-sequence current, Real component, Terminal U	Amps [A] (Secondary)
I1WR	Instantaneous positive-sequence current, Real component, Terminal W	Amps [A] (Secondary)
I1XR	Instantaneous positive-sequence current, Real component, Terminal X	Amps [A] (Secondary)
I1SI	Instantaneous positive-sequence current, Imaginary component, Terminal S	Amps [A] (Secondary)
I1TI	Instantaneous positive-sequence current, Imaginary component, Terminal T	Amps [A] (Secondary)
I1UI	Instantaneous positive-sequence current, Imaginary component, Terminal U	Amps [A] (Secondary)
I1WI	Instantaneous positive-sequence current, Imaginary component, Terminal W	Amps [A] (Secondary)
I1XI	Instantaneous positive-sequence current, Imaginary component, Terminal X	Amps [A] (Secondary)
3I2SM	Instantaneous negative-sequence current magnitude, Terminal S	Amps [A] (Secondary)
3I2TM	Instantaneous negative-sequence current magnitude, Terminal T	Amps [A] (Secondary)
3I2UM	Instantaneous negative-sequence current magnitude, Terminal U	Amps [A] (Secondary)
3I2WM	Instantaneous negative-sequence current magnitude, Terminal W	Amps [A] (Secondary)
3I2XM	Instantaneous negative-sequence current magnitude, Terminal X	Amps [A] (Secondary)
3I2SA	Instantaneous negative-sequence current angle, Terminal S	Degrees [°] (±180°)
3I2TA	Instantaneous negative-sequence current angle, Terminal T	Degrees [°] (±180°)
3I2UA	Instantaneous negative-sequence current angle, Terminal U	Degrees [°] (±180°)
3I2WA	Instantaneous negative-sequence current angle, Terminal W	Degrees [°] (±180°)
3I2XA	Instantaneous negative-sequence current angle, Terminal X	Degrees [°] (±180°)
3I2SR	Instantaneous negative-sequence current, Real component, Terminal S	Amps [A] (Secondary)
3I2TR	Instantaneous negative-sequence current, Real component, Terminal T	Amps [A] (Secondary)
3I2UR	Instantaneous negative-sequence current, Real component, Terminal U	Amps [A] (Secondary)
3I2WR	Instantaneous negative-sequence current, Real component, Terminal W	Amps [A] (Secondary)
3I2XR	Instantaneous negative-sequence current, Real component, Terminal X	Amps [A] (Secondary)
3I2SI	Instantaneous negative-sequence current, Imaginary component, Terminal S	Amps [A] (Secondary)
3I2TI	Instantaneous negative-sequence current, Imaginary component, Terminal T	Amps [A] (Secondary)
3I2UI	Instantaneous negative-sequence current, Imaginary component, Terminal U	Amps [A] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 8 of 40)

Label	Description	Units
3I2WI	Instantaneous negative-sequence current, Imaginary component, Terminal W	Amps [A] (Secondary)
3I2XI	Instantaneous negative-sequence current, Imaginary component, Terminal X	Amps [A] (Secondary)
3I0SM	Instantaneous zero-sequence current magnitude, Terminal S	Amps [A] (Secondary)
3I0TM	Instantaneous zero-sequence current magnitude, Terminal T	Amps [A] (Secondary)
3I0UM	Instantaneous zero-sequence current magnitude, Terminal U	Amps [A] (Secondary)
3I0WM	Instantaneous zero-sequence current magnitude, Terminal W	Amps [A] (Secondary)
3I0XM	Instantaneous zero-sequence current magnitude, Terminal X	Amps [A] (Secondary)
3I0SA	Instantaneous zero-sequence current angle, Terminal S	Degrees [°] (±180°)
3I0TA	Instantaneous zero-sequence current angle, Terminal T	Degrees [°] (±180°)
3I0UA	Instantaneous zero-sequence current angle, Terminal U	Degrees [°] (±180°)
3I0WA	Instantaneous zero-sequence current angle, Terminal W	Degrees [°] (±180°)
3I0XA	Instantaneous zero-sequence current angle, Terminal X	Degrees [°] (±180°)
3I0SR	Instantaneous zero-sequence current, Real component, Terminal S	Amps [A] (Secondary)
3I0TR	Instantaneous zero-sequence current, Real component, Terminal T	Amps [A] (Secondary)
3I0UR	Instantaneous zero-sequence current, Real component, Terminal U	Amps [A] (Secondary)
3I0WR	Instantaneous zero-sequence current, Real component, Terminal W	Amps [A] (Secondary)
3I0XR	Instantaneous zero-sequence current, Real component, Terminal X	Amps [A] (Secondary)
3I0SI	Instantaneous zero-sequence current, Imaginary component, Terminal S	Amps [A] (Secondary)
3I0TI	Instantaneous zero-sequence current, Imaginary component, Terminal T	Amps [A] (Secondary)
3I0UI	Instantaneous zero-sequence current, Imaginary component, Terminal U	Amps [A] (Secondary)
3I0WI	Instantaneous zero-sequence current, Imaginary component, Terminal W	Amps [A] (Secondary)
3I0XI	Instantaneous zero-sequence current, Imaginary component, Terminal X	Amps [A] (Secondary)
I1STM	Instantaneous positive-sequence current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
I1TUM	Instantaneous positive-sequence current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
I1UWM	Instantaneous positive-sequence current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
I1WXM	Instantaneous positive-sequence current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
I1STA	Instantaneous positive-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
I1TUA	Instantaneous positive-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
I1UWA	Instantaneous positive-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
I1WXA	Instantaneous positive-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
I1STR	Instantaneous positive-sequence current, Real component, Comb. Terminals ST	Amps [A] (Secondary)
I1TUR	Instantaneous positive-sequence current, Real component, Comb. Terminals TU	Amps [A] (Secondary)
I1UWR	Instantaneous positive-sequence current, Real component, Comb. Terminals UW	Amps [A] (Secondary)
I1WXR	Instantaneous positive-sequence current, Real component, Comb. Terminals WX	Amps [A] (Secondary)
I1STI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals ST	Amps [A] (Secondary)
I1TUI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals TU	Amps [A] (Secondary)
I1UWI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals UW	Amps [A] (Secondary)
I1WXI	Instantaneous positive-sequence current, Imaginary comp, Comb. Terminals WX	Amps [A] (Secondary)
3I2STM	Instantaneous negative-sequence current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
3I2TUM	Instantaneous negative-sequence current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
3I2UWM	Instantaneous negative-sequence current magnitude, Comb. Terminals UW	Amps [A] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 9 of 40)

Label	Description	Units
3I2WXM	Instantaneous negative-sequence current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
3I2STA	Instantaneous negative-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I2TUA	Instantaneous negative-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I2UWA	Instantaneous negative-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I2WXA	Instantaneous negative-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I2STR	Instantaneous negative-sequence current, Real component, Comb. Terminals ST	Amps [A] (Secondary)
3I2TUR	Instantaneous negative-sequence current, Real component, Comb. Terminals TU	Amps [A] (Secondary)
3I2UWR	Instantaneous negative-sequence current, Real component, Comb. Terminals UW	Amps [A] (Secondary)
3I2WXR	Instantaneous negative-sequence current, Real component, Comb. Terminals WX	Amps [A] (Secondary)
3I2STI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals ST	Amps [A] (Secondary)
3I2TUI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals TU	Amps [A] (Secondary)
3I2UWI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals UW	Amps [A] (Secondary)
3I2WXI	Instantaneous negative-sequence current, Imaginary component, Comb. Terminals WX	Amps [A] (Secondary)
3I0STM	Instantaneous zero-sequence current magnitude, Comb. Terminals ST	Amps [A] (Secondary)
3I0TUM	Instantaneous zero-sequence current magnitude, Comb. Terminals TU	Amps [A] (Secondary)
3I0UWM	Instantaneous zero-sequence current magnitude, Comb. Terminals UW	Amps [A] (Secondary)
3I0WXM	Instantaneous zero-sequence current magnitude, Comb. Terminals WX	Amps [A] (Secondary)
3I0STA	Instantaneous zero-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I0TUA	Instantaneous zero-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I0UWA	Instantaneous zero-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I0WXA	Instantaneous zero-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I0STR	Instantaneous zero-sequence current, Real component, Comb. Terminals ST	Amps [A] (Secondary)
3I0TUR	Instantaneous zero-sequence current, Real component, Comb. Terminals TU	Amps [A] (Secondary)
3I0UWR	Instantaneous zero-sequence current, Real component, Comb. Terminals UW	Amps [A] (Secondary)
3I0WXR	Instantaneous zero-sequence current, Real component, Comb. Terminals WX	Amps [A] (Secondary)
3I0STI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals ST	Amps [A] (Secondary)
3I0TUI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals TU	Amps [A] (Secondary)
3I0UWI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals UW	Amps [A] (Secondary)
3I0WXI	Instantaneous zero-sequence current, Imaginary component, Comb. Terminals WX	Amps [A] (Secondary)
Instantaneous RMS Voltages		
VAVRMS	Instantaneous RMS phase to neutral voltage, Phase A, Terminal V	Volts [V] (Secondary)
VBVRMS	Instantaneous RMS phase to neutral voltage, Phase B, Terminal V	Volts [V] (Secondary)
VCVRMS	Instantaneous RMS phase to neutral voltage, Phase C, Terminal V	Volts [V] (Secondary)
VAZRMS	Instantaneous RMS phase to neutral voltage, Phase A, Terminal Z	Volts [V] (Secondary)
VBZRMS	Instantaneous RMS phase to neutral voltage, Phase B, Terminal Z	Volts [V] (Secondary)
VCZRMS	Instantaneous RMS phase to neutral voltage, Phase C, Terminal Z	Volts [V] (Secondary)
VABVRMS	Instantaneous RMS phase-to-phase voltage Phases AB, Terminal V	Volts [V] (Secondary)
VBCVRMS	Instantaneous RMS phase-to-phase voltage Phases BC, Terminal V	Volts [V] (Secondary)
VCAVRMS	Instantaneous RMS phase-to-phase voltage Phases CA, Terminal V	Volts [V] (Secondary)
VABZRMS	Instantaneous RMS phase-to-phase voltage Phases AB, Terminal Z	Volts [V] (Secondary)
VBCZRMS	Instantaneous RMS phase-to-phase voltage Phases BC, Terminal Z	Volts [V] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 10 of 40)

Label	Description	Units
VCAZRMS	Instantaneous RMS phase-to-phase voltage Phases CA, Terminal Z	Volts [V] (Secondary)
VNMAXVR	Instantaneous RMS Maximum phase-to-neutral voltage, Terminal V	Volts [V] (Secondary)
VNMAXZR	Instantaneous RMS Maximum phase-to-neutral voltage, Terminal Z	Volts [V] (Secondary)
VNMINVR	Instantaneous RMS Minimum phase-to-neutral voltage, Terminal V	Volts [V] (Secondary)
VNMINZR	Instantaneous RMS Minimum phase-to-neutral voltage, Terminal Z	Volts [V] (Secondary)
VPMAXVR	Instantaneous RMS Maximum phase-to-phase voltage, Terminal V	Volts [V] (Secondary)
VPMAXZR	Instantaneous RMS Maximum phase-to-phase voltage, Terminal Z	Volts [V] (Secondary)
VPMINVR	Instantaneous RMS Minimum phase-to-phase voltage, Terminal V	Volts [V] (Secondary)
VPMINZR	Instantaneous RMS Minimum phase-to-phase voltage, Terminal Z	Volts [V] (Secondary)
Instantaneous RMS Currents		
IASRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal S	Amps [A] (Secondary)
IBSRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal S	Amps [A] (Secondary)
ICSRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal S	Amps [A] (Secondary)
IATRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal T	Amps [A] (Secondary)
IBTRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal T	Amps [A] (Secondary)
ICTRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal T	Amps [A] (Secondary)
IAURMS	Instantaneous RMS phase current magnitude, Phase A, Terminal U	Amps [A] (Secondary)
IBURMS	Instantaneous RMS phase current magnitude, Phase B, Terminal U	Amps [A] (Secondary)
ICURMS	Instantaneous RMS phase current magnitude, Phase C, Terminal U	Amps [A] (Secondary)
IAWRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal W	Amps [A] (Secondary)
IBWRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal W	Amps [A] (Secondary)
ICWRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal W	Amps [A] (Secondary)
IAXRMS	Instantaneous RMS phase current magnitude, Phase A, Terminal X	Amps [A] (Secondary)
IBXRMS	Instantaneous RMS phase current magnitude, Phase B, Terminal X	Amps [A] (Secondary)
ICXRMS	Instantaneous RMS phase current magnitude, Phase C, Terminal X	Amps [A] (Secondary)
IASTRMS	Instantaneous RMS phase current, Phase A, Comb. Terminals ST	Amps [A] (Secondary)
IBSTRMS	Instantaneous RMS phase current, Phase B, Comb. Terminals ST	Amps [A] (Secondary)
ICSTRMS	Instantaneous RMS phase current, Phase C, Comb. Terminals ST	Amps [A] (Secondary)
IATURMS	Instantaneous RMS phase current, Phase A, Comb. Terminals TU	Amps [A] (Secondary)
IBTURMS	Instantaneous RMS phase current, Phase B, Comb. Terminals TU	Amps [A] (Secondary)
ICTURMS	Instantaneous RMS phase current, Phase C, Comb. Terminals TU	Amps [A] (Secondary)
IAUWRMS	Instantaneous RMS phase current, Phase A, Comb. Terminals UW	Amps [A] (Secondary)
IBUWRMS	Instantaneous RMS phase current, Phase B, Comb. Terminals UW	Amps [A] (Secondary)
ICUWRMS	Instantaneous RMS phase current, Phase C, Comb. Terminals UW	Amps [A] (Secondary)
IAWXRMS	Instantaneous RMS phase current, Phase A, Comb. Terminals WX	Amps [A] (Secondary)
IBWXRMS	Instantaneous RMS phase current, Phase B, Comb. Terminals WX	Amps [A] (Secondary)
ICWXRMS	Instantaneous RMS phase current, Phase C, Comb. Terminals WX	Amps [A] (Secondary)
IMAXSR	Instantaneous RMS Maximum phase current, Terminal S	Amps [A] (Secondary)
IMAXTR	Instantaneous RMS Maximum phase current, Terminal T	Amps [A] (Secondary)
IMAXUR	Instantaneous RMS Maximum phase current, Terminal U	Amps [A] (Secondary)
IMAXWR	Instantaneous RMS Maximum phase current, Terminal W	Amps [A] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 11 of 40)

Label	Description	Units
IMAXXR	Instantaneous RMS Maximum phase current, Terminal X	Amps [A] (Secondary)
IMINSR	Instantaneous RMS Minimum phase current, Terminal S	Amps [A] (Secondary)
IMINTR	Instantaneous RMS Minimum phase current, Terminal T	Amps [A] (Secondary)
IMINUR	Instantaneous RMS Minimum phase current, Terminal U	Amps [A] (Secondary)
IMINWR	Instantaneous RMS Minimum phase current, Terminal W	Amps [A] (Secondary)
IMINXR	Instantaneous RMS Minimum phase current, Terminal X	Amps [A] (Secondary)
IMAXSTR	Instantaneous RMS Maximum phase current, Comb. Terminals ST	Amps [A] (Secondary)
IMAXTUR	Instantaneous RMS Maximum phase current, Comb. Terminals TU	Amps [A] (Secondary)
IMAXUWR	Instantaneous RMS Maximum phase current, Comb. Terminals UW	Amps [A] (Secondary)
IMAXWXR	Instantaneous RMS Maximum phase current, Comb. Terminals WX	Amps [A] (Secondary)
IMINSTR	Instantaneous RMS Minimum phase current, Comb. Terminals ST	Amps [A] (Secondary)
IMINTUR	Instantaneous RMS Minimum phase current, Comb. Terminals TU	Amps [A] (Secondary)
IMINUWR	Instantaneous RMS Minimum phase current, Comb. Terminals UW	Amps [A] (Secondary)
IMINWXR	Instantaneous RMS Minimum phase current, Comb. Terminals WX	Amps [A] (Secondary)
Synchrophasor Filtering		
VAVPMM	Synchrophasor Voltage magnitude, Phase A, Terminal V	Kilovolts [kV] (Primary)
VBVPMM	Synchrophasor Voltage magnitude, Phase B, Terminal V	Kilovolts [kV] (Primary)
VCVPMM	Synchrophasor Voltage magnitude, Phase C, Terminal V	Kilovolts [kV] (Primary)
VAZPMM	Synchrophasor Voltage magnitude, Phase A, Terminal Z	Kilovolts [kV] (Primary)
VBZPMM	Synchrophasor Voltage magnitude, Phase B, Terminal Z	Kilovolts [kV] (Primary)
VCZPMM	Synchrophasor Voltage magnitude, Phase C, Terminal Z	Kilovolts [kV] (Primary)
VAVPMA	Synchrophasor Voltage angle, Phase A, Terminal V	Degrees [°] (±180°)
VBVPMA	Synchrophasor Voltage angle, Phase B, Terminal V	Degrees [°] (±180°)
VCVPMA	Synchrophasor Voltage angle, Phase C, Terminal V	Degrees [°] (±180°)
VAZPMA	Synchrophasor Voltage angle, Phase A, Terminal Z	Degrees [°] (±180°)
VBZPMA	Synchrophasor Voltage angle, Phase B, Terminal Z	Degrees [°] (±180°)
VCZPMA	Synchrophasor Voltage angle, Phase C, Terminal Z	Degrees [°] (±180°)
VAVPMR	Synchrophasor Voltage Real component, Phase A, Terminal V	Kilovolts [kV] (Primary)
VBVPMR	Synchrophasor Voltage Real component, Phase B, Terminal V	Kilovolts [kV] (Primary)
VCVPMR	Synchrophasor Voltage Real component, Phase C, Terminal V	Kilovolts [kV] (Primary)
VAZPMR	Synchrophasor Voltage Real component, Phase A, Terminal Z	Kilovolts [kV] (Primary)
VBZPMR	Synchrophasor Voltage Real component, Phase B, Terminal Z	Kilovolts [kV] (Primary)
VCZPMR	Synchrophasor Voltage Real component, Phase C, Terminal Z	Kilovolts [kV] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 12 of 40)

Label	Description	Units
VAVPMI	Synchrophasor Voltage Imaginary component, Phase A, Terminal V	Kilovolts [kV] (Primary)
VBVPMI	Synchrophasor Voltage Imaginary component, Phase B, Terminal V	Kilovolts [kV] (Primary)
VCVPMI	Synchrophasor Voltage Imaginary component, Phase C, Terminal V	Kilovolts [kV] (Primary)
VAZPMI	Synchrophasor Voltage Imaginary component, Phase A, Terminal Z	Kilovolts [kV] (Primary)
VBZPMI	Synchrophasor Voltage Imaginary component, Phase B, Terminal Z	Kilovolts [kV] (Primary)
VCZPMI	Synchrophasor Voltage Imaginary component, Phase C, Terminal Z	Kilovolts [kV] (Primary)
V1VPMM	Positive-sequence Synchrophasor Voltage magnitude, Terminal V	Kilovolts [kV] (Primary)
V1ZPMM	Positive-sequence Synchrophasor Voltage magnitude, Terminal Z	Kilovolts [kV] (Primary)
V1VPMA	Positive-sequence Synchrophasor Voltage angle, Terminal V	Degrees [°] (±180°)
V1ZPMA	Positive-sequence Synchrophasor Voltage angle, Terminal Z	Degrees [°] (±180°)
V1VPMR	Positive-sequence Synchrophasor Voltage Real component, Terminal V	Kilovolts [kV] (Primary)
V1ZPMR	Positive-sequence Synchrophasor Voltage Real component, Terminal Z	Kilovolts [kV] (Primary)
V1VPMI	Positive-sequence Synchrophasor Voltage Imaginary component, Terminal V	Kilovolts [kV] (Primary)
V1ZPMI	Positive-sequence Synchrophasor Voltage Imaginary component, Terminal Z	Kilovolts [kV] (Primary)
IASPMM	Synchrophasor current magnitude, Phase A, Terminal S	Amperes [A] (Primary)
IBSPMM	Synchrophasor current magnitude, Phase B, Terminal S	Amperes [A] (Primary)
ICSPMM	Synchrophasor current magnitude, Phase C, Terminal S	Amperes [A] (Primary)
IATPMM	Synchrophasor current magnitude, Phase A, Terminal T	Amperes [A] (Primary)
IBTPMM	Synchrophasor current magnitude, Phase B, Terminal T	Amperes [A] (Primary)
ICTPMM	Synchrophasor current magnitude, Phase C, Terminal T	Amperes [A] (Primary)
IAUPMM	Synchrophasor current magnitude, Phase A, Terminal U	Amperes [A] (Primary)
IBUPMM	Synchrophasor current magnitude, Phase B, Terminal U	Amperes [A] (Primary)
ICUPMM	Synchrophasor current magnitude, Phase C, Terminal U	Amperes [A] (Primary)
IAWPMM	Synchrophasor current magnitude, Phase A, Terminal W	Amperes [A] (Primary)
IBWPMM	Synchrophasor current magnitude, Phase B, Terminal W	Amperes [A] (Primary)
ICWPMM	Synchrophasor current magnitude, Phase C, Terminal W	Amperes [A] (Primary)
IAXPMM	Synchrophasor current magnitude, Phase A, Terminal X	Amperes [A] (Primary)
IBXPMM	Synchrophasor current magnitude, Phase B, Terminal X	Amperes [A] (Primary)
ICXPMM	Synchrophasor current magnitude, Phase C, Terminal X	Amperes [A] (Primary)
IAYPMM	Synchrophasor current magnitude, Phase A, Terminal Y	Amperes [A] (Primary)
IBYPMM	Synchrophasor current magnitude, Phase B, Terminal Y	Amperes [A] (Primary)
ICYPMM	Synchrophasor current magnitude, Phase C, Terminal Y	Amperes [A] (Primary)
IASPMA	Synchrophasor current angle, Phase A, Terminal S	Degrees [°] (±180°)

Table H.2 Analog Quantities Sorted By Function (Sheet 13 of 40)

Label	Description	Units
IBSPMA	Synchrophasor current angle, Phase B, Terminal S	Degrees [°] (±180°)
ICSPMA	Synchrophasor current angle, Phase C, Terminal S	Degrees [°] (±180°)
IATPMA	Synchrophasor current angle, Phase A, Terminal T	Degrees [°] (±180°)
IBTPMA	Synchrophasor current angle, Phase B, Terminal T	Degrees [°] (±180°)
ICTPMA	Synchrophasor current angle, Phase C, Terminal T	Degrees [°] (±180°)
IAUPMA	Synchrophasor current angle, Phase A, Terminal U	Degrees [°] (±180°)
IBUPMA	Synchrophasor current angle, Phase B, Terminal U	Degrees [°] (±180°)
ICUPMA	Synchrophasor current angle, Phase C, Terminal U	Degrees [°] (±180°)
IAWPMA	Synchrophasor current angle, Phase A, Terminal W	Degrees [°] (±180°)
IBWPMA	Synchrophasor current angle, Phase B, Terminal W	Degrees [°] (±180°)
ICWPMA	Synchrophasor current angle, Phase C, Terminal W	Degrees [°] (±180°)
IAXPMA	Synchrophasor current angle, Phase A, Terminal X	Degrees [°] (±180°)
IBXPMA	Synchrophasor current angle, Phase B, Terminal X	Degrees [°] (±180°)
ICXPMA	Synchrophasor current angle, Phase C, Terminal X	Degrees [°] (±180°)
IAYPMA	Synchrophasor current angle, Phase A, Terminal Y	Degrees [°] (±180°)
IBYPMA	Synchrophasor current angle, Phase B, Terminal Y	Degrees [°] (±180°)
ICPMA	Synchrophasor current angle, Phase C, Terminal Y	Degrees [°] (±180°)
IASPMR	Synchrophasor current Real component, Phase A, Terminal S	Amperes [A] (Primary)
IBSPMR	Synchrophasor current Real component, Phase B, Terminal S	Amperes [A] (Primary)
ICSPMR	Synchrophasor current Real component, Phase C, Terminal S	Amperes [A] (Primary)
IATPMR	Synchrophasor current Real component, Phase A, Terminal T	Amperes [A] (Primary)
IBTPMR	Synchrophasor current Real component, Phase B, Terminal T	Amperes [A] (Primary)
ICTPMR	Synchrophasor current Real component, Phase C, Terminal T	Amperes [A] (Primary)
IAUPMR	Synchrophasor current Real component, Phase A, Terminal U	Amperes [A] (Primary)
IBUPMR	Synchrophasor current Real component, Phase B, Terminal U	Amperes [A] (Primary)
ICUPMR	Synchrophasor current Real component, Phase C, Terminal U	Amperes [A] (Primary)
IAWPMR	Synchrophasor current Real component, Phase A, Terminal W	Amperes [A] (Primary)
IBWPMR	Synchrophasor current Real component, Phase B, Terminal W	Amperes [A] (Primary)
ICWPMR	Synchrophasor current Real component, Phase C, Terminal W	Amperes [A] (Primary)
IAXPMR	Synchrophasor current Real component, Phase A, Terminal X	Amperes [A] (Primary)
IBXPMR	Synchrophasor current Real component, Phase B, Terminal X	Amperes [A] (Primary)
ICXPMR	Synchrophasor current Real component, Phase C, Terminal X	Amperes [A] (Primary)
IAYPMR	Synchrophasor current Real component, Phase A, Terminal Y	Amperes [A] (Primary)
IBYPMR	Synchrophasor current Real component, Phase B, Terminal Y	Amperes [A] (Primary)
ICYPMR	Synchrophasor current Real component, Phase C, Terminal Y	Amperes [A] (Primary)
IASPMI	Synchrophasor current Imaginary component, Phase A, Terminal S	Amperes [A] (Primary)
IBSPMI	Synchrophasor current Imaginary component, Phase B, Terminal S	Amperes [A] (Primary)
ICSPMI	Synchrophasor current Imaginary component, Phase C, Terminal S	Amperes [A] (Primary)
IATPMI	Synchrophasor current Imaginary component, Phase A, Terminal T	Amperes [A] (Primary)
IBTPMI	Synchrophasor current Imaginary component, Phase B, Terminal T	Amperes [A] (Primary)
ICTPMI	Synchrophasor current Imaginary component, Phase C, Terminal T	Amperes [A] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 14 of 40)

Label	Description	Units
IAUPMI	Synchrophasor current Imaginary component, Phase A, Terminal U	Amperes [A] (Primary)
IBUPMI	Synchrophasor current Imaginary component, Phase B, Terminal U	Amperes [A] (Primary)
ICUPMI	Synchrophasor current Imaginary component, Phase C, Terminal U	Amperes [A] (Primary)
IAWPMI	Synchrophasor current Imaginary component, Phase A, Terminal W	Amperes [A] (Primary)
IBWPMI	Synchrophasor current Imaginary component, Phase B, Terminal W	Amperes [A] (Primary)
ICWPMI	Synchrophasor current Imaginary component, Phase C, Terminal W	Amperes [A] (Primary)
IAXPMI	Synchrophasor current Imaginary component, Phase A, Terminal X	Amperes [A] (Primary)
IBXPMI	Synchrophasor current Imaginary component, Phase B, Terminal X	Amperes [A] (Primary)
ICXPMI	Synchrophasor current Imaginary component, Phase C, Terminal X	Amperes [A] (Primary)
IAYPMI	Synchrophasor current Imaginary component, Phase A, Terminal Y	Amperes [A] (Primary)
IBYPMI	Synchrophasor current Imaginary component, Phase B, Terminal Y	Amperes [A] (Primary)
ICYPMI	Synchrophasor current Imaginary component, Phase C, Terminal Y	Amperes [A] (Primary)
I1SPMM	Positive-sequence Synchrophasor current magnitude, Terminal S	Amperes [A] (Primary)
I1TPMM	Positive-sequence Synchrophasor current magnitude, Terminal T	Amperes [A] (Primary)
I1UPMM	Positive-sequence Synchrophasor current magnitude, Terminal U	Amperes [A] (Primary)
I1WPMM	Positive-sequence Synchrophasor current magnitude, Terminal W	Amperes [A] (Primary)
I1XPMM	Positive-sequence Synchrophasor current magnitude, Terminal X	Amperes [A] (Primary)
I1YPMM	Positive-sequence Synchrophasor current magnitude, Terminal Y	Amperes [A] (Primary)
I1SPMA	Positive-sequence Synchrophasor current angle, Terminal S	Degrees [°] (±180°)
I1TPMA	Positive-sequence Synchrophasor current angle, Terminal T	Degrees [°] (±180°)
I1UPMA	Positive-sequence Synchrophasor current angle, Terminal U	Degrees [°] (±180°)
I1WPMA	Positive-sequence Synchrophasor current angle, Terminal W	Degrees [°] (±180°)
I1XPMA	Positive-sequence Synchrophasor current angle, Terminal X	Degrees [°] (±180°)
I1YPMA	Positive-sequence Synchrophasor current angle, Terminal Y	Degrees [°] (±180°)
I1SPMR	Positive-sequence Synchrophasor current Real component, Terminal S	Amperes [A] (Primary)
I1TPMR	Positive-sequence Synchrophasor current Real component, Terminal T	Amperes [A] (Primary)
I1UPMR	Positive-sequence Synchrophasor current Real component, Terminal U	Amperes [A] (Primary)
I1WPMR	Positive-sequence Synchrophasor current Real component, Terminal W	Amperes [A] (Primary)
I1XPMR	Positive-sequence Synchrophasor current Real component, Terminal X	Amperes [A] (Primary)
I1YPMR	Positive-sequence Synchrophasor current Real component, Terminal Y	Amperes [A] (Primary)
I1SPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal S	Amperes [A] (Primary)
I1TPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal T	Amperes [A] (Primary)
I1UPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal U	Amperes [A] (Primary)
I1WPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal W	Amperes [A] (Primary)
I1XPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal X	Amperes [A] (Primary)
I1YPMI	Positive-sequence Synchrophasor current Imaginary component, Terminal Y	Amperes [A] (Primary)
SODPM	Second of Day of the Synchrophasor Data Packet	Seconds [s]
FOSPM	Fraction of Second of the Synchrophasor Data Packet	Seconds [s]
Synchrophasor Frequency		
FREQPM	Frequency for Synchrophasor Data	Hertz [Hz]
DFDTPM	Rate-of-change of Frequency for Synchrophasor Data	Hertz/seconds [Hz/s]

Table H.2 Analog Quantities Sorted By Function (Sheet 15 of 40)

Label	Description	Units
Aligned and Remote Synchrophasors		
SODPMD	Second of Day for the Synchrophasor Data Packet, delayed for RTC alignment	Seconds [s]
FOSPMD	Fraction of Second of the Synchrophasor Data Packet, delayed for RTC alignment	Seconds [s]
FREQPMD	Frequency for Synchrophasor Data, delayed for RTC alignment	Hertz [Hz]
DFDTPMD	Rate-of-change of Frequency for Synchrophasor Data, delayed for RTC alignment	Hertz/seconds [Hz/s]
IASPMMD	Synchrophasor current magnitude, Phase A, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IASPMAD	Synchrophasor current angle, Phase A, Terminal S, delayed for RTC alignment	Degrees
IASPMRD	Synchrophasor current real component, Phase A, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IASPMID	Synchrophasor current imaginary component, Phase A, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IBSPMMD	Synchrophasor current magnitude, Phase B, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IBSPMAD	Synchrophasor current angle, Phase B, Terminal S, delayed for RTC alignment	Degrees
IBSPMRD	Synchrophasor current real component, Phase B, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IBSPMID	Synchrophasor current imaginary component, Phase B, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
ICSPMMD	Synchrophasor current magnitude, Phase C, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
ICSPMAD	Synchrophasor current angle, Phase C, Terminal S, delayed for RTC alignment	Degrees
ICSPMRD	Synchrophasor current real component, Phase C, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
ICSPMID	Synchrophasor current imaginary component, Phase C, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1SPMMD	Positive-sequence Synchrophasor current magnitude, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1SPMAD	Positive-sequence Synchrophasor current angle, Terminal S, delayed for RTC alignment	Degrees
I1SPMRD	Positive-sequence Synchrophasor current real component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
I1SPMID	Positive-sequence Synchrophasor current imaginary component, Terminal S, delayed for RTC alignment	Amperes [A] (primary)
IATPMMD	Synchrophasor current magnitude, Phase A, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
IATPMAD	Synchrophasor current angle, Phase A, Terminal T, delayed for RTC alignment	Degrees
IATPMRD	Synchrophasor current real component, Phase A, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
IATPMID	Synchrophasor current imaginary component, Phase A, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
IBTPMMD	Synchrophasor current magnitude, Phase B, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
IBTPMAD	Synchrophasor current angle, Phase B, Terminal T, delayed for RTC alignment	Degrees
IBTPMRD	Synchrophasor current real component, Phase B, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
IBTPMID	Synchrophasor current imaginary component, Phase B, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
ICTPMMD	Synchrophasor current magnitude, Phase C, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
ICTPMAD	Synchrophasor current angle, Phase C, Terminal T, delayed for RTC alignment	Degrees
ICTPMRD	Synchrophasor current real component, Phase C, Terminal T, delayed for RTC alignment	Amperes [A] (primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 16 of 40)

Label	Description	Units
ICTPMID	Synchrophasor current imaginary component, Phase C, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
I1TPMMD	Positive-sequence Synchrophasor current magnitude, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
I1TPMAD	Positive-sequence Synchrophasor current angle, Terminal T, delayed for RTC alignment	Degrees
I1TPMRD	Positive-sequence Synchrophasor current real component, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
I1TPMID	Positive-sequence Synchrophasor current imaginary component, Terminal T, delayed for RTC alignment	Amperes [A] (primary)
IAUPMMD	Synchrophasor current magnitude, Phase A, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
IAUPMAD	Synchrophasor current angle, Phase A, Terminal U, delayed for RTC alignment	Degrees
IAUPMRD	Synchrophasor current real component, Phase A, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
IAUPMID	Synchrophasor current imaginary component, Phase A, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
IBUPMMD	Synchrophasor current magnitude, Phase B, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
IBUPMAD	Synchrophasor current angle, Phase B, Terminal U, delayed for RTC alignment	Degrees
IBUPMRD	Synchrophasor current real component, Phase B, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
IBUPMID	Synchrophasor current imaginary component, Phase B, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
ICUPMMD	Synchrophasor current magnitude, Phase C, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
ICUPMAD	Synchrophasor current angle, Phase C, Terminal U, delayed for RTC alignment	Degrees
ICUPMRD	Synchrophasor current real component, Phase C, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
ICUPMID	Synchrophasor current imaginary component, Phase C, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
I1UPMMD	Positive-sequence Synchrophasor current magnitude, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
I1UPMAD	Positive-sequence Synchrophasor current angle, Terminal U, delayed for RTC alignment	Degrees
I1UPMRD	Positive-sequence Synchrophasor current real component, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
I1UPMID	Positive-sequence Synchrophasor current imaginary component, Terminal U, delayed for RTC alignment	Amperes [A] (primary)
IAWPMMD	Synchrophasor current magnitude, Phase A, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAWPMAD	Synchrophasor current angle, Phase A, Terminal W, delayed for RTC alignment	Degrees
IAWPMRD	Synchrophasor current real component, Phase A, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAWPMID	Synchrophasor current imaginary component, Phase A, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IBWPMMD	Synchrophasor current magnitude, Phase B, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IBWPMAD	Synchrophasor current angle, Phase B, Terminal W, delayed for RTC alignment	Degrees
IBWPMRD	Synchrophasor current real component, Phase B, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IBWPMID	Synchrophasor current imaginary component, Phase B, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
ICWPMMD	Synchrophasor current magnitude, Phase C, Terminal W, delayed for RTC alignment	Amperes [A] (primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 17 of 40)

Label	Description	Units
ICWPMAD	Synchrophasor current angle, Phase C, Terminal W, delayed for RTC alignment	Degrees
ICWPMRD	Synchrophasor current real component, Phase C, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
ICWPMID	Synchrophasor current imaginary component, Phase C, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1WPMMD	Positive-sequence Synchrophasor current magnitude, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1WPMAD	Positive-sequence Synchrophasor current angle, Terminal W, delayed for RTC alignment	Degrees
I1WPMRD	Positive-sequence Synchrophasor current real component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
I1WPMID	Positive-sequence Synchrophasor current imaginary component, Terminal W, delayed for RTC alignment	Amperes [A] (primary)
IAXPMMD	Synchrophasor current magnitude, Phase A, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IAXPMAD	Synchrophasor current angle, Phase A, Terminal X, delayed for RTC alignment	Degrees
IAXPMRD	Synchrophasor current real component, Phase A, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IAXPMID	Synchrophasor current imaginary component, Phase A, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IBXPMMD	Synchrophasor current magnitude, Phase B, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IBXPMAD	Synchrophasor current angle, Phase B, Terminal X, delayed for RTC alignment	Degrees
IBXPMRD	Synchrophasor current real component, Phase B, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IBXPMID	Synchrophasor current imaginary component, Phase B, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
ICXPMMD	Synchrophasor current magnitude, Phase C, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
ICXPMAD	Synchrophasor current angle, Phase C, Terminal X, delayed for RTC alignment	Degrees
ICXPMRD	Synchrophasor current real component, Phase C, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
ICXPMID	Synchrophasor current imaginary component, Phase C, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1XPMMD	Positive-sequence Synchrophasor current magnitude, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1XPMAD	Positive-sequence Synchrophasor current angle, Terminal X, delayed for RTC alignment	Degrees
I1XPMRD	Positive-sequence Synchrophasor current real component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
I1XPMID	Positive-sequence Synchrophasor current imaginary component, Terminal X, delayed for RTC alignment	Amperes [A] (primary)
IAYPMMD	Synchrophasor current magnitude, Phase A, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
IAYPMAD	Synchrophasor current angle, Phase A, Terminal Y, delayed for RTC alignment	Degrees
IAYPMRD	Synchrophasor current real component, Phase A, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
IAYPMID	Synchrophasor current imaginary component, Phase A, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
IBYPMMD	Synchrophasor current magnitude, Phase B, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
IBYPMAD	Synchrophasor current angle, Phase B, Terminal Y, delayed for RTC alignment	Degrees

Table H.2 Analog Quantities Sorted By Function (Sheet 18 of 40)

Label	Description	Units
IBYPMRD	Synchrophasor current real component, Phase B, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
IBYPMID	Synchrophasor current imaginary component, Phase B, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
ICYPMMD	Synchrophasor current magnitude, Phase C, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
ICYPMAD	Synchrophasor current angle, Phase C, Terminal Y, delayed for RTC alignment	Degrees
ICYPMRD	Synchrophasor current real component, Phase C, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
ICYPMID	Synchrophasor current imaginary component, Phase C, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
I1YPMMD	Positive-sequence Synchrophasor current magnitude, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
I1YPMAD	Positive-sequence Synchrophasor current angle, Terminal Y, delayed for RTC alignment	Degrees
I1YPMRD	Positive-sequence Synchrophasor current real component, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
I1YPMID	Positive-sequence Synchrophasor current imaginary component, Terminal Y, delayed for RTC alignment	Amperes [A] (primary)
VAVPMMD	Synchrophasor voltage magnitude, Phase A, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VAVPMAD	Synchrophasor voltage angle, Phase A, Terminal V, delayed for RTC alignment	Degrees
VAVPMRD	Synchrophasor voltage real component, Phase A, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VAVPMID	Synchrophasor voltage imaginary component, Phase A, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VBVPMMD	Synchrophasor voltage magnitude, Phase B, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VBVPMAD	Synchrophasor voltage angle, Phase B, Terminal V, delayed for RTC alignment	Degrees
VBVPMRD	Synchrophasor voltage real component, Phase B, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VBVPMID	Synchrophasor voltage imaginary component, Phase B, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VCVPMMD	Synchrophasor voltage magnitude, Phase C, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VCVPMAD	Synchrophasor voltage angle, Phase C, Terminal V, delayed for RTC alignment	Degrees
VCVPMRD	Synchrophasor voltage real component, Phase C, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
VCVPMID	Synchrophasor voltage imaginary component, Phase C, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
V1VPMMD	Positive-sequence Synchrophasor magnitude, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
V1VPMAD	Positive-sequence Synchrophasor angle, Terminal V, delayed for RTC alignment	Degrees
V1VPMRD	Positive-sequence Synchrophasor real component, Terminal V, delayed for RTC alignment	Amperes [A] (primary)
V1ZPMID	Positive-sequence Synchrophasor imaginary component, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VAZPMMD	Synchrophasor voltage magnitude, Phase A, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VAZPMAD	Synchrophasor voltage angle, Phase A, Terminal Z, delayed for RTC alignment	Degrees
VAZPMRD	Synchrophasor voltage real component, Phase A, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VAZPMID	Synchrophasor voltage imaginary component, Phase A, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 19 of 40)

Label	Description	Units
VBZPMMD	Synchrophasor voltage magnitude, Phase B, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VBZPMAD	Synchrophasor voltage angle, Phase B, Terminal Z, delayed for RTC alignment	Degrees
VBZPMRD	Synchrophasor voltage real component, Phase B, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VBZPMID	Synchrophasor voltage imaginary component, Phase B, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VCZPMMD	Synchrophasor voltage magnitude, Phase C, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VCZPMAD	Synchrophasor voltage angle, Phase C, Terminal Z, delayed for RTC alignment	Degrees
VCZPMRD	Synchrophasor voltage real component, Phase C, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
VCZPMID	Synchrophasor voltage imaginary component, Phase C, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
V1ZPMMD	Positive-sequence Synchrophasor magnitude, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
V1ZPMAD	Positive-sequence Synchrophasor angle, Terminal Z, delayed for RTC alignment	Degrees
V1ZPMRD	Positive-sequence Synchrophasor real component, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
V1ZPMID	Positive-sequence Synchrophasor imaginary component, Terminal Z, delayed for RTC alignment	Amperes [A] (primary)
RTCFA	RTC Remote Frequency, Channel A	Hertz [Hz]
RTCDFA	RTC Remote Frequency Rate of Change, Channel A	Hertz/seconds [Hz/s]
RTCAP01–RTCAP32	RTC Remote Phasor Values, Channel A	
RTCAA01–RTCAA08	RTC Remote Analog Values, Channel A	
RTCFB	RTC Remote Frequency, Channel B	Hertz [Hz]
RTCDFB	RTC Remote Frequency Rate of Change, Channel B	Hertz/seconds [Hz/s]
RTCBP01–RTCBP32	RTC Remote Phasor Values, Channel B	
RTCBA01–RTCBA08	RTC Remote Analog Values, Channel B	
Instantaneous Power Elements (Secondary Quantities)		
PASF	Instantaneous phase fundamental active power, Phase A, Terminal S	Watts [W] (Secondary)
PBSF	Instantaneous phase fundamental active power, Phase B, Terminal S	Watts [W] (Secondary)
PCSF	Instantaneous phase fundamental active power, Phase C, Terminal S	Watts [W] (Secondary)
PATF	Instantaneous phase fundamental active power, Phase A, Terminal T	Watts [W] (Secondary)
PBTF	Instantaneous phase fundamental active power, Phase B, Terminal T	Watts [W] (Secondary)
PCTF	Instantaneous phase fundamental active power, Phase C, Terminal T	Watts [W] (Secondary)
PAUF	Instantaneous phase fundamental active power, Phase A, Terminal U	Watts [W] (Secondary)
PBUF	Instantaneous phase fundamental active power, Phase B, Terminal U	Watts [W] (Secondary)
PCUF	Instantaneous phase fundamental active power, Phase C, Terminal U	Watts [W] (Secondary)
PAWF	Instantaneous phase fundamental active power, Phase A, Terminal W	Watts [W] (Secondary)
PBWF	Instantaneous phase fundamental active power, Phase B, Terminal W	Watts [W] (Secondary)
PCWF	Instantaneous phase fundamental active power, Phase C, Terminal W	Watts [W] (Secondary)
PAXF	Instantaneous phase fundamental active power, Phase A, Terminal X	Watts [W] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 20 of 40)

Label	Description	Units
PBXF	Instantaneous phase fundamental active power, Phase B, Terminal X	Watts [W] (Secondary)
PCXF	Instantaneous phase fundamental active power, Phase C, Terminal X	Watts [W] (Secondary)
QASF	Instantaneous phase fundamental reactive power, Phase A, Terminal S	VARS [Var] (Secondary)
QBSF	Instantaneous phase fundamental reactive power, Phase B, Terminal S	VARS [Var] (Secondary)
QCSF	Instantaneous phase fundamental reactive power, Phase C, Terminal S	VARS [Var] (Secondary)
QATF	Instantaneous phase fundamental reactive power, Phase A, Terminal T	VARS [Var] (Secondary)
QBTF	Instantaneous phase fundamental reactive power, Phase B, Terminal T	VARS [Var] (Secondary)
QCTF	Instantaneous phase fundamental reactive power, Phase C, Terminal T	VARS [Var] (Secondary)
QAUF	Instantaneous phase fundamental reactive power, Phase A, Terminal U	VARS [Var] (Secondary)
QBUF	Instantaneous phase fundamental reactive power, Phase B, Terminal U	VARS [Var] (Secondary)
QCUF	Instantaneous phase fundamental reactive power, Phase C, Terminal U	VARS [Var] (Secondary)
QAWF	Instantaneous phase fundamental reactive power, Phase A, Terminal W	VARS [Var] (Secondary)
QBWF	Instantaneous phase fundamental reactive power, Phase B, Terminal W	VARS [Var] (Secondary)
QCWF	Instantaneous phase fundamental reactive power, Phase C, Terminal W	VARS [Var] (Secondary)
QAXF	Instantaneous phase fundamental reactive power, Phase A, Terminal X	VARS [Var] (Secondary)
QBXF	Instantaneous phase fundamental reactive power, Phase B, Terminal X	VARS [Var] (Secondary)
QCXF	Instantaneous phase fundamental reactive power, Phase C, Terminal X	VARS [Var] (Secondary)
SASF	Instantaneous phase fundamental apparent power, Phase A, Terminal S	Voltamps [VA] (Secondary)
SBSF	Instantaneous phase fundamental apparent power, Phase B, Terminal S	Voltamps [VA] (Secondary)
SCSF	Instantaneous phase fundamental apparent power, Phase C, Terminal S	Voltamps [VA] (Secondary)
SATF	Instantaneous phase fundamental apparent power, Phase A, Terminal T	Voltamps [VA] (Secondary)
SBTF	Instantaneous phase fundamental apparent power, Phase B, Terminal T	Voltamps [VA] (Secondary)
SCTF	Instantaneous phase fundamental apparent power, Phase C, Terminal T	Voltamps [VA] (Secondary)
SAUF	Instantaneous phase fundamental apparent power, Phase A, Terminal U	Voltamps [VA] (Secondary)
SBUF	Instantaneous phase fundamental apparent power, Phase B, Terminal U	Voltamps [VA] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 21 of 40)

Label	Description	Units
SCUF	Instantaneous phase fundamental apparent power, Phase C, Terminal U	Voltamps [VA] (Secondary)
SAWF	Instantaneous phase fundamental apparent power, Phase A, Terminal W	Voltamps [VA] (Secondary)
SBWF	Instantaneous phase fundamental apparent power, Phase B, Terminal W	Voltamps [VA] (Secondary)
SCWF	Instantaneous phase fundamental apparent power, Phase C, Terminal W	Voltamps [VA] (Secondary)
SAXF	Instantaneous phase fundamental apparent power, Phase A, Terminal X	Voltamps [VA] (Secondary)
SBXF	Instantaneous phase fundamental apparent power, Phase B, Terminal X	Voltamps [VA] (Secondary)
SCXF	Instantaneous phase fundamental apparent power, Phase C, Terminal X	Voltamps [VA] (Secondary)
3PSF	Instantaneous 3-phase fundamental active power, Terminal S	Watts [W] (Secondary)
3PTF	Instantaneous 3-phase fundamental active power, Terminal T	Watts [W] (Secondary)
3PUF	Instantaneous 3-phase fundamental active power, Terminal U	Watts [W] (Secondary)
3PWF	Instantaneous 3-phase fundamental active power, Terminal W	Watts [W] (Secondary)
3PXF	Instantaneous 3-phase fundamental active power, Terminal X	Watts [W] (Secondary)
3QSF	Instantaneous 3-phase fundamental reactive power, Terminal S	VARS [Var] (Secondary)
3QTF	Instantaneous 3-phase fundamental reactive power, Terminal T	VARS [Var] (Secondary)
3QUF	Instantaneous 3-phase fundamental reactive power, Terminal U	VARS [Var] (Secondary)
3QWF	Instantaneous 3-phase fundamental reactive power, Terminal W	VARS [Var] (Secondary)
3QXF	Instantaneous 3-phase fundamental reactive power, Terminal X	VARS [Var] (Secondary)
3SSF	Instantaneous 3-phase fundamental apparent power, Terminal S	Voltamps [VA] (Secondary)
3STF	Instantaneous 3-phase fundamental apparent power, Terminal T	Voltamps [VA] (Secondary)
3SUF	Instantaneous 3-phase fundamental apparent power, Terminal U	Voltamps [VA] (Secondary)
3SWF	Instantaneous 3-phase fundamental apparent power, Terminal W	Voltamps [VA] (Secondary)
3SXF	Instantaneous 3-phase fundamental apparent power, Terminal X	Voltamps [VA] (Secondary)
PASTF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals ST	Watts [W] (Secondary)
PBSTF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals ST	Watts [W] (Secondary)
PCSTF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals ST	Watts [W] (Secondary)
PATUF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals TU	Watts [W] (Secondary)
PBTUF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals TU	Watts [W] (Secondary)
PCTUF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals TU	Watts [W] (Secondary)
PAUWF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals UW	Watts [W] (Secondary)
PBUWF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals UW	Watts [W] (Secondary)

Table H.2 **Analog Quantities Sorted By Function** (Sheet 22 of 40)

Label	Description	Units
PCUWF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals UW	Watts [W] (Secondary)
PAWXF	Instantaneous phase fundamental active power, Phase A, Comb. Terminals WX	Watts [W] (Secondary)
PBWXF	Instantaneous phase fundamental active power, Phase B, Comb. Terminals WX	Watts [W] (Secondary)
PCWXF	Instantaneous phase fundamental active power, Phase C, Comb. Terminals WX	Watts [W] (Secondary)
QASTF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals ST	VARS [Var] (Secondary)
QBSTF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals ST	VARS [Var] (Secondary)
QCSTF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals ST	VARS [Var] (Secondary)
QATUF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals TU	VARS [Var] (Secondary)
QBTUF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals TU	VARS [Var] (Secondary)
QCTUF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals TU	VARS [Var] (Secondary)
QAUWF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals UW	VARS [Var] (Secondary)
QBUWF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals UW	VARS [Var] (Secondary)
QCUWF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals UW	VARS [Var] (Secondary)
QAWXF	Instantaneous phase fundamental reactive power, Phase A, Comb. Terminals WX	VARS [Var] (Secondary)
QBWXF	Instantaneous phase fundamental reactive power, Phase B, Comb. Terminals WX	VARS [Var] (Secondary)
QCWXF	Instantaneous phase fundamental reactive power, Phase C, Comb. Terminals WX	VARS [Var] (Secondary)
SASTF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals ST	Voltamps [VA] (Secondary)
SBSTF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals ST	Voltamps [VA] (Secondary)
SCSTF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals ST	Voltamps [VA] (Secondary)
SATUF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals TU	Voltamps [VA] (Secondary)
SBTUF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals TU	Voltamps [VA] (Secondary)
SCTUF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals TU	Voltamps [VA] (Secondary)
SAUWF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals UW	Voltamps [VA] (Secondary)
SBUWF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals UW	Voltamps [VA] (Secondary)
SCUWF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals UW	Voltamps [VA] (Secondary)
SAWXF	Instantaneous phase fundamental apparent power, Phase A, Comb. Terminals WX	Voltamps [VA] (Secondary)

Table H.2 Analog Quantities Sorted By Function (Sheet 23 of 40)

Label	Description	Units
SBWXF	Instantaneous phase fundamental apparent power, Phase B, Comb. Terminals WX	Voltamps [VA] (Secondary)
SCWXF	Instantaneous phase fundamental apparent power, Phase C, Comb. Terminals WX	Voltamps [VA] (Secondary)
3PSTF	Instantaneous 3-phase fundamental active power, Comb. Terminals ST	Watts [W] (Secondary)
3PTUF	Instantaneous 3-phase fundamental active power, Comb. Terminals TU	Watts [W] (Secondary)
3PUWF	Instantaneous 3-phase fundamental active power, Comb. Terminals UW	Watts [W] (Secondary)
3PWXF	Instantaneous 3-phase fundamental active power, Comb. Terminals WX	Watts [W] (Secondary)
3QSTF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals ST	VARS [Var] (Secondary)
3QTUF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals TU	VARS [Var] (Secondary)
3QUWF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals UW	VARS [Var] (Secondary)
3QWXF	Instantaneous 3-phase fundamental reactive power, Comb. Terminals WX	VARS [Var] (Secondary)
3SSTF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals ST	Voltamps [VA] (Secondary)
3STUF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals TU	Voltamps [VA] (Secondary)
3SUWF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals UW	Voltamps [VA] (Secondary)
3SWXF	Instantaneous 3-phase fundamental apparent power, Comb. Terminals WX	Voltamps [VA] (Secondary)
1 Cycle Average Voltages (Primary Quantities)		
VAVFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase A, Terminal V	Kilovolts [kV] (primary)
VBVFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase B, Terminal V	Kilovolts [kV] (primary)
VCVFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase C, Terminal V	Kilovolts [kV] (primary)
VAZFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase A, Terminal Z	Kilovolts [kV] (primary)
VBZFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase B, Terminal Z	Kilovolts [kV] (primary)
VCZFMC	1 cycle average filtered phase-to-neutral Voltage magnitude, Phase C, Terminal Z	Kilovolts [kV] (primary)
VAVFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase A, Terminal V	Degrees [°] (±180°)
VBVFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase B, Terminal V	Degrees [°] (±180°)
VCVFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase C, Terminal V	Degrees [°] (±180°)
VAZFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase A, Terminal Z	Degrees [°] (±180°)
VBZFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase B, Terminal Z	Degrees [°] (±180°)
VCZFAC	1 cycle average filtered phase-to-neutral Voltage angle, Phase C, Terminal Z	Degrees [°] (±180°)
VABVFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases AB, Terminal V	Kilovolts [V] (primary)
VBCVFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases BC, Terminal V	Kilovolts [V] (primary)
VCAVFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases CA, Terminal V	Kilovolts [V] (primary)
VABZFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases AB, Terminal Z	Kilovolts [V] (primary)
VBCZFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases BC, Terminal Z	Kilovolts [V] (primary)
VCAZFMC	1 cycle average filtered phase-to-phase Voltage magnitude, Phases CA, Terminal Z	Kilovolts [V] (primary)
VABVFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases AB, Terminal V	Degrees [°] (±180°)

Table H.2 Analog Quantities Sorted By Function (Sheet 24 of 40)

Label	Description	Units
VBCVFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases BC, Terminal V	Degrees [°] (±180°)
VCAVFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases CA, Terminal V	Degrees [°] (±180°)
VABZFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases AB, Terminal Z	Degrees [°] (±180°)
VBCZFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases BC, Terminal Z	Degrees [°] (±180°)
VCAZFAC	1 cycle average filtered phase-to-phase Voltage angle, Phases CA, Terminal Z	Degrees [°] (±180°)
VAVRC	1 cycle average RMS phase-to-neutral Voltage, Phase A, Terminal V	Kilovolts [kV] (primary)
VBVRC	1 cycle average RMS phase-to-neutral Voltage, Phase B, Terminal V	Kilovolts [kV] (primary)
VCVRC	1 cycle average RMS phase-to-neutral Voltage, Phase C, Terminal V	Kilovolts [kV] (primary)
VAZRC	1 cycle average RMS phase-to-neutral Voltage, Phase A, Terminal Z	Kilovolts [kV] (primary)
VBZRC	1 cycle average RMS phase-to-neutral Voltage, Phase B, Terminal Z	Kilovolts [kV] (primary)
VCZRC	1 cycle average RMS phase-to-neutral Voltage, Phase C, Terminal Z	Kilovolts [kV] (primary)
VABVRC	1 cycle average RMS phase-to-phase Voltage, Phases AB, Terminal V	Kilovolts [kV] (primary)
VBCVRC	1 cycle average RMS phase-to-phase Voltage, Phases BC, Terminal V	Kilovolts [kV] (primary)
VCAVRC	1 cycle average RMS phase-to-phase Voltage, Phases CA, Terminal V	Kilovolts [kV] (primary)
VABZRC	1 cycle average RMS phase-to-phase Voltage, Phases AB, Terminal Z	Kilovolts [kV] (primary)
VBCZRC	1 cycle average RMS phase-to-phase Voltage, Phases BC, Terminal Z	Kilovolts [kV] (primary)
VCAZRC	1 cycle average RMS phase-to-phase Voltage, Phases CA, Terminal Z	Kilovolts [kV] (primary)
V1VMC	1 cycle average positive-sequence Voltage magnitude, Terminal V	Kilovolts [kV] (primary)
V1ZMC	1 cycle average positive-sequence Voltage magnitude, Terminal Z	Kilovolts [kV] (primary)
V1VAC	1 cycle average positive-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
V1ZAC	1 cycle average positive-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V2VMC	1 cycle average negative-sequence Voltage magnitude, Terminal V	Kilovolts [kV] (primary)
3V2ZMC	1 cycle average negative-sequence Voltage magnitude, Terminal Z	Kilovolts [kV] (primary)
3V2VAC	1 cycle average negative-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V2ZAC	1 cycle average negative-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
3V0VMC	1 cycle average zero-sequence Voltage magnitude, Terminal V	Kilovolts [kV] (primary)
3V0ZMC	1 cycle average zero-sequence Voltage magnitude, Terminal Z	Kilovolts [kV] (primary)
3V0VAC	1 cycle average zero-sequence Voltage angle, Terminal V	Degrees [°] (±180°)
3V0ZAC	1 cycle average zero-sequence Voltage angle, Terminal Z	Degrees [°] (±180°)
1 Cycle Average Currents (Primary Quantities)		
IASFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal S	Amps [A] (primary)
IBSFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal S	Amps [A] (primary)
ICSFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal S	Amps [A] (primary)
IATFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal T	Amps [A] (primary)
IBTFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal T	Amps [A] (primary)
ICTFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal T	Amps [A] (primary)
IAUFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal U	Amps [A] (primary)
IBUFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal U	Amps [A] (primary)
ICUFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal U	Amps [A] (primary)
IAWFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal W	Amps [A] (primary)
IBWFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal W	Amps [A] (primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 25 of 40)

Label	Description	Units
ICWFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal W	Amps [A] (primary)
IAXFMC	1 cycle average filtered phase current magnitude, Phase A, Terminal X	Amps [A] (primary)
IBXFMC	1 cycle average filtered phase current magnitude, Phase B, Terminal X	Amps [A] (primary)
ICXFMC	1 cycle average filtered phase current magnitude, Phase C, Terminal X	Amps [A] (primary)
IASFAC	1 cycle average filtered phase current angle, Phase A, Terminal S	Degrees [°] (±180°)
IBSFAC	1 cycle average filtered phase current angle, Phase B, Terminal S	Degrees [°] (±180°)
ICSFAC	1 cycle average filtered phase current angle, Phase C, Terminal S	Degrees [°] (±180°)
IATFAC	1 cycle average filtered phase current angle, Phase A, Terminal T	Degrees [°] (±180°)
IBTFAC	1 cycle average filtered phase current angle, Phase B, Terminal T	Degrees [°] (±180°)
ICTFAC	1 cycle average filtered phase current angle, Phase C, Terminal T	Degrees [°] (±180°)
IAUFAC	1 cycle average filtered phase current angle, Phase A, Terminal U	Degrees [°] (±180°)
IBUFAC	1 cycle average filtered phase current angle, Phase B, Terminal U	Degrees [°] (±180°)
ICUFAC	1 cycle average filtered phase current angle, Phase C, Terminal U	Degrees [°] (±180°)
IAWFAC	1 cycle average filtered phase current angle, Phase A, Terminal W	Degrees [°] (±180°)
IBWFAC	1 cycle average filtered phase current angle, Phase B, Terminal W	Degrees [°] (±180°)
ICWFAC	1 cycle average filtered phase current angle, Phase C, Terminal W	Degrees [°] (±180°)
IAXFAC	1 cycle average filtered phase current angle, Phase A, Terminal X	Degrees [°] (±180°)
IBXFAC	1 cycle average filtered phase current angle, Phase B, Terminal X	Degrees [°] (±180°)
ICXFAC	1 cycle average filtered phase current angle, Phase C, Terminal X	Degrees [°] (±180°)
IY1FMC–IY3FMC	1 cycle average filtered current magnitude, Channel 1, Terminal Y	Amps [A] (primary)
IY1FAC–IY3FAC	1 cycle average filtered current angle, channel 1, Terminal Y	Degrees [°] (±180°)
IASRC	1 cycle average RMS phase current, Phase A, Terminal S	Amps [A] (primary)
IBSRC	1 cycle average RMS phase current, Phase B, Terminal S	Amps [A] (primary)
ICSRC	1 cycle average RMS phase current, Phase C, Terminal S	Amps [A] (primary)
IATRC	1 cycle average RMS phase current, Phase A, Terminal T	Amps [A] (primary)
IBTRC	1 cycle average RMS phase current, Phase B, Terminal T	Amps [A] (primary)
ICTRC	1 cycle average RMS phase current, Phase C, Terminal T	Amps [A] (primary)
IAURC	1 cycle average RMS phase current, Phase A, Terminal U	Amps [A] (primary)
IBURC	1 cycle average RMS phase current, Phase B, Terminal U	Amps [A] (primary)
ICURC	1 cycle average RMS phase current, Phase C, Terminal U	Amps [A] (primary)
IAWRC	1 cycle average RMS phase current, Phase A, Terminal W	Amps [A] (primary)
IBWRC	1 cycle average RMS phase current, Phase B, Terminal W	Amps [A] (primary)
ICWRC	1 cycle average RMS phase current, Phase C, Terminal W	Amps [A] (primary)
IAXRC	1 cycle average RMS phase current, Phase A, Terminal X	Amps [A] (primary)
IBXRC	1 cycle average RMS phase current, Phase B, Terminal X	Amps [A] (primary)
ICXRC	1 cycle average RMS phase current, Phase C, Terminal X	Amps [A] (primary)
IASTFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals ST	Amps [A] (primary)
IBSTFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals ST	Amps [A] (primary)
ICSTFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals ST	Amps [A] (primary)
IATUFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals TU	Amps [A] (primary)

Table H.2 **Analog Quantities Sorted By Function** (Sheet 26 of 40)

Label	Description	Units
IBTUFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals TU	Amps [A] (primary)
ICTUFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals TU	Amps [A] (primary)
IAUWFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals UW	Amps [A] (primary)
IBUWFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals UW	Amps [A] (primary)
ICUWFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals UW	Amps [A] (primary)
IAWXFMC	1 cycle average filtered phase current magnitude, Phase A, Comb. Terminals WX	Amps [A] (primary)
IBWXFMC	1 cycle average filtered phase current magnitude, Phase B, Comb. Terminals WX	Amps [A] (primary)
ICWXFMC	1 cycle average filtered phase current magnitude, Phase C, Comb. Terminals WX	Amps [A] (primary)
IASTFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals ST	Degrees [°] (±180°)
IBSTFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals ST	Degrees [°] (±180°)
ICSTFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals ST	Degrees [°] (±180°)
IATUFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals TU	Degrees [°] (±180°)
IBTUFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals TU	Degrees [°] (±180°)
ICTUFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals TU	Degrees [°] (±180°)
IAUWFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals UW	Degrees [°] (±180°)
IBUWFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals UW	Degrees [°] (±180°)
ICUWFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals UW	Degrees [°] (±180°)
IAWXFAC	1 cycle average filtered phase current angle, Phase A, Comb. Terminals WX	Degrees [°] (±180°)
IBWXFAC	1 cycle average filtered phase current angle, Phase B, Comb. Terminals WX	Degrees [°] (±180°)
ICWXFAC	1 cycle average filtered phase current angle, Phase C, Comb. Terminals WX	Degrees [°] (±180°)
IASTRC	1 cycle average RMS phase current, Phase A, Comb. Terminals ST	Amps [A] (primary)
IBSTRC	1 cycle average RMS phase current, Phase B, Comb. Terminals ST	Amps [A] (primary)
ICSTRC	1 cycle average RMS phase current, Phase C, Comb. Terminals ST	Amps [A] (primary)
IATURC	1 cycle average RMS phase current, Phase A, Comb. Terminals TU	Amps [A] (primary)
IBTURC	1 cycle average RMS phase current, Phase B, Comb. Terminals TU	Amps [A] (primary)
ICTURC	1 cycle average RMS phase current, Phase C, Comb. Terminals TU	Amps [A] (primary)
IAUWRC	1 cycle average RMS phase current, Phase A, Comb. Terminals UW	Amps [A] (primary)
IBUWRC	1 cycle average RMS phase current, Phase B, Comb. Terminals UW	Amps [A] (primary)
ICUWRC	1 cycle average RMS phase current, Phase C, Comb. Terminals UW	Amps [A] (primary)
IAWXRC	1 cycle average RMS phase current, Phase A, Comb. Terminals WX	Amps [A] (primary)
IBWXRC	1 cycle average RMS phase current, Phase B, Comb. Terminals WX	Amps [A] (primary)
ICWXRC	1 cycle average RMS phase current, Phase C, Comb. Terminals WX	Amps [A] (primary)
I1SMC	1 cycle average positive-sequence current magnitude, Terminal S	Amps [A] (primary)
I1TMC	1 cycle average positive-sequence current magnitude, Terminal T	Amps [A] (primary)
I1UMC	1 cycle average positive-sequence current magnitude, Terminal U	Amps [A] (primary)
I1WMC	1 cycle average positive-sequence current magnitude, Terminal W	Amps [A] (primary)
I1XMC	1 cycle average positive-sequence current magnitude, Terminal X	Amps [A] (primary)
I1SAC	1 cycle average positive-sequence current angle, Terminal S	Degrees [°] (±180°)
I1TAC	1 cycle average positive-sequence current angle, Terminal T	Degrees [°] (±180°)
I1UAC	1 cycle average positive-sequence current angle, Terminal U	Degrees [°] (±180°)
I1WAC	1 cycle average positive-sequence current angle, Terminal W	Degrees [°] (±180°)

Table H.2 Analog Quantities Sorted By Function (Sheet 27 of 40)

Label	Description	Units
I1XAC	1 cycle average positive-sequence current angle, Terminal X	Degrees [°] (±180°)
3I2SMC	1 cycle average negative-sequence current magnitude, Terminal S	Amps [A] (primary)
3I2TMC	1 cycle average negative-sequence current magnitude, Terminal T	Amps [A] (primary)
3I2UMC	1 cycle average negative-sequence current magnitude, Terminal U	Amps [A] (primary)
3I2WMC	1 cycle average negative-sequence current magnitude, Terminal W	Amps [A] (primary)
3I2XMC	1 cycle average negative-sequence current magnitude, Terminal X	Amps [A] (primary)
3I2SAC	1 cycle average negative-sequence current angle, Terminal S	Degrees [°] (±180°)
3I2TAC	1 cycle average negative-sequence current angle, Terminal T	Degrees [°] (±180°)
3I2UAC	1 cycle average negative-sequence current angle, Terminal U	Degrees [°] (±180°)
3I2WAC	1 cycle average negative-sequence current angle, Terminal W	Degrees [°] (±180°)
3I2XAC	1 cycle average negative-sequence current angle, Terminal X	Degrees [°] (±180°)
3I0SMC	1 cycle average zero-sequence current magnitude, Terminal S	Amps [A] (primary)
3I0TMC	1 cycle average zero-sequence current magnitude, Terminal T	Amps [A] (primary)
3I0UMC	1 cycle average zero-sequence current magnitude, Terminal U	Amps [A] (primary)
3I0WMC	1 cycle average zero-sequence current magnitude, Terminal W	Amps [A] (primary)
3I0XMC	1 cycle average zero-sequence current magnitude, Terminal X	Amps [A] (primary)
3I0SAC	1 cycle average zero-sequence current angle, Terminal S	Degrees [°] (±180°)
3I0TAC	1 cycle average zero-sequence current angle, Terminal T	Degrees [°] (±180°)
3I0UAC	1 cycle average zero-sequence current angle, Terminal U	Degrees [°] (±180°)
3I0WAC	1 cycle average zero-sequence current angle, Terminal W	Degrees [°] (±180°)
3I0XAC	1 cycle average zero-sequence current angle, Terminal X	Degrees [°] (±180°)
I1STMC	1 cycle average positive-sequence current magnitude, Comb. Terminals ST	Amps [A] (primary)
I1TUMC	1 cycle average positive-sequence current magnitude, Comb. Terminals TU	Amps [A] (primary)
I1UWMC	1 cycle average positive-sequence current magnitude, Comb. Terminals UW	Amps [A] (primary)
I1WXMC	1 cycle average positive-sequence current magnitude, Comb. Terminals WX	Amps [A] (primary)
I1STAC	1 cycle average positive-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
I1TUAC	1 cycle average positive-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
I1UWAC	1 cycle average positive-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
I1WXAC	1 cycle average positive-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I2STMC	1 cycle average negative-sequence current magnitude, Comb. Terminals ST	Amps [A] (primary)
3I2TUMC	1 cycle average negative-sequence current magnitude, Comb. Terminals TU	Amps [A] (primary)
3I2UWMC	1 cycle average negative-sequence current magnitude, Comb. Terminals UW	Amps [A] (primary)
3I2WXMC	1 cycle average negative-sequence current magnitude, Comb. Terminals WX	Amps [A] (primary)
3I2STAC	1 cycle average negative-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I2TUAC	1 cycle average negative-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I2UWAC	1 cycle average negative-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I2WXAC	1 cycle average negative-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
3I0STMC	1 cycle average zero-sequence current magnitude, Comb. Terminals ST	Amps [A] (primary)
3I0TUMC	1 cycle average zero-sequence current magnitude, Comb. Terminals TU	Amps [A] (primary)
3I0UWMC	1 cycle average zero-sequence current magnitude, Comb. Terminals UW	Amps [A] (primary)
3I0WXMC	1 cycle average zero-sequence current magnitude, Comb. Terminals WX	Amps [A] (primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 28 of 40)

Label	Description	Units
3I0STAC	1 cycle average zero-sequence current angle, Comb. Terminals ST	Degrees [°] (±180°)
3I0TUAC	1 cycle average zero-sequence current angle, Comb. Terminals TU	Degrees [°] (±180°)
3I0UWAC	1 cycle average zero-sequence current angle, Comb. Terminals UW	Degrees [°] (±180°)
3I0WXAC	1 cycle average zero-sequence current angle, Comb. Terminals WX	Degrees [°] (±180°)
IASRS	1 second average RMS phase current, Phase A, Terminal S	Amperes [A]
IBSRS	1 second average RMS phase current, Phase B, Terminal S	Amperes [A]
ICSRS	1 second average RMS phase current, Phase C, Terminal S	Amperes [A]
IATRS	1 second average RMS phase current, Phase A, Terminal T	Amperes [A]
IBTRS	1 second average RMS phase current, Phase B, Terminal T	Amperes [A]
ICTRS	1 second average RMS phase current, Phase C, Terminal T	Amperes [A]
IAURS	1 second average RMS phase current, Phase A, Terminal U	Amperes [A]
IBURS	1 second average RMS phase current, Phase B, Terminal U	Amperes [A]
ICURS	1 second average RMS phase current, Phase C, Terminal U	Amperes [A]
IAWRS	1 second average RMS phase current, Phase A, Terminal W	Amperes [A]
IBWRS	1 second average RMS phase current, Phase B, Terminal W	Amperes [A]
ICWRS	1 second average RMS phase current, Phase C, Terminal W	Amperes [A]
IAXRS	1 second average RMS phase current, Phase A, Terminal X	Amperes [A]
IBXRS	1 second average RMS phase current, Phase B, Terminal X	Amperes [A]
ICXRS	1 second average RMS phase current, Phase C, Terminal X	Amperes [A]
IASTRS	1 second average RMS phase current, Phase A, Comb. Terminals ST	Amperes [A]
IBSTRS	1 second average RMS phase current, Phase B, Comb. Terminals ST	Amperes [A]
ICSTRS	1 second average RMS phase current, Phase C, Comb. Terminals ST	Amperes [A]
IATURS	1 second average RMS phase current, Phase A, Comb. Terminals TU	Amperes [A]
IBTURS	1 second average RMS phase current, Phase B, Comb. Terminals TU	Amperes [A]
ICTURS	1 second average RMS phase current, Phase C, Comb. Terminals TU	Amperes [A]
IAUWRS	1 second average RMS phase current, Phase A, Comb. Terminals UW	Amperes [A]
IBUWRS	1 second average RMS phase current, Phase B, Comb. Terminals UW	Amperes [A]
ICUWRS	1 second average RMS phase current, Phase C, Comb. Terminals UW	Amperes [A]
IAWXRS	1 second average RMS phase current, Phase A, Comb. Terminals WX	Amperes [A]
IBWXRS	1 second average RMS phase current, Phase B, Comb. Terminals WX	Amperes [A]
ICWXRS	1 second average RMS phase current, Phase C, Comb. Terminals WX	Amperes [A]
IMXSRS	1 second average Maximum RMS phase current, Terminal S, Amperes [A]	Amperes [A]
IMXTRS	1 second average Maximum RMS phase current, Terminal T, Amperes [A]	Amperes [A]
IMXURS	1 second average Maximum RMS phase current, Terminal U, Amperes [A]	Amperes [A]
IMXWRS	1 second average Maximum RMS phase current, Terminal W, Amperes [A]	Amperes [A]
IMXXRS	1 second average Maximum RMS phase current, Terminal X, Amperes [A]	Amperes [A]
IMXSTRS	1 second average Maximum RMS phase current, Comb. Terminals ST	Amperes [A]
IMXTURS	1 second average Maximum RMS phase current, Comb. Terminals TU	Amperes [A]
IMXUWRS	1 second average Maximum RMS phase current, Comb. Terminals UW	Amperes [A]
IMXWXRS	1 second average Maximum RMS phase current, Comb. Terminals WX	Amperes [A]
3I2SMS	1 second average negative-sequence current magnitude, Terminal S	Amperes [A]

Table H.2 Analog Quantities Sorted By Function (Sheet 29 of 40)

Label	Description	Units
3I2TMS	1 second average negative-sequence current magnitude, Terminal T	Amperes [A]
3I2UMS	1 second average negative-sequence current magnitude, Terminal U	Amperes [A]
3I2WMS	1 second average negative-sequence current magnitude, Terminal W	Amperes [A]
3I2XMS	1 second average negative-sequence current magnitude, Terminal X	Amperes [A]
3I2STMS	1 second average negative-sequence current magnitude, Comb. Terminals ST	Amperes [A]
3I2TUMS	1 second average negative-sequence current magnitude, Comb. Terminals TU	Amperes [A]
3I2UWMS	1 second average negative-sequence current magnitude, Comb. Terminals UW	Amperes [A]
3I2WXMS	1 second average negative-sequence current magnitude, Comb. Terminals WX	Amperes [A]
3I0SMS	1 second average zero-sequence current magnitude, Terminal S	Amperes [A]
3I0TMS	1 second average zero-sequence current magnitude, Terminal T	Amperes [A]
3I0UMS	1 second average zero-sequence current magnitude, Terminal U	Amperes [A]
3I0WMS	1 second average zero-sequence current magnitude, Terminal W	Amperes [A]
3I0XMS	1 second average zero-sequence current magnitude, Terminal X	Amperes [A]
3I0STMS	1 second average zero-sequence current magnitude, Comb. Terminals ST	Amperes [A]
3I0TUMS	1 second average zero-sequence current magnitude, Comb. Terminals TU	Amperes [A]
3I0UWMS	1 second average zero-sequence current magnitude, Comb. Terminals UW	Amperes [A]
3I0WXMS	1 second average zero-sequence current magnitude, Comb. Terminals WX	Amperes [A]
1 Cycle Average Power (Primary Quantities)		
PASFC	1 cycle average phase fundamental active power, Phase A, Terminal S	Megawatts [MW] (Primary)
PBSFC	1 cycle average phase fundamental active power, Phase B, Terminal S	Megawatts [MW] (Primary)
PCSFC	1 cycle average phase fundamental active power, Phase C, Terminal S	Megawatts [MW] (Primary)
PATFC	1 cycle average phase fundamental active power, Phase A, Terminal T	Megawatts [MW] (Primary)
PBTFC	1 cycle average phase fundamental active power, Phase B, Terminal T	Megawatts [MW] (Primary)
PCTFC	1 cycle average phase fundamental active power, Phase C, Terminal T	Megawatts [MW] (Primary)
PAUFC	1 cycle average phase fundamental active power, Phase A, Terminal U	Megawatts [MW] (Primary)
PBUFC	1 cycle average phase fundamental active power, Phase B, Terminal U	Megawatts [MW] (Primary)
PCUFC	1 cycle average phase fundamental active power, Phase C, Terminal U	Megawatts [MW] (Primary)
PAWFC	1 cycle average phase fundamental active power, Phase A, Terminal W	Megawatts [MW] (Primary)
PBWFC	1 cycle average phase fundamental active power, Phase B, Terminal W	Megawatts [MW] (Primary)
PCWFC	1 cycle average phase fundamental active power, Phase C, Terminal W	Megawatts [MW] (Primary)
PAXFC	1 cycle average phase fundamental active power, Phase A, Terminal X	Megawatts [MW] (Primary)
PBXFC	1 cycle average phase fundamental active power, Phase B, Terminal X	Megawatts [MW] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 30 of 40)

Label	Description	Units
PCXFC	1 cycle average phase fundamental active power, Phase C, Terminal X	Megawatts [MW] (Primary)
QASFC	1 cycle average phase fundamental reactive power, Phase A, Terminal S	Megavars [Mvar] (Primary)
QBSFC	1 cycle average phase fundamental reactive power, Phase B, Terminal S	Megavars [Mvar] (Primary)
QCSFC	1 cycle average phase fundamental reactive power, Phase C, Terminal S	Megavars [Mvar] (Primary)
QATFC	1 cycle average phase fundamental reactive power, Phase A, Terminal T	Megavars [Mvar] (Primary)
QBTFC	1 cycle average phase fundamental reactive power, Phase B, Terminal T	Megavars [Mvar] (Primary)
QCTFC	1 cycle average phase fundamental reactive power, Phase C, Terminal T	Megavars [Mvar] (Primary)
QAUFC	1 cycle average phase fundamental reactive power, Phase A, Terminal U	Megavars [Mvar] (Primary)
QBUFC	1 cycle average phase fundamental reactive power, Phase B, Terminal U	Megavars [Mvar] (Primary)
QCUFC	1 cycle average phase fundamental reactive power, Phase C, Terminal U	Megavars [Mvar] (Primary)
QAWFC	1 cycle average phase fundamental reactive power, Phase A, Terminal W	Megavars [Mvar] (Primary)
QBWFC	1 cycle average phase fundamental reactive power, Phase B, Terminal W	Megavars [Mvar] (Primary)
QCWFC	1 cycle average phase fundamental reactive power, Phase C, Terminal W	Megavars [Mvar] (Primary)
QAXFC	1 cycle average phase fundamental reactive power, Phase A, Terminal X	Megavars [Mvar] (Primary)
QBXFC	1 cycle average phase fundamental reactive power, Phase B, Terminal X	Megavars [Mvar] (Primary)
QCXFC	1 cycle average phase fundamental reactive power, Phase C, Terminal X	Megavars [Mvar] (Primary)
SASFC	1 cycle average phase fundamental apparent power, Phase A, Terminal S	Mega Voltamps [MVA] (Primary)
SBSFC	1 cycle average phase fundamental apparent power, Phase B, Terminal S	Mega Voltamps [MVA] (Primary)
SCSFC	1 cycle average phase fundamental apparent power, Phase C, Terminal S	Mega Voltamps [MVA] (Primary)
SATFC	1 cycle average phase fundamental apparent power, Phase A, Terminal T	Mega Voltamps [MVA] (Primary)
SBTFC	1 cycle average phase fundamental apparent power, Phase B, Terminal T	Mega Voltamps [MVA] (Primary)
SCTFC	1 cycle average phase fundamental apparent power, Phase C, Terminal T	Mega Voltamps [MVA] (Primary)
SAUFC	1 cycle average phase fundamental apparent power, Phase A, Terminal U	Mega Voltamps [MVA] (Primary)
SBUFC	1 cycle average phase fundamental apparent power, Phase B, Terminal U	Mega Voltamps [MVA] (Primary)
SCUFC	1 cycle average phase fundamental apparent power, Phase C, Terminal U	Mega Voltamps [MVA] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 31 of 40)

Label	Description	Units
SAWFC	1 cycle average phase fundamental apparent power, Phase A, Terminal W	Mega Voltamps [MVA] (Primary)
SBWFC	1 cycle average phase fundamental apparent power, Phase B, Terminal W	Mega Voltamps [MVA] (Primary)
SCWFC	1 cycle average phase fundamental apparent power, Phase C, Terminal W	Mega Voltamps [MVA] (Primary)
SAXFC	1 cycle average phase fundamental apparent power, Phase A, Terminal X	Mega Voltamps [MVA] (Primary)
SBXFC	1 cycle average phase fundamental apparent power, Phase B, Terminal X	Mega Voltamps [MVA] (Primary)
SCXFC	1 cycle average phase fundamental apparent power, Phase C, Terminal X	Mega Voltamps [MVA] (Primary)
3PSFC	1 cycle average 3-phase fundamental active power, Terminal S	Megawatts [MW] (Primary)
3PTFC	1 cycle average 3-phase fundamental active power, Terminal T	Megawatts [MW] (Primary)
3PUFC	1 cycle average 3-phase fundamental active power, Terminal U	Megawatts [MW] (Primary)
3PWFC	1 cycle average 3-phase fundamental active power, Terminal W	Megawatts [MW] (Primary)
3PXFC	1 cycle average 3-phase fundamental active power, Terminal X	Megawatts [MW] (Primary)
3QSFC	1 cycle average 3-phase fundamental reactive power, Terminal S	Megavars [Mvar] (Primary)
3QTFC	1 cycle average 3-phase fundamental reactive power, Terminal T	Megavars [Mvar] (Primary)
3QUFC	1 cycle average 3-phase fundamental reactive power, Terminal U	Megavars [Mvar] (Primary)
3QWFC	1 cycle average 3-phase fundamental reactive power, Terminal W	Megavars [Mvar] (Primary)
3QXFC	1 cycle average 3-phase fundamental reactive power, Terminal X	Megavars [Mvar] (Primary)
3SSFC	1 cycle average 3-phase fundamental apparent power, Terminal S	Mega Voltamps [MVA] (Primary)
3STFC	1 cycle average 3-phase fundamental apparent power, Terminal T	Mega Voltamps [MVA] (Primary)
3SUFC	1 cycle average 3-phase fundamental apparent power, Terminal U	Mega Voltamps [MVA] (Primary)
3SWFC	1 cycle average 3-phase fundamental apparent power, Terminal W	Mega Voltamps [MVA] (Primary)
3SXFC	1 cycle average 3-phase fundamental apparent power, Terminal X	Mega Voltamps [MVA] (Primary)
PASTFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals ST	Megawatts [MW] (Primary)
PBSTFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals ST	Megawatts [MW] (Primary)
PCSTFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals ST	Megawatts [MW] (Primary)
PATUFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals TU	Megawatts [MW] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 32 of 40)

Label	Description	Units
PBTUFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals TU	Megawatts [MW] (Primary)
PCTUFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals TU	Megawatts [MW] (Primary)
PAUWFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals UW	Megawatts [MW] (Primary)
PBUWFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals UW	Megawatts [MW] (Primary)
PCUWFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals UW	Megawatts [MW] (Primary)
PAWXFC	1 cycle average phase fundamental active power, Phase A, Comb. Terminals WX	Megawatts [MW] (Primary)
PBWXFC	1 cycle average phase fundamental active power, Phase B, Comb. Terminals WX	Megawatts [MW] (Primary)
PCWXFC	1 cycle average phase fundamental active power, Phase C, Comb. Terminals WX	Megawatts [MW] (Primary)
QASTFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals ST	Megavars [Mvar] (Primary)
QBSTFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals ST	Megavars [Mvar] (Primary)
QCSTFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals ST	Megavars [Mvar] (Primary)
QATUFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals TU	Megavars [Mvar] (Primary)
QBTUFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals TU	Megavars [Mvar] (Primary)
QCTUFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals TU	Megavars [Mvar] (Primary)
QAUWFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals UW	Megavars [Mvar] (Primary)
QBUWFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals UW	Megavars [Mvar] (Primary)
QCUWFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals UW	Megavars [Mvar] (Primary)
QAWXFC	1 cycle average phase fundamental reactive power, Phase A, Comb. Terminals WX	Megavars [Mvar] (Primary)
QBWXFC	1 cycle average phase fundamental reactive power, Phase B, Comb. Terminals WX	Megavars [Mvar] (Primary)
QCWXFC	1 cycle average phase fundamental reactive power, Phase C, Comb. Terminals WX	Megavars [Mvar] (Primary)
SASTFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)
SBSTFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)
SCSTFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)
SATUFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)
SBTUFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 33 of 40)

Label	Description	Units
SCTUFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)
SAUWFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
SBUWFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
SCUWFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
SAWXFC	1 cycle average phase fundamental apparent power, Phase A, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
SBWXFC	1 cycle average phase fundamental apparent power, Phase B, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
SCWXFC	1 cycle average phase fundamental apparent power, Phase C, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
3PSTFC	1 cycle average 3-phase fundamental active power, Comb. Terminals ST	Megawatts [MW] (Primary)
3PTUFC	1 cycle average 3-phase fundamental active power, Comb. Terminals TU	Megawatts [MW] (Primary)
3PUWFC	1 cycle average 3-phase fundamental active power, Comb. Terminals UW	Megawatts [MW] (Primary)
3PWXFC	1 cycle average 3-phase fundamental active power, Comb. Terminals WX	Megawatts [MW] (Primary)
3QSTFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals ST	Megavars [Mvar] (Primary)
3QTUFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals TU	Megavars [Mvar] (Primary)
3QUWFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals UW	Megavars [Mvar] (Primary)
3QWXFC	1 cycle average 3-phase fundamental reactive power, Comb. Terminals WX	Megavars [Mvar] (Primary)
3SSTFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals ST	Mega Voltamps [MVA] (Primary)
3STUFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals TU	Mega Voltamps [MVA] (Primary)
3SUWFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals UW	Mega Voltamps [MVA] (Primary)
3SWXFC	1 cycle average 3-phase fundamental apparent power, Comb. Terminals WX	Mega Voltamps [MVA] (Primary)
Power Factor		
DPFAS	Phase Displacement power factor, Phase A, Terminal S	(unitless - ratio)
DPFBS	Phase Displacement power factor, Phase B, Terminal S	(unitless - ratio)
DPFCS	Phase Displacement power factor, Phase C, Terminal S	(unitless - ratio)
DPFAT	Phase Displacement power factor, Phase A, Terminal T	(unitless - ratio)
DPFBT	Phase Displacement power factor, Phase B, Terminal T	(unitless - ratio)
DPFCT	Phase Displacement power factor, Phase C, Terminal T	(unitless - ratio)
DPFAU	Phase Displacement power factor, Phase A, Terminal U	(unitless - ratio)
DPFBU	Phase Displacement power factor, Phase B, Terminal U	(unitless - ratio)
DPFCU	Phase Displacement power factor, Phase C, Terminal U	(unitless - ratio)

Table H.2 Analog Quantities Sorted By Function (Sheet 34 of 40)

Label	Description	Units
DPFAW	Phase Displacement power factor, Phase A, Terminal W	(unitless - ratio)
DPFBW	Phase Displacement power factor, Phase B, Terminal W	(unitless - ratio)
DPFCW	Phase Displacement power factor, Phase C, Terminal W	(unitless - ratio)
DPFAX	Phase Displacement power factor, Phase A, Terminal X	(unitless - ratio)
DPFBX	Phase Displacement power factor, Phase B, Terminal X	(unitless - ratio)
DPFCX	Phase Displacement power factor, Phase C, Terminal X	(unitless - ratio)
3DPFS	3-Phase Displacement power factor, Terminal S	(unitless - ratio)
3DPFT	3-Phase Displacement power factor, Terminal T	(unitless - ratio)
3DPFU	3-Phase Displacement power factor, Terminal U	(unitless - ratio)
3DPFW	3-Phase Displacement power factor, Terminal W	(unitless - ratio)
3DPFX	3-Phase Displacement power factor, Terminal X	(unitless - ratio)
DPFAST	Phase Displacement power factor, Phase A, Comb. Terminals ST	(unitless - ratio)
DPFBST	Phase Displacement power factor, Phase B, Comb. Terminals ST	(unitless - ratio)
DPFCST	Phase Displacement power factor, Phase C, Comb. Terminals ST	(unitless - ratio)
DPFATU	Phase Displacement power factor, Phase A, Comb. Terminals TU	(unitless - ratio)
DPFBTU	Phase Displacement power factor, Phase B, Comb. Terminals TU	(unitless - ratio)
DPFCTU	Phase Displacement power factor, Phase C, Comb. Terminals TU	(unitless - ratio)
DPFAUW	Phase Displacement power factor, Phase A, Comb. Terminals UW	(unitless - ratio)
DPFBUW	Phase Displacement power factor, Phase B, Comb. Terminals UW	(unitless - ratio)
DPFCUW	Phase Displacement power factor, Phase C, Comb. Terminals UW	(unitless - ratio)
DPFAWX	Phase Displacement power factor, Phase A, Comb. Terminals WX	(unitless - ratio)
DPFBWX	Phase Displacement power factor, Phase B, Comb. Terminals WX	(unitless - ratio)
DPFCWX	Phase Displacement power factor, Phase C, Comb. Terminals WX	(unitless - ratio)
3DPFST	3-Phase Displacement power factor, Comb. Terminals ST	(unitless - ratio)
3DPFTU	3-Phase Displacement power factor, Comb. Terminals TU	(unitless - ratio)
3DPFUW	3-Phase Displacement power factor, Comb. Terminals UW	(unitless - ratio)
3DPFWX	3-Phase Displacement power factor, Comb. Terminals WX	(unitless - ratio)
Differential Element Quantities per unit (1 Cycle Average)		
87IOPAC	1 cycle average differential element operating current	Per Unit [p.u]
87IOPBC	1 cycle average differential element operating current	Per Unit [p.u]
87IOPCC	1 cycle average differential element operating current	Per Unit [p.u]
87IRTAC	1 cycle average differential element restraint current	Per Unit [p.u]
87IRTBC	1 cycle average differential element restraint current	Per Unit [p.u]
87IRTCC	1 cycle average differential element restraint current	Per Unit [p.u]
IRTKA	Biased Instantaneous restraint current, Phase A	Per Unit [p.u]
IRTKB	Biased Instantaneous restraint current, Phase B	Per Unit [p.u]
IRTKC	Biased Instantaneous restraint current, Phase C	Per Unit [p.u]
IRTHRA	Instantaneous Harmonic restraint current, Phase A	Per Unit [p.u]
IRTHRB	Instantaneous Harmonic restraint current, Phase B	Per Unit [p.u]
IRTHRC	Instantaneous Harmonic restraint current, Phase B	Per Unit [p.u]

Table H.2 Analog Quantities Sorted By Function (Sheet 35 of 40)

Label	Description	Units
Demand Metering		
DM01–DM10	Demand Metering value	Amps (A) (secondary)
DMM01–DMM10	Demand Metering maximum value	Amps (A) (secondary)
Energy Metering (Primary Quantities)		
3PSMWhp	Three phase active energy exported, Terminal S	Megawatts hours [MWh] (Primary)
3PTMWhp	Three phase active energy exported, Terminal T	Megawatts hours [MWh] (Primary)
3PUMWhp	Three phase active energy exported, Terminal U	Megawatts hours [MWh] (Primary)
3PWMWhp	Three phase active energy exported, Terminal W	Megawatts hours [MWh] (Primary)
3PXMWhp	Three phase active energy exported, Terminal X	Megawatts hours [MWh] (Primary)
3QSMVhp	Three phase reactive energy exported, Terminal S	Megavars hours [Mvarh] (Primary)
3QTMVhp	Three phase reactive energy exported, Terminal T	Megavars hours [Mvarh] (Primary)
3QUMVhp	Three phase reactive energy exported, Terminal U	Megavars hours [Mvarh] (Primary)
3QWMVhp	Three phase reactive energy exported, Terminal W	Megavars hours [Mvarh] (Primary)
3QXMVhp	Three phase reactive energy exported, Terminal X	Megavars hours [Mvarh] (Primary)
3PSMWhn	Three phase active energy imported, Terminal S	Megawatts hours [MWh] (Primary)
3PTMWhn	Three phase active energy imported, Terminal T	Megawatts hours [MWh] (Primary)
3PUMWhn	Three phase active energy imported, Terminal U	Megawatts hours [MWh] (Primary)
3PWMWhn	Three phase active energy imported, Terminal W	Megawatts hours [MWh] (Primary)
3PXMWhn	Three phase active energy imported, Terminal X	Megawatts hours [MWh] (Primary)
3QSMVhn	Three phase reactive energy imported, Terminal S	Megavars hours [Mvarh] (Primary)
3QTMVhn	Three phase reactive energy imported, Terminal T	Megavars hours [Mvarh] (Primary)
3QUMVhn	Three phase reactive energy imported, Terminal U	Megavars hours [Mvarh] (Primary)
3QWMVhn	Three phase reactive energy imported, Terminal W	Megavars hours [Mvarh] (Primary)
3QXMVhn	Three phase reactive energy imported, Terminal X	Megavars hours [Mvarh] (Primary)
3PSMWhT	Total Three phase active energy, Terminal S	Megawatts hours [MWh] (Primary)
3PTMWhT	Total Three phase active energy, Terminal T	Megawatts hours [MWh] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 36 of 40)

Label	Description	Units
3PUMWhT	Total Three phase active energy, Terminal U	Megawatts hours [MWh] (Primary)
3PWMWhT	Total Three phase active energy, Terminal W	Megawatts hours [MWh] (Primary)
3PXMWhT	Total Three phase active energy, Terminal X	Megawatts hours [MWh] (Primary)
3QSMVhT	Total Three phase reactive energy, Terminal S	Megavars hours [Mvarh] (Primary)
3QTMVhT	Total Three phase reactive energy, Terminal T	Megavars hours [Mvarh] (Primary)
3QUMVhT	Total Three phase reactive energy, Terminal U	Megavars hours [Mvarh] (Primary)
3QWMVhT	Total Three phase reactive energy, Terminal W	Megavars hours [Mvarh] (Primary)
3QXMVhT	Total Three phase reactive energy, Terminal X	Megavars hours [Mvarh] (Primary)
3PSTWhp	Three phase active energy exported, Comb. Terminals ST	Megawatts hours [MWh] (Primary)
3PTUWhp	Three phase active energy exported, Comb. Terminals TU	Megawatts hours [MWh] (Primary)
3PUWWhp	Three phase active energy exported, Comb. Terminals UW	Megawatts hours [MWh] (Primary)
3PWXWhp	Three phase active energy exported, Comb. Terminals WX	Megawatts hours [MWh] (Primary)
3QSTVhp	Three phase reactive energy exported, Comb. Terminals ST	Megavars hours [Mvarh] (Primary)
3QTUVhp	Three phase reactive energy exported, Comb. Terminals TU	Megavars hours [Mvarh] (Primary)
3QUWVhp	Three phase reactive energy exported, Comb. Terminals UW	Megavars hours [Mvarh] (Primary)
3QWXVhp	Three phase reactive energy exported, Comb. Terminals WX	Megavars hours [Mvarh] (Primary)
3PSTWhn	Three phase active energy imported, Comb. Terminals ST	Megawatts hours [MWh] (Primary)
3PTUWhn	Three phase active energy imported, Comb. Terminals TU	Megawatts hours [MWh] (Primary)
3PUWWhn	Three phase active energy imported, Comb. Terminals UW	Megawatts hours [MWh] (Primary)
3PWXWhn	Three phase active energy imported, Comb. Terminals WX	Megawatts hours [MWh] (Primary)
3QSTVhn	Three phase reactive energy imported, Comb. Terminals ST	Megavars hours [Mvarh] (Primary)
3QTUVhn	Three phase reactive energy imported, Comb. Terminals TU	Megavars hours [Mvarh] (Primary)
3QUWVhn	Three phase reactive energy imported, Comb. Terminals UW	Megavars hours [Mvarh] (Primary)
3QWXVhn	Three phase reactive energy imported, Comb. Terminals WX	Megavars hours [Mvarh] (Primary)
3PSTWhT	Total Three phase active energy, Comb. Terminals ST	Megawatts hours [MWh] (Primary)

Table H.2 Analog Quantities Sorted By Function (Sheet 37 of 40)

Label	Description	Units
3PTUWhT	Total Three phase active energy, Comb. Terminals TU	Megawatts hours [MWh] (Primary)
3PUWWhT	Total Three phase active energy, Comb. Terminals UW	Megawatts hours [MWh] (Primary)
3PWXWhT	Total Three phase active energy, Comb. Terminals WX	Megawatts hours [MWh] (Primary)
3QSTVhT	Total Three phase reactive energy, Comb. Terminals ST	Megavars hours [Mvarh] (Primary)
3QTUVhT	Total Three phase reactive energy, Comb. Terminals TU	Megavars hours [Mvarh] (Primary)
3QUWVhT	Total Three phase reactive energy, Comb. Terminals UW	Megavars hours [Mvarh] (Primary)
3QWXVhT	Total Three phase reactive energy, Comb. Terminals WX	Megavars hours [Mvarh] (Primary)
Differential Element Quantities per unit (Instantaneous)		
IOPA	Instantaneous operating current	Per Unit [p.u]
IOPB	Instantaneous operating current	Per Unit [p.u]
IOPC	Instantaneous operating current	Per Unit [p.u]
IRTA	Instantaneous restraint current	Per Unit [p.u]
IRTB	Instantaneous restraint current	Per Unit [p.u]
IRTC	Instantaneous restraint current	Per Unit [p.u]
IAM2	2nd Harmonic current content of operating current	Per Unit [p.u]
IBM2	2nd Harmonic current content of operating current	Per Unit [p.u]
ICM2	2nd Harmonic current content of operating current	Per Unit [p.u]
Differential Element Quantities per unit (Instantaneous)		
IAM4	4th Harmonic current content of operating current	Per Unit [p.u]
IBM4	4th Harmonic current content of operating current	Per Unit [p.u]
ICM4	4th Harmonic current content of operating current	Per Unit [p.u]
IAM5	5th Harmonic current content of operating current	Per Unit [p.u]
IBM5	5th Harmonic current content of operating current	Per Unit [p.u]
ICM5	5th Harmonic current content of operating current	Per Unit [p.u]
Restricted Earth Fault Element Analogs		
REFTQ1–REFTQ3	Restricted Earth Fault Element 1 Torque quantity	Amps secondary
Volts/Hertz Analogs		
24Rpu	Volts/Hertz	unitless (ratio)
Current Unbalance Element		
46AS	Current Unbalance Phase A, Terminal S	percent
46BS	Current Unbalance Phase B, Terminal S	percent
46CS	Current Unbalance Phase C, Terminal S	percent
46AT	Current Unbalance Phase A, Terminal T	percent
46BT	Current Unbalance Phase B, Terminal T	percent
46CT	Current Unbalance Phase C, Terminal T	percent
46AU	Current Unbalance Phase A, Terminal U	percent

Table H.2 Analog Quantities Sorted By Function (Sheet 38 of 40)

Label	Description	Units
46BU	Current Unbalance Phase B, Terminal U	percent
46CU	Current Unbalance Phase C, Terminal U	percent
46AW	Current Unbalance Phase A, Terminal W	percent
46BW	Current Unbalance Phase B, Terminal W	percent
46CW	Current Unbalance Phase C, Terminal W	percent
46AX	Current Unbalance Phase A, Terminal X	percent
46BX	Current Unbalance Phase B, Terminal X	percent
46CX	Current Unbalance Phase C, Terminal X	percent
Breaker Monitoring Elements		
BSBCWPA	Breaker S Breaker-Contact Wear for pole A	percent
BSBCWPB	Breaker S Breaker-Contact Wear for pole B	percent
BSBCWPC	Breaker S Breaker-Contact Wear for pole C	percent
BTBCWPA	Breaker T Breaker-Contact Wear for pole A	percent
BTBCWPB	Breaker T Breaker-Contact Wear for pole B	percent
BTBCWPC	Breaker T Breaker-Contact Wear for pole C	percent
BUBCWPA	Breaker U Breaker-Contact Wear for pole A	percent
BUBCWPB	Breaker U Breaker-Contact Wear for pole B	percent
BUBCWPC	Breaker U Breaker-Contact Wear for pole C	percent
BWBCWPA	Breaker W Breaker-Contact Wear for pole A	percent
BWBCWPB	Breaker W Breaker-Contact Wear for pole B	percent
BWBCWPC	Breaker W Breaker-Contact Wear for pole C	percent
BXBCWPA	Breaker X Breaker-Contact Wear for pole A	percent
BXBCWPB	Breaker X Breaker-Contact Wear for pole B	percent
BXBCWPC	Breaker X Breaker-Contact Wear for pole C	percent
Thermal Elements and RTD		
T1LOAD–T3LOAD	Percentage of full load	percent
T1OILC–T3OILC	Calculated transformer top oil temperature	°C (degrees Celsius)
MAMBT	Measured ambient temperature	°C (degrees Celsius)
MTOIL1–MTOIL3	Measured top oil temperature	°C (degrees Celsius)
T1HS–T3HS	Calculated Hot spot temperature	°C (degrees Celsius)
T1FAA–T3FAA	Insulation Aging Acceleration Factor	unitless
T1RLOL–T3RLOL	Rate of Loss-of-Life	percent
T1TLOL–T3TLOL	Total Loss-of-Life	percent
T1TLL–T3TLL	Time to Total Loss-of-Life Alarm	hrs (hours)
RTD01TV–RTD12TV	RTD temperature value	°C (degrees Celsius)
TEC1–TEC3	Thermal element Condition	unitless

Table H.2 Analog Quantities Sorted By Function (Sheet 39 of 40)

Label	Description	Units
Protection Frequency		
FREQ	Tracking frequency	Hz
FREQP	Frequency for Under/Over frequency elements	Hz
Positive-Sequence Impedance Elements		
Z1MS	Positive-Sequence Impedance Magnitude, Terminal S	Ohms Secondary
Z1MT	Positive-Sequence Impedance Magnitude, Terminal T	Ohms Secondary
Z1MU	Positive-Sequence Impedance Magnitude, Terminal U	Ohms Secondary
Z1MW	Positive-Sequence Impedance Magnitude, Terminal W	Ohms Secondary
Z1MX	Positive-Sequence Impedance Magnitude, Terminal X	Ohms Secondary
Z1AS	Positive-Sequence Impedance Angle, Terminal S	Degrees [°] (±180°)
Z1AT	Positive-Sequence Impedance Angle, Terminal T	Degrees [°] (±180°)
Z1AU	Positive-Sequence Impedance Angle, Terminal U	Degrees [°] (±180°)
Z1AW	Positive-Sequence Impedance Angle, Terminal W	Degrees [°] (±180°)
Z1AX	Positive-Sequence Impedance Angle, Terminal X	Degrees [°] (±180°)
Station DC monitoring		
VDC	Station Battery 1 DC voltage	Volts [V]
DCPO	Average Positive to Ground DC 1 voltage	Volts [V]
DCNE	Average Negative to Ground DC 1 voltage	Volts [V]
DCRI	AC ripple of DC 1 voltage	Volts [V]
DCMIN	Minimum DC 1 voltage	Volts [V]
DCMAX	Maximum DC 1 voltage	Volts [V]
Mirrored Bits Analogs		
MB1A–MB7B	A Channel Received Mirrored Bit Analog Values	Function of selection
Protection Math Variables		
PMV01–PMV64	Protection SELogic Math Variable	
Protection Conditioning Timers		
PCT01PU–PCT32PU	Protection SELogic Conditioning Timer Pickup Time	unitless
PCT01DO–PCT32DO	Protection SELogic Conditioning Timer Dropout Time	unitless
Protection Sequencing Timers		
PST01ET–PST32ET	Protection SELogic Sequencing Timer Elapsed Time	unitless
PST01PT–PST32PT	Protection SELogic Sequencing Timer Preset Time	unitless
Protection Counters		
PCN01CV–PCN32CV	Protection SELogic Counter Current Value	unitless
PCN01PV–PCN32PV	Protection SELogic Counter Preset Value	unitless
Automation SELogic Math Variable		
AMV001–AMV256	Automation SELogic Math Variable	Function dependent

Table H.2 Analog Quantities Sorted By Function (Sheet 40 of 40)

Label	Description	Units
Automation Sequencing Timer		
AST01ET–AST32ET	Automation SELOGIC Sequencing Timer Elapsed Time	unitless
AST01PT–AST32PT	Automation SELOGIC Sequencing Timer Preset Time	unitless
Automation Counters		
ACN01CV–ACN32PV	Automation SELOGIC Counter Current Value	unitless
Group Switch		
ACTGRP	Active Group setting	
Time and Date Management		
TODMS	Time of Day	millisecond
THR	Time	hour
TMIN	Time	minute
TSEC	Time	second
TMSEC	Time	millisecond
TNSEC	Time	nanosecond
DDOW	Date	
DDOM	Date	day
DDOY	Date	day
DMON	Date	month
DYEAR	Date	year
IRIG-B Control Elements		
TUTC	Offset from IRIG-B time to UTC time	hour
TQUAL	Worst case IRIG-B clock time error	second
Remote Analogs From 27XX Card		
RA001–RA256	Remote analogs from 27XX card	Function dependent
Relay Temperature		
RLYTEMP	Relay temperature (temperature of the box)	°C (degrees Celsius)
51 Element Analogs		
51P01–51P10	51 element 01–10 pickup value	Amperes [A] (secondary)
51TD01–51TD10	51 element 01–10 Time dial setting	NA

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Appendix I
Communications Card

Overview

PORT 5 of the SEL-487E is a communications card slot for a SEL-2702 communications card. This optional SEL-2700 series communications card is an Ethernet card with FTP, Telnet, DNP3, IEC 61850, and synchrophasor protocols. This is a factory-installed option available at the time of purchase of a new SEL-487E or as a factory-installed conversion to an existing relay.

You should carefully design your Ethernet network to maximize reliability, minimize system administration effort, and provide adequate security. Work with a networking professional to design your substation Ethernet network.

The Ethernet card is available with standard twisted-pair and fiber-optic physical interfaces. For security, the Ethernet card includes redundant physical interfaces with the capability to automatically transfer communications to the backup interface in the event that the primary network fails. *Table I.1* lists the popular physical and data-link standards that Ethernet card supports.

Table I.1 Ethernet Connection Options

Name	Connector	Media
10BASE-T/100BASE-TX selectable	RJ-45	CAT 5 (Category 5 twisted pair) cable
10BASE-F	Standard ST	Multimode fiber-optic cable
100BASE-FX	Standard ST	Multimode fiber-optic cable

Once installed in an SEL-487E, the Ethernet card settings become part of the relay settings. The card cannot be set directly—it must be set as relay PORT 5. The settings needed for network operation and data exchange protocols, including DNP3 and IEC 61850, are available in the PORT 5 settings.

Ethernet Network Operation Settings

Several settings control how the SEL-487E communicate with the Ethernet card on an Ethernet network. These settings include IP addressing information, network port fail-over options, and network speed.

Network Configuration

Use the network configuration settings shown in *Table I.2* to configure the SEL-487E for operation on an IP network and to set other parameters affecting the physical Ethernet network interface operation.

Table I.2 Ethernet Card Network Configuration Settings

Label	Description	Range	Default
IPADDR	IP network address	IP address	192.92.92.92
SUBNETM	IP network subnet mask	IP address	255.255.255.0
DEFRTR	Default router	IP address	NA
ETCPKA[a]	TCP keep-alive functionality enable[a]	Y, N	N
KAIDLE	Length of time to wait with no detected activity before sending a keep-alive packet	1–20 s (must be greater than or equal to KAINTV)	10
KAINTV	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet	1–20 s (must be less than or equal to KAIDLE)	1
KACNT	Maximum number of keep-alive packets to send	1–20	6
NETPORT	Primary network port (D disables all network ports)	A, B, D	A
FAILOVR	Automatic fail-over enable	Y, N	Y
FTIME	Fail-over time-out	5–65535 ms	5
NETASPD[b]	Network speed or auto-detect on Port A	A, 10 Mbps, 100 Mbps	A
NETBSPD[b]	Network speed or auto-detect on Port B	A, 10 Mbps, 100 Mbps	A

[a] This setting applies only to IEC 61850 communications.
[b] This setting applies only to twisted-pair ports (10/100BASE-T).

The SEL-487E uses the IPADDR and SUBNETM settings to determine its local network and node address. The SUBNETM setting defines the subnet mask. The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

The SEL-487E uses the DEFRTR address setting to determine how to communicate with nodes on other local networks. The SEL-487E communicates with the default router to send data to nodes on other local networks. If you change the DEFRTR setting from the default value of Null (meaning that there is no default router), then the default router must be on the same local network as the SEL-487E or the SEL-487E will reject the DEFRTR setting. You must also coordinate the default router with your general network implementation and administration plan. See *Table I.3* for examples of how IPADDR and SUBNETM define the network and node and how these settings affect the DEFRTR setting.

Table I.3 DEFRTR Address Setting Examples

IPADDR	SUBNETM	Network Number	Node Address	DEFRTR
192.92.92.92	255.255.255.0	192.92.92	92	192.92.92.a[a]
192.92.92.92	255.255.0.0	192.92	92.92	192.92.a[a], b[a]
192.92.92.92	255.0.0.0	192	92.92.92	192.a[a], b[a], c[a]
192.92.92.92	0.0.0.0	n/a	192.92.92.92	a[a], b[a], c[a], d[a]

[a] Value in the range 0–255.

If the SEL-487E is purchased with IEC 61850 support, the ETCPKA setting, along with the KAIDLE, KAINTV, and KACNT settings, can be used to verify that the computer at the remote end of a TCP connection is still available. If ETCPKA is enabled and the SEL-487E does not transmit any TCP data within the interval specified by the KAIDLE setting, the SEL-487E sends a keep-alive packet to the remote computer. If the SEL-487E does not receive a response from the remote computer within the time specified by KAINTV, the keep-alive packet is re-transmitted as many as KACNT times. After this count is reached, the SEL-487E remote device is no longer available, so the SEL-487E can terminate the connection without waiting for the idle timer (TIDLE or FTPIDLE) to expire.

The SEL-487E Ethernet card operates over either twisted-pair or fiber-optic media. Each Ethernet card is equipped with two network ports. With an initial ordering option, you can select the medium for each port (10/100 Mbps twisted pair or 100 Mbps fiber optic). Speeds for the physical media are fixed for fiber-optic connections. For twisted-pair connections, the Ethernet card can auto-detect the network speed or you can set a fixed speed.

Network Port Fail-Over Operation

The SEL-487E Ethernet card has two network ports. Network port fail-over mode enables the Ethernet card to operate as a single network adapter with a primary and standby physical interface. You can connect the two network ports to the same network or different networks depending on your specific Ethernet network architecture. If you have a single network and want to use only one network port, set NETPORT to the port you want to use and set FAILOVR to N. Only one network port operates at a time. The fail-over mode operation determines the active port. To use fail-over mode, proceed with the following steps.

NOTE: If you change settings for the host port where the Ethernet card is installed and the standby network port is active, the Ethernet card resets and returns to operation on the primary port.

Step 1. Set NETPORT to the preferred network interface.

Step 2. Set FAILOVR to Y.

Step 3. Set FTIME to the desired network port fail-over time.

If the Ethernet card detects a link failure on the primary port, it activates the standby port after the fail-over time, FTIME, elapses. If the link status on the primary link returns to normal before the fail-over time expires, the fail-over timer resets; uninterrupted operation continues on the primary network port.

Network Address Resolution

The SEL-487E Ethernet card can resolve 20 network host names to corresponding IP addresses. Settings for Network Address Resolution (NAR) are shown in *Table I.4*. The Ethernet card uses address resolution any place settings or commands require an IP network name. NAR is similar to DNS (Domain Name Services) used on the Internet, except that NAR uses a local name list rather than a remote name server. You can use names rather than numeric IP addresses for settings like DEFRTR (default router) or when using the Ethernet card **PING** command. If a remote network host name (HOST 1–HOST 20) is set NA, then the Ethernet card ignores the corresponding IP address setting (IPADR 1–IPADR 20).

Table I.4 IP Network Address Resolution Settings

Label	Description	Range	Default
HOST1	Remote network host name	16 characters	NA
IPADR1	Remote network host IP address	IP address	NA
HOST 2	Remote network host name	16 characters	NA
IPADR2	Remote network host IP address	IP address	NA
•			
•			
•			
HOST20	Remote network host name	16 characters	NA
IPADR20	Remote network host IP address	IP address	NA

Data Access Settings

Access data using either the standard TCP/IP Telnet and FTP interfaces or, optionally, through the DNP3 LAN/WAN or IEC 61850 interface. You cannot access all data through all interfaces. See the appropriate interface section below for details on data access.

FTP

FTP is a standard application-level protocol for exchanging files between computers over a TCP/IP network. The SEL-487E Ethernet card operates as an FTP server, presenting Ethernet card and host files to FTP clients. The SEL-487E Ethernet card can support as many as three simultaneous FTP sessions, allowing simultaneous FTP access to as many as three separate users.

The host maintains the access control list that determines FTP log-in IDs and passwords. The host also determines which files are available. Some files are available at specific log-in levels, while other files are read-only access. Subsequent host-specific sections describe access control for each host.

File Structure

The basic file structure common to all hosts is organized as a directory and subdirectory tree similar to that used by Unix, DOS, Windows, and other operating systems. The root directory is “/” and has at least one subdirectory. The basic file structure is shown in *Table I.5*.

Table I.5 Basic File Structure (Sheet 1 of 2)

Host Directory	Subdirectories	Files
/	Host	See the host-specific sections for available files and directories.
	SEL-2702	DIAGNOSTICS.TXT ERR.TXT
	DD01_DeviceID	REGION1.TXT
	DD*nn_DeviceID*	REGION1.CAS

Table I.5 Basic File Structure (Sheet 2 of 2)

Host Directory	Subdirectories	Files
		• • • REGION*n*.TXT REGION*n*.CAS

The root directory contains the following files if the IEC 61850 protocol is installed and enabled:

- ➤ CID (Configured IED Description) file—contains the IEC 61850 SCL configuration for the SEL-487E
- ➤ ERR.TXT file—contains any errors found during downloading of the CID file, and is present when the download is complete
- ➤ CFG.XML file—contains the Ethernet card and SEL-487E configuration information

The first subdirectory is for the host. Some hosts do not have a subdirectory. The HOST_ID string, if set, determines this subdirectory name. The Ethernet card strips any leading or following white-space characters. The Ethernet card then substitutes the "_" character for any white-space or delimiter characters. For example, if the HOST_ID is IED#983 Sub#45, then the host subdirectory name is IED_983_Sub_45. If the converted HOST_ID is longer than 31 characters, the host subdirectory name becomes the first 31 characters of the converted HOST_ID. The host subdirectory contains settings, reports, and diagnostic files for the host.

The next subdirectory is SEL-2702. This subdirectory contains the file DIAGNOSTICS.TXT that contains records for Ethernet card system failures. The time and date for the diagnostics file are the same as the time and date of the last system failure event. This directory will also contain the DNPMAP.TXT and DNPMAPx.TXT files if DNP LAN/WAN is enabled. The ERR.TXT file contains any error messages generated by the Ethernet card and host pertaining to these files.

The Ethernet card creates a subdirectory for each virtual device in the host. The subdirectory name is DD*nn_DeviceID*, where *nn* is the virtual device number and DeviceID is the device name derived from an identification string stored in the host that is associated with the virtual device. The Ethernet card uses the first identification string that it finds in the PORTID, DEVICEID, and FIDID strings. The same substitution rules that govern substitutions for the host subdirectory name govern creation of the substring. For example, if you have an SEL-351 connected to an SEL-2030 on Port 3 with a PORTID setting of "Feeder 1," the subdirectory name will be "DD03_Feeder_1."

Each virtual device subdirectory contains files that represent valid host data regions associated with the virtual device. Data region files provide snapshots of the corresponding host database regions. When an FTP client requests the file, the Ethernet card sends a file containing values from the host database region. If the voltage VA is 12.47 kV when you make an FTP request for the METER.TXT file, then the file METER.TXT will contain VA = 12.47. If you request the file at another time, when VA is 12.40, the file will contain VA = 12.40. Two file formats are available, ASCII text and compressed ASCII (CASCII). Names of the files correspond to the data region name (i.e., METER.TXT, METER.CAS).

Access Control

FTP settings control some basic file access features. The host is responsible for maintaining names and passwords for access control. The special FTP user name "anonymous" does not require a password. It has the same access rights as the user name in the FTPAUSR setting. For example, if FTPAUSR is set to ACC, the FTP anonymous user has Access Level 1 rights. See the host-specific sections for additional information about access rights. *Table I.6* lists the settings that affect FTP server operation.

NOTE: SEL advises against enabling anonymous FTP logins (FTPANMS = Y) except under test conditions. The Ethernet card does not require a password for the special FTP user name "anonymous." If you enable anonymous FTP logins, you are allowing unrestricted access to the Ethernet card and host files.

Table I.6 Ethernet Card FTP Settings

Label	Description	Range	Default
FTPSERV[a]	FTP session enable	Y, N	N
FTPCBAN	FTP connect banner	254 characters	FTP SERVER:
FTPIDLE[a]	FTP connection timeout	5–255 minutes	5
FTPANMS[a]	Anonymous login enable	Y, N	N
FTPAUSR	Host user from which anonymous FTP client inherits access rights	See host-specific section	Empty String

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

Telnet

Telnet is also part of the TCP/IP protocol suite. You can use Telnet to establish terminal access to a remote device. A Telnet connection provides access to the user interface of either the host or the Ethernet card. Host user interface access is similar to an ASCII terminal connection to the front port of an SEL device.

You can use Telnet in the Ethernet card in one of three ways:

1. Connect from your PC to the Ethernet card user interface.
2. Connect from your PC to the host user interface.
3. Connect from a host to another Telnet server.

To determine which modes are available in your installation, see the host-specific section. The Ethernet card acts as a Telnet server for connections to the Ethernet card user interface. The user interface provides access to commands for diagnostics and other special features of the Ethernet card. Telnet settings are listed in *Table I.7*.

Table I.7 Ethernet Card Telnet Settings (Sheet 1 of 2)

Label	Description	Range	Default
T1CBAN	Host Telnet connect banner	254 characters	HOST TERMINAL SERVER:
T1INIT	Telnet session from host enable	Y, N	Y
T1RECV	Telnet session to host enable	Y, N	N
T1PNUM[a]	Host Telnet TCP/IP port	1–65534 except 20, 21, 102	23
T2CBAN	Ethernet card Telnet connect banner	254 characters	CARD TERMINAL SERVER:
T2RECV	Telnet session to Ethernet card enable	Y, N	N

Table I.7 Ethernet Card Telnet Settings (Sheet 2 of 2)

Label	Description	Range	Default
T2PNUM[a]	Ethernet card Telnet TCP/IP port	1–65534 except 20, 21, 102	1024
TIDLE	Telnet connection timeout (0 prevents timeout)	0–255 minutes	5

[a] If you change these settings and accept the new settings, the Ethernet card closes all active network connections and briefly pauses network operation.

Ethernet Card Commands

The SEL-487E Ethernet card user interface accepts Ethernet card commands. There are two ways you can connect to the Ethernet card. First, if your host allows, you can make a transparent connection to the Ethernet card. Second, you can establish a Telnet connection to the Ethernet card user interface. See the host-specific sections for more information on connecting to the Ethernet card user interface. Other connections to the Ethernet card, including FTP, require standard protocol commands and do not respond to the Ethernet card user-interface commands.

Using Commands

When you type commands, you can type in either the entire command or just use the first three letters. For example, if you type **STATUS <Enter>** or **STA <Enter>**, the Ethernet card displays status information. Commands are not case sensitive; you may use upper- or lowercase characters. Access level password entry is case sensitive. *Table I.9* summarizes the user commands.

As with serial ports on SEL devices, you can control character transmission in a Telnet session using control characters. Send the control characters listed in *Table I.8* to control long transmissions like event reports and SER reports.

Table I.8 Control Characters

Control Characters	Key Commands	Results
XON	**<CTRL+Q>**	Restart paused transmission and enable subsequent transmissions.
XOFF	**<CTRL+S>**	Pause current transmission and block any subsequent transmissions.
CAN	**<CTRL+X>**	Cancel current transmission or command and return to cursor.

Command Summary

Table I.9 summarizes the Ethernet card commands. Subsequent subsections provide full descriptions of each command in alphabetical order.

Table I.9 Ethernet Card Command Summary (Sheet 1 of 2)

Command	Description	Access Level
2ACCESS	Go to Access Level 2.	1
ACCESS	Go to Access Level 1.	0 or 2
DATE	View or change date.	1[a] or 2
DNPMAP	Display data map(s) accessible to a DNP LAN/WAN master	1 or 2

Table I.9 Ethernet Card Command Summary (Sheet 2 of 2)

Command	Description	Access Level
GOOSE	Display GOOSE message multicast information and status for transmit and receive GOOSE messages.	1 or 2
HELP	Display available commands or command help.	Any
ID	View internal identification parameters for the Ethernet card.	1 or 2
MEMORY	Display RAM statistics for the Ethernet card.	1 or 2
PING	Ping another node on the network.	2
QUIT	Go to Access Level 0.	Any
STATUS	Display self-test status.	1 or 2
TIME	View or change internal clock.	1[a] or 2

[a] Limited functions at this access level. See command description below for details.

Access Levels

Access levels control whether you can perform different operations within SEL products. For example, at Access Level 1, you can view settings. You cannot change settings unless you are at Access Level 2. A complete list of access levels for the SEL-487E is shown in *Table I.10*.

Table I.10 Ethernet Card Access Levels

Access Level	Prompt	Allowed Ethernet Card User-Interface Operations
0	#	Log in to Access Level 1.
1	#>	View data and status information.
2	#>>	Perform all Access Level 1 functions plus advanced diagnostics and set date/time.

Each access level has a password. The Ethernet card uses passwords set in the SEL-487E for the same access level. For example, if you have an Ethernet card, and have set the Access Level 2 password to SUB35L2, then SUB35L2 is the password for Access Level 2 on your Ethernet card.

The Ethernet card uses access levels and passwords in two ways. First, if you are connected to the Ethernet card user interface, the Ethernet card limits command access based on your access level. You are connected to the Ethernet card user interface if you are using a terminal or Telnet program and see one of the prompts shown in *Table I.10*.

Second, the Ethernet card uses access level names and passwords as user names and passwords for protocols that require you to log in to establish a connection. For example, if you are making an FTP connection to the Ethernet card, you will be prompted for an FTP user name and password. In this case, use the SEL-487E access levels and passwords to connect. Use the SEL-487E access level for the FTP user name and the corresponding password for the FTP password. Access levels are listed with corresponding passwords in *Table I.11*.

Table I.11 Access Level User Names and Passwords

Access Level	User Name	Password
0	QUI	None
1	ACC	User-definable
2	2AC	User-definable

Connections that are closed manually by ending the network connection or by using the Ethernet card **QUIT** command are terminated. This means that to reestablish the connection and return to the original access level, you must log in using the access level commands and passwords.

When a connection with the Ethernet card or the SEL-487E "times out," the connection is closed and the access level is reduced to 0. There is a timeout setting associated with connections to the Ethernet card and connections to the SEL-487E through the Ethernet card. The timeout settings and their specific operation are described in the SEL-487E sections.

Access failures cause the Ethernet card to close connections, assert the alarm bit, and prevent connections for a variable delay period.

2ACCESS

Use the **2ACCESS** command to change to Access Level 2. If the current level is not Access Level 1, the Ethernet card responds with "Invalid access level." When you enter the **2AC** command, the Ethernet card prompts you to enter the Access Level 2 password. If the password is Null or you enter the password set in the SEL-487E, the access level changes to Access Level 2. Passwords are case sensitive; you must enter them exactly as set. The SEL-487E maintains the password and user list.

If you are unable to enter the correct password after the third failed attempt, the Ethernet card asserts the ALARM bit in the Status register and terminates the connection for some connection types.

If your connection to the Ethernet card has an inactivity timeout, the Ethernet card automatically closes the connection and changes to Access Level 0 when the timeout expires.

ACCESS

Use the **ACCESS** command to change to Access Level 1. For example, if you are at Access Level 0, the Ethernet card prompts you for the password and moves you to Access Level 1 if you enter the password correctly. For additional details on access level commands, see *2ACCESS*.

DATE

Table I.12 illustrates how to use the **DATE** command to view or set the date.

Table I.12 DATE Command

Command	Description
DATE	Display internal Ethernet card date.
DATE mm/dd/yyyy	Set the date if the date format setting for the host is mm/dd/yyyy, where mm is the month, dd is the day of month, and yyyy is the year.
DATE dd/mm/yyyy	Set the date if the date setting for the host is dd/mm/yyyy.
DATE yyyy/mm/dd	Set the date if the date setting for the host is yyyy/mm/dd.

The **DATE** command displays the internal clock date. A setting in the host determines the date format. In order to avoid confusion, the Ethernet card displays the date format along with the date. For example, if you set the host for a European style date, the Ethernet card displays the current date and the date format text “dd/mm/yyyy.” The date format options are mm/dd/yyyy, dd/mm/yyyy, and yyyy/mm/dd.

Use the **DATE** command with a date to set the internal clock date. Enter the year in four-digit form. Enter the date in a form that matches the date form of the host. Because there is no way to differentiate between mm/dd/yyyy and dd/mm/yyyy for certain dates (02/03/2001 could be February 3 or March 2), check the date format before entering the date. To see the date format, use the **DATE** command.

DNPMAP

Use the **DNPMAP** command to display the data (object types, indices, default variation and source) and controls (object type, indices and destination) that are accessible via DNP3. The output of the **DNPMAP** command documents the DNP3 data map in the SEL-487E to help with the configuration of the DNP3 master.

If the DNPMAP setting is set to CUSTOM, then an additional integer parameter corresponding to an assigned DNPMAP number (1–5) must be specified to view each custom DNP3 data map. For example, the command **DNPMAP 2** would be used to view the custom data map for DNP session 2. If a DNPMAP number is not specified, a summary of DNP3 map settings for all configured sessions will be displayed.

Summary and detailed map configurations are also available in the DNPMAP.TXT and DNPMAP*nn*.TXT files from the Ethernet card FTP interface. The individual file names associated with the detailed custom map settings follow the DNPMAP*nn*.TXT naming convention.

GOOSE

This command outputs the GOOSE multicast information and status for every GOOSE transmit and receive message connected to the SEL-487E.

The multicast information displayed includes:

Field	Description
GOOSE Control Reference	A concatenation of the IED name, LN0 lnClass (Logical Node Class) and GSEControl name (GSE Control Block Name)
Multicast Address (MultiCastAddr)	Hexadecimal representation of the multicast addresses
Priority Tag (Ptag)	VLAN priority tag (3-bit decimal). If the priority tag is unknown, then empty spaces will be displayed in lieu of the value.
VLAN	Virtual LAN Setting (12-bit decimal value). If the Virtual LAN setting is unknown, then empty spaces will be displayed in lieu of a decimal value.

The status information includes:

Field	Description
State Number (StNum)	Increments each time a state changes
Sequence Number (SqNum)	Increments each time a GOOSE message is sent
Time to Live (TTL)	Remaining time in ms before the next message is expected
Code	Indicate a warning or error condition. See below for descriptions.

The status codes are abbreviated as:

Code Abbreviation	Description
OUT OF SEQUENC	Out of sequence error
CONF REV MISMA	Configuration Revision mismatch
NEED COMMISSIO	Needs Commissioning
TEST MODE	Test Mode
MSG CORRUPTED	Message Corrupted
TTL EXPIRED	Time to live expired
HOST DISABLED	Host disabled/not responding

Examples of **GOOSE** command outputs follow:

```
#>>GOO <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
-----------------------------------------------------------------------------
SEL_2702_GOOSE/LLN0$GO$GooseDSet1
   01-03-A7-00-00-01  2:5     1256       347        6
   Data Set: SEL_2701_GOOSE/LLN2$Master

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
-----------------------------------------------------------------------------
SEL-2702/LLN0$GO$GooseDSet13
   01-03-A7-00-00-01  3:1     1253758689 4786543985 123456 MSG CORRUPTED
   Data Set: SEL-2701-2/LLN0$Positions

GE-F60/LLN0$GO$GEGooseDSet
   01-03-A7-00-00-01  3:23    12568945   34         0      TTL EXPIRED
   Data Set: GE-F60/LLN1$Station1

GE-C30/LLN0$GO$GEGooseDSet
   01-03-A7-00-00-01  3:343   1945       34456      456
   Data Set: GE-C30/LLN2$Terminal

COOPER-EDISONPRO/LLN0$GO$CooperGooseDSet
   01-03-A7-00-00-01  3:4987  45         347        123456
   Data Set: COOPER-EDISONPRO/LLN2$Transmission

SEL-351-RECLOSING_DIRECTIONAL_OVERCURRENT/LLN0$GO$GooseDSet
   01-03-A7-00-00-01  3:5     12568945   34783456   123456
   Data Set: SEL-351-RECLOSING_DIRECTIONAL_OVERCURRENT/LLN3$Recloser

GEC_ALSTOM_123/LLN0$GO$GECGooseDSet
   01-03-A7-00-00-01  3:643   12568      56         126    MSG CORRUPTED
   Data Set: GEC_ALSTOM_123/LLN2$Relay

#>>
```

No GOOSE receive and/or GOOSE transmit subscriptions:

```
##>>GOO <Enter>

GOOSE Transmit Status

   MultiCastAddr   Ptag:Vlan  StNum   SqNum   TTL      Code
-----------------------------------------------------------------------------
No GOOSE Tx subscriptions available

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum   SqNum   TTL      Code
-----------------------------------------------------------------------------
No GOOSE Rx subscriptions available

##>>
```

GOOSE is disabled by settings (EGSE := N):

```
#>GOO <Enter>

GOOSE is disabled by settings.  No GOOSE statistics available.

#>
```

Error during the processing of the IEC 61850 CID file:

```
#>GOO <Enter>

Error detected in the CID file parsing. All GOOSE processing disabled.

#>
```

GOOSE command is executed during CID file processing:

```
#>GOO <Enter>

CID file is currently being parsed. No GOOSE statistics available.

#>
```

SEL-487E is disabled (after CID file parsed successfully):

```
#>GOO <Enter>

Host Disabled. All GOOSE processing disabled.

#>
```

The **GOOSE** command supports only one optional parameter, *cnt*. The *cnt* parameter causes the **GOOSE** command to be repeated *cnt* times. The valid range of *cnt* is from 1–65535; and the default value of *cnt* is 1.

HELP

Because only a limited set of commands may be available at your current access level, you may want to display a list of available commands. Use the **HELP** command to display a list of available commands for your current access level. The **HELP** command format and options are shown in *Table I.13*.

Table I.13 HELP Command Options

Command	Description
HELP	Display command information for the current access level.
HELP *command*	Display information for a specific command.

ID

It may be necessary to identify the firmware version of your Ethernet card for diagnostic purposes or to verify that it is compatible with the firmware version of your host. Use the **ID** command to identify the firmware version and several other internal parameters for your Ethernet card. The information displayed by the **ID** command is described in *Table I.14*.

Table I.14 ID Command Internal Parameters Displayed

Parameter	Description
FID	Firmware ID
BFID	SELBOOT Firmware ID
CID	Firmware Checksum
DEVID	Device ID
PARTNO	Part Number
CONFIG	Configuration ID

If the Ethernet card includes the IEC 61850 protocol option and the protocol is enabled (E61850 := Y), the **ID** command will display the following additional information:

- iedName: the IED name (e.g., SEL-487E_OtterTail)
- type: the IED type (e.g., SEL-487E)
- configVersion: the CID file configuration version (e.g., ICD-487E-R100-V0-Z001001-20060512)

If the Ethernet card encounters an error while parsing the CID file, the value of the iedName, type, and configVersion fields shall be set to “PARSE FAILURE”; otherwise, the fields shall contain the CID file values as shown in the examples above.

MEMORY

The **MEMORY** command is a diagnostic command for determining if the Ethernet card is using onboard RAM properly. Use the **MEMORY** command to display RAM statistics for the following areas: memory in use, free memory, free memory blocks, and bytes in largest available block.

PING

When you are setting up or testing substation networks, it is helpful to determine if the network is connected properly and if the other devices are powered up and configured properly. Use the **PING** command to determine if another node on the network is available and connected to the network. The Ethernet card sends ping messages to the remote node until you interrupt the Ethernet card by pressing **<Enter>**. Command options for the **PING** command are shown in *Table I.15*.

Table I.15 PING Command Options

Command	Description
PING addr	Ping the address represented by addr every second.
PING addr n	Ping the address addr once every n seconds, where n is a value from 1–255.

The **PING** command requires the *addr* parameter, which can either be a name in the NAR table for the host, or an actual IP address. In response to the **PING** command, the Ethernet card displays the status of each ping attempt. When you stop the ping process, the Ethernet card displays several statistics to summarize the ping attempts.

QUIT

To close your connection to the Ethernet card and start a connection to another device without closing your terminal application, use the **QUIT** command. For example, use **QUIT** to log out and automatically terminate a Telnet session. You may then open a new Telnet session from your Telnet application. You can also use the **QUIT** command to log out of the Ethernet card for security purposes when the connection will not be closed. For example, if you are connected to an Ethernet card in a host from one of the host serial ports, you can log out without closing the transparent connection to the Ethernet card.

STATUS

Use the **STATUS** command to display the self-test status and configuration of the Ethernet card. The Ethernet card displays self-test results as either OK or FAIL. The Ethernet card displays network configuration information and network statistics.

TIME

The **TIME** command is described in *Table I.16*.

Table I.16 TIME Command

Command	Description	Access Level
TIME	Display internal clock date.	1 or 2
TIME hh:mm	Set internal clock time to hh hours (24 hour time), mm minutes and 0 seconds.	2
TIME hh:mm:ss	Set internal clock time to hh hours (24 hour time), mm minutes, and ss seconds.	2

Some hosts support time synchronization of the Ethernet card from the host or time synchronization of the host from the Ethernet card. See the host-specific section for more information on time synchronization.

Communications Card Database

The SEL-487E presents a database to an installed communications card. This database includes a variety of data within the relay that are available for the communications card. The database includes the regions and data described in *Table I.17*. Use the **MAP** and **VIEW** commands to display maps and contents of the database regions.

Table I.17 Communications Card Database Regions

Region Name	Contents	Update Rate
LOCAL	Relay identification data including FID, Relay ID, and active protection settings group	Updated on settings change and whenever monitored values change
METER	Real-time metering and measurement data	0.5 s
DEMAND	Demand and peak demand measurement data	15 s
TARGET	Selected rows of Relay Word bit data	0.5 s
HISTORY	Relay event history records for the 20 most recent events	Within 15 s of any new event
BREAKER	Summary circuit breaker monitor data updated every 15 s	15 s
STATUS	Self-test diagnostic status data	5 s
ANALOGS	Protection and automation math variables	0.5 s
STATE	Elements defined as SER points	0.5 s of any new event
D1	Analog Outputs RA001–RA256	N/A

Data within the communications card regions is available for mapping to any protocol over the Ethernet interface.

The LOCAL region contains the device FID, SID, and RID. It will also provide appropriate status points. This region is updated on settings changes and whenever monitored status points change. See *Table I.18*.

Table I.18 SEL-487E Communications Card Database Structure—LOCAL Region

Address (Hex)	Name	Type	Description
0000	FID	char[48]	FID string
0030	BFID	char[48]	SELboot FID string
0060	SER_NUM	char[16]	Device Serial number, from factory settings
0070	PART_NUM	char[24]	Device part number, from factory settings
0088	CONFIG	char[8]	Device configuration string (as reported in **ID** command)
0090	SPECIAL	char[8]	Special device configuration string (as reported in **ID** command)
0098	DEVICE_ID	char[40]	Relay ID setting, from global settings
00C0	NODE_ID	char[40]	Station ID from global settings
00E8	GROUP	int	Active group
00E9	STATUS	int	Bit map of status flags: 0 for okay, 1 for failure

The METER region contains all the basic meter and energy information. This region is updated every 0.5 seconds. See *Table I.19* for the Map.

Table I.19 SEL-487E DNP LAN/WAN Database Structure—METER Region (Sheet 1 of 5)

Address (Hex)	Name	Type	Description
1000	_YEAR	int	4-digit year when data was sampled
1001	DAY_OF_YEAR	int	1–366 day when data was sampled
1002	TIME(ms) long	int	Time of day in msec when data was sampled (0–86,400,00)
1004	FREQ	float	System frequency (FREQ)
1006	VDC1	float	Battery 1 voltage (VDC1)
1008	IS(A)	float[6]	Terminal S, phase current magnitude and phase (IASFMC, IASFAC, IBSFMC, IBSFAC, ICS-FMC, ICSFAC)
1014	IT(A)	float[6]	Terminal T, phase current magnitude and phase (IATFMC, IATFAC, IBTFMC, IBTFAC, ICT-FMC, ICTFAC)
1020	IU(A)	float[6]	Terminal U, phase current magnitude and phase (IAUFMC, IAUFAC, IBUFMC, IBUFAC, ICUFMC, ICUFAC)
1038	IX(A)	float[6]	Terminal X, phase current magnitude and phase (IAXFMC, IAXFAC. IBXFMC, IBXFAC, ICXFMC, ICXFAC)
1044	IY(A)	float[6]	Terminal Y, phase current magnitude and phase (IY1FMC, IY1FAC, IY2FMC, IY2FAC, IY3FMC, IY3FAC)
1050	VV(V)	float[6]	Terminal V, phase voltage magnitude and phase (VAVFMC, VAVFAC, VBVFMC, VBVFAC, VCVFMC, VCVFAC)

Table I.19 SEL-487E DNP LAN/WAN Database Structure—METER Region (Sheet 2 of 5)

Address (Hex)	Name	Type	Description
105C	VZ(V)	float[6]	Terminal Z, phase voltage magnitude and phase (VAZFMC, VAZFAC, VBZFMC, VBZFAC, VCZFMC, VCZFAC)
1068	IST(A)	float[6]	Terminal ST, phase current magnitude and phase (IASTFMC, IASTFAC, IBSTFMC, IBSTFAC, ICSTFMC, ICSTFAC)
1074	ITU(A)	float[6]	Terminal TU, phase current magnitude and phase (IATUFMC, IATUFAC, IBTUFMC, IBTUFAC, ICTUFMC, ICTUFAC)
1080	IUW(A)	float[6]	Terminal UW, phase current magnitude and phase (IAUWFMC, IAUWFAC, IBUWFMC, IBUWFAC, ICUWFMC, ICUWFAC)
108C	IWX(A)	float[6]	Terminal WX, phase current magnitude and phase (IAWXFMC, IAWXFAC, IBWXFMC, IBWXFAC, ICWXFMC, ICWXFAC)
1098	ISEQ_S(A)	float[6]	Terminal S sequence current magnitude and phase (3I0SMC/3, 3I0SAC, I1SMC, I1SAC, 3I2SMC/3, 3I2SAC)
10A4	ISEQ_T(A)	float[6]	Terminal T sequence current magnitude and phase (3I0TMC/3, 3I0TAC, I1TMC, I1TAC, 3I2TMC/3, 3I2TAC)
10B0	ISEQ_U(A)	float[6]	Terminal U sequence current magnitude and phase (3I0UMC/3, 3I0UAC, I1UMC, I1UAC, 3I2UMC/3, 3I2UAC)
10BC	ISEQ_W(A)	float[6]	Terminal W sequence current magnitude and phase (3I0WMC/3, 3I0WAC, I1WMC, I1WAC, 3I2WMC/3, 3I2WAC)
10C8	ISEQ_X(A)	float[6]	Terminal X sequence current magnitude and phase (3I0XMC/3, 3I0XAC, I1XMC, I1XAC, 3I2XMC/3, 3I2XAC)
10D4	ISEQ_ST(A)	float[6]	Terminal ST sequence current magnitude and phase (3I0STMC/3, 3I0STAC, I1STMC, I1STAC, 3I2STMC/3, 3I2STAC)
10E0	ISEQ_TU(A)	float[6]	Terminal TU sequence current magnitude and phase (3I0TUMC/3, 3I0TUAC, I1TUMC, I1TUAC, 3I2TUMC/3, 3I2TUAC)
10EC	ISEQ_UW(A)	float[6]	Terminal UW sequence current magnitude and phase (3I0UWMC/3, 3I0UWAC, I1UWMC, I1UWAC, 3I2UWMC/3, 3I2UWAC)
10F8	ISEQ_WX(A)	float[6]	Terminal WX sequence current magnitude and phase (3I0WXMC/3, 3I0WXAC, I1WXMC, I1WXAC, 3I2WXMC/3, 3I2WXAC)
1104	VV_LL(V)	float[6]	Terminal V, phase-phase voltage magnitude and phase (VABVFMC, VABVFAC, VBCVFMC, VBCVFAC, VCAVFMC, VCAVFAC)
1110	VZ_LL(V)	float[6]	Terminal Z, phase-phase voltage magnitude and phase (VABZFMC, VABZFAC, VBCZFMC, VBCZFAC, VCAZFMC, VCAZFAC)
111C	VSEQ_V(V)	float[6]	Terminal V, sequence voltage magnitude and phase (3V0VMC/3, 3V0VAC, V1VMC, 3V1VAC, 3V2VMC/3, 3V2VAC)

Table I.19 SEL-487E DNP LAN/WAN Database Structure—METER Region (Sheet 3 of 5)

Address (Hex)	Name	Type	Description
1128	VSEQ_Z(V)	float[6]	Terminal Z, sequence voltage magnitude and phase (3V0ZMC/3, 3V0ZAC, V1ZMC, 3V1ZAC, 3V2ZMC/3, 3V2ZAC)
1134	PS(W)	float[4]	Terminal S, phase real power (PASFS, PBSFS, PCSFS, 3PSFS)
113C	QS(VAR)	float[4]	Terminal S, phase reactive power (QASFS, QBSFS, QCSFS, 3QSFS)
1144	SS(VA)	float[4]	Terminal S, phase apparent power (SASFS, SBSFS, SCSFS, 3SSFS)
1154	QT(VAR)	float[4]	Terminal T, phase reactive power (QATFS, QBTFS, QCTFS, 3QTFS)
115C	ST(VA)	float[4]	Terminal T, phase apparent power (SATFS, SBTFS, SCTFS, 3STFS)
1164	PU(W)	float[4]	Terminal U, phase real power (PAUFS, PBUFS, PCUFS, 3PUFS)
116C	QU(VAR)	float[4]	Terminal U, phase reactive power (QAUFS, QBUFS, QCUFS, 3QUFS)
1174	SU(VA)	float[4]	Terminal U, phase apparent power (SAUFS, SBUFS, SCUFS, 3SUFS)
117C	PW(W)	float[4]	Terminal W, phase real power (PAWFS, PBWFS, PCWFS, 3PWFS)
1184	QW(VAR)	float[4]	Terminal W, phase reactive power (QAWFS, QBWFS, QCWFS, 3QWFS)
118C	SW(VA)	float[4]	Terminal W, phase apparent power (SAWFS, SAWFS, SCWFS, 3SWFS)
1194	PX(W)	float[4]	Terminal X, phase real power (PAXFS, PBXFS, PCXFS, 3PXFS)
119C	QX(VAR)	float[4]	Terminal X, phase reactive power (QAXFS, QBXFS, QCXFS, 3QXFS)
11A4	SX(VA)	float[4]	Terminal X, phase apparent power (SAXFS, SBXFS, SCXFS, 3SXFS)
11AC	PST(W)	float[4]	Terminal ST, phase real power (PASTFS, PBSTFS, PCSTFS, 3PSTFS)
11B4	QST(VAR)	float[4]	Terminal ST, phase reactive power (QASTFS, QBSTFS, QCSTFS, 3QSTFS)
11BC	SST(VA)	float[4]	Terminal ST, phase apparent power (SASTFS, SBSTFS, SCSTFS, 3SSTFS)
11C4	PTU(W)	float[4]	Terminal TU, phase real power (PATUFS, PBTUFS, PCTUFS, 3PTUFS)
11CC	QTU(VAR)	float[4]	Terminal TU, phase reactive power (QATUFS, QBTUFS, QCTUFS, 3QTUFS)
11D4	STU(VA)	float[4]	Terminal TU, phase apparent power (SATUFS, SBTUFS, SCTUFS, 3STUFS)
11DC	PUW(W)	float[4]	Terminal UW, phase real power (PAUWFS, PBUWFS, PCUWFS, 3PUWFS)
11E4	QUW(VAR)	float[4]	Terminal UW, phase reactive power (QAUWFS, QBUWFS, QCUWFS, 3QUWFS)

Table I.19 SEL-487E DNP LAN/WAN Database Structure—METER Region (Sheet 4 of 5)

Address (Hex)	Name	Type	Description
11EC	SUW(VA)	float[4]	Terminal UW, phase apparent power (SAUWFS, SBUWFS, SCUWFS, 3SUWFS)
11F4	PWX(W)	float[4]	Terminal WX, phase real power (PAWXFS, PBWXFS, PCWXFS, 3PWXFS)
11FC	QWX(VAR)	float[4]	Terminal WX, phase reactive power (QAWXFS, QBWXFS, QCWXFS, 3QWXFS)
1204	SWX(VA)	float[4]	Terminal WX, phase apparent power (SAWXFS, SBWXFS, SCWXFS, 3SWXFS)
120C	PFS	float[4]	Terminal S, phase power factor (TPFAS, TPFBS, TPFCS, 3TPFS)
1214	PFT	float[4]	Terminal T, phase power factor (TPFAT, TPFBT, TPFCT, 3TPFT)
121C	PFU	float[4]	Terminal U, phase power factor (TPFAU, TPFBU, TPFCU, 3TPFU)
1224	PFW	float[4]	Terminal W, phase power factor (TPFAW, TPFBW, TPFCW, 3TPFW)
122C	PFX	float[4]	Terminal X, phase power factor (TPFAX, TPFBX, TPFCX, 3TPFX)
1234	PFST	float[4]	Terminal ST, phase power factor (TPFAST, TPFBST, TPFCST, 3TPFST)
123C	PFTU	float[4]	Terminal TU, phase power factor (TPFATU, TPFBTU, TPFCTU, 3TPFTU)
1244	PFUW	float[4]	Terminal UW, phase power factor (TPFAUW, TPFBUW, TPFCUW, 3TPFUW)
124C	PFWX	float[4]	Terminal WX, phase power factor (TPFAWX, TPFBWX, TPFCWX, 3TPFWX)
1254	ES(kWh)	float[4]	Terminal S, energy export/import in KWh (3PSP_MWh, 3PSN_MWh, 3QSP_Mvarh, 3QSN_Mvarh)
25C1	ET(kWh)	float[4]	Terminal T, energy export/import in KWh (3PTP_MWh, 3PTN_MWh, 3QTP_Mvarh, 3QTN_Mvarh)
1264	EU(kWh)	float[4]	Terminal U, energy export/import in KWh (3PUP_MWh, 3PUN_MWh, 3QUP_Mvarh, 3QUN_Mvarh)
126C	EW(kWh)	float[4]	Terminal W, energy export/import in KWh (3PWP_MWh, 3PWN_MWh, 3QWP_Mvarh, 3QWN_Mvarh)
1274	EX(kWh)	float[4]	Terminal X, energy export/import in KWh (3PXP_MWh, 3PXN_MWh, 3QXP_Mvarh, 3QXN_Mvarh)
127C	EST(kWh)	float[4]	Terminal ST, energy export/import in KWh (3PSTP_MWh, 3PSTN_MWh, 3QSTP_Mvarh, 3QSTN_Mvarh)
1284	ETU(kWh)	float[4]	Terminal TU, energy export/import in KWh (3PTUP_MWh, 3PTUN_MWh, 3QTUP_Mvarh, 3QTUN_Mvarh)

Table I.19 SEL-487E DNP LAN/WAN Database Structure—METER Region (Sheet 5 of 5)

Address (Hex)	Name	Type	Description
128C	EUW(kWh)	float[4]	Terminal UW, energy export/import in KWh (3PUWP_MWh, 3PUWN_MWh, 3QUWP_Mvarh, 3QUWN_Mvarh)
1294	EWX(kWh)	float[4]	Terminal WX, energy export/import in KWh (3PWXP_MWh, 3PWXN_MWh, 3QWXP_Mvarh, 3QWXN_Mvarh)

The DEMAND region contains demand and peak demand information. This region is updated every 15 seconds. See *Table I.20* for the Map.

Table I.20 SEL-487E DNP LAN/WAN Database Structure—DEMAND Region

Address (Hex)	Name	Type	Description
2000	_YEAR	int	4-digit year when data was sampled
2001	DAY_OF_YEAR	int	1–366 day when data was sampled
2002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,00)
2004	DM	float[10]	Demand quantity 01 (DM_01–DM_10)
2018	DMP	float[10]	Peak Demand quantity 01 (DMM_01–DMM_10)

The TARGET region contains the entire visible Relay Word plus the rows designated specifically for the TARGET region. This region is updated every 0.5 seconds. See *Table I.21* for the Map.

Table I.21 SEL-487E DNP LAN/WAN Database Structure—TARGET Region

Address (Hex)	Name	Type	Description
3000	_YEAR	int	4-digit year when data was sampled
3001	DAY_OF_YEAR	int	1–366 day when data was sampled
3002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
3004	TARGET	char[~240]	Entire Relay Word with bit labels

The HISTORY region contains all information available in a History report for the most recent 10 events. This region is updated within 15 seconds of any new events. See *Table I.22* for the Map.

Table I.22 SEL-487E Communications Card Database Structure—HISTORY Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
4000	_YEAR	int	4-digit year when data was sampled
4001	DAY_OF_YEAR	int	1–366 day when data was sampled
4002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,000)
4004	REF_NUM	int[10]	Event serial number
400E	MONTH	int[10]	Month of event

Table I.22 SEL-487E Communications Card Database Structure—HISTORY Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
4018	DAY	int[10]	Day of event
4022	YEAR	int[10]	Year of event
402C	HOUR	int[10]	Hour of event
4036	MIN	int[10]	Minute of event
4040	SEC	int[10]	Second of event
404A	MSEC	int[10]	Milliseconds of event
4054	EVENT	char[60]	Event type string
4090	GROUP	int[10]	Active group during fault
409A	FREQ	float[10]	System frequency at time of fault
40AE	TARGETS	char[160]	System targets from event

The BREAKER region contains some of the information available in a summary Breaker report. This region is updated every 15 seconds. See *Table I.23* for the Map.

Table I.23 SEL-487E DNP LAN/WAN Database Structure—BREAKER Region (Sheet 1 of 2)

Address (Hex)	Name	Type	Description
5000	_YEAR	int	4-digit year when data was sampled
5001	DAY_OF_YEAR	int	1–366 day when data was sampled
5002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,00)
5004	BCW_S	float[3]	Breaker S phase breaker wear (%) (BSBCWPA, BSBCWPB, BSBCWPC)
500A	BCW_T	float[3]	Breaker T phase breaker wear (%) (BTBCWPA, BTBCWPB, BTBCWPC)
5010	BCW_U	float[3]	Breaker U phase breaker wear (%) (BUB-CWPA, BUBCWPB, BUBCWPC)
5016	BCW_W	float[3]	Breaker W phase breaker wear (%) (BWB-CWPA, BWBCWPB, BWBCWPC)
501C	BCW_X	float[3]	Breaker X phase breaker wear (%) (BXB-CWPA, BXBCWPB, BXBCWPC)
5022	CUR_S	float[3]	Breaker S phase accumulated current (kA) (IASRMS_TRIP_ACC, IBSRMS_TRIP_ACC, ICSRMS_TRIP_ACC)
5028	CUR_T	float[3]	Breaker T phase accumulated current (kA) (IATRMS_TRIP_ACC, IBTRMS_TRIP_ACC, ICTRMS_TRIP_ACC)
502E	CUR_U	float[3]	Breaker U phase accumulated current (kA) (IAURMS_TRIP_ACC, IBURMS_TRIP_ACC, ICURMS_TRIP_ACC)
5034	CUR_W	float[3]	Breaker W phase accumulated current (kA) (IAWRMS_TRIP_ACC, IBWRMS_TRIP_ACC, ICWRMS_TRIP_ACC)

Table I.23 SEL-487E DNP LAN/WAN Database Structure—BREAKER Region (Sheet 2 of 2)

Address (Hex)	Name	Type	Description
503A	CUR_X	float[3]	Breaker X phase accumulated current (kA) (IAXRMS_TRIP_ACC, IBXRMS_TRIP_ACC, ICXRMS_TRIP_ACC)
5040	NOP_S	long int	Breaker S number of operations (BS_TRP_CNT)
5042	NOP_T	long int	Breaker T number of operations (BT_TRP_CNT)
5044	NOP_U	long int	Breaker U number of operations (BU_TRP_CNT)
5046	NOP_W	long int	Breaker W number of operations (BW_TRP_CNT)
5048	NOP_X	long int	Breaker X number of operations (BX_TRP_CNT)

The STATUS region contains complete relay status information. This region is updated every 5 seconds. See *Table I.24* for the Map.

Table I.24 SEL-487E DNP LAN/WAN Database Structure—STATUS Region

Address (Hex)	Name	Type	Description
6000	_YEAR	int	4-digit year when data was sampled
6001	DAY_OF_YEAR	int	1–366 day when data was sampled
6002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86,400,00)
6004	CH1_24(mV)	int[24]	Channel offsets, use 0 if not measured
601C	MOF(mV)	int	Master offset
601D	MOF2(mV)	int	Master offset 2
601E	OFF_WARN	char[8]	Offset warning string
6026	OFF_FAIL	char[8]	Offset failure string
602E	PS3(V)	float	3.3 Volt power supply voltage
6030	PS5(V)	float	5 Volt power supply voltage
6032	PS_N5(V)	float	–5 Volt regulated voltage
6034	PS15(V)	float	15 Volt power supply voltage
6036	PS_N15(V)	float	–15 Volt power supply voltage
6038	PS_WARN	char[8]	Power supply warning string
6040	PS_FAIL	char[8]	Power supply failure string
6048	HW_FAIL	char[40]	Hardware failure strings
6070	CC_STA	char[40]	Communication card status strings
6098	PORT_STA	char[160]	Serial port status strings
6138	TIME_SRC	char[10]	Time source
6142	LOG_ERR	char[40]	SELOGIC error strings
616A	TEST_MD	char[160]	Test mode string

The ANALOGS region contains protection and automation variables. This region is updated every 0.5 seconds. See Table I.25 for the Map.

Table I.25 SEL-487E DNP LAN/WAN Database Structure—ANALOGS Region

Address (Hex)	Name	Type	Description
7000	_YEAR	int	4-digit year when data was sampled
7001	DAY_OF_YEAR	int	1–366 day when data was sampled
7002	TIME(ms)	long int	Time of day in msec when data was sampled (0–86400000)
7004	PMV01_64	float[64]	PMV01–PMV64
7084	AMV001_256	float[256]	AMV001–AMV256

The STATE region is for elements defined as SER points. This region has an attached SOE queue which holds 100 records. This region must be reinitialized if there is a queue overflow or SER settings change. This data is updated within 0.5 seconds of any new events being generated. See Table I.26 for the Map.

Table I.26 SEL-487E DNP LAN/WAN Database Structure—STATE Region

Address (Hex)	Name	Type	Description
8000	_YEAR	int	4-digit year when data was updated
8001	DAY_OF_YEAR	int	1–366 day when data was updated
8002	TIME(ms)	long int	Time of day in msec when data was updated (0–86,400,00)
8004	ELEMENTS	int[16]	250 Relay Word bits defined to be SER points; SER point 1 goes in first register bit 0,...
8014	CARD_SER	int[8]	128 Relay Word bits defined to be SER points from R CC settings.

The communications card database is virtual device 1 in the relay. You can display the contents of a region using the **MAP 1:region** command (where region is one of the database region names listed in Table I.17). An example of the **MAP** command is shown in Figure I.1.

```
=>>MAP 1:meter <Enter>

Virtual Device 1, Data Region METER Map

Data Item    Starting Address   Type

_YEAR        1000h              int
DAY_OF_YEAR  1001h              int
TIME(ms)     1002h              int[2]
FREQ         1004h              float
VDC1         1006h              float
IS(A)        1008h              float[6]
IT(A)        1014h              float[6]
IU(A)        1020h              float[6]
IW(A)        102ch              float[6]
IX(A)        1038h              float[6]
IY(A)        1044h              float[6]
VV(V)        1050h              float[6]
VZ(V)        105ch              float[6]
IST(A)       1068h              float[6]
ITU(A)       1074h              float[6]
IUW(A)       1080h              float[6]
IWX(A)       108ch              float[6]
ISEQ_S(A)    1098h              float[6]
ISEQ_T(A)    10a4h              float[6]
ISEQ_U(A)    10b0h              float[6]
ISEQ_W(A)    10bch              float[6]
ISEQ_X(A)    10c8h              float[6]
ISEQ_ST(A)   10d4h              float[6]
ISEQ_TU(A)   10e0h              float[6]
ISEQ_UW(A)   10ech              float[6]
ISEQ_WX(A)   10f8h              float[6]
VV_LL(V)     1104h              float[6]
VZ_LL(V)     1110h              float[6]
VSEQ_V(V)    111ch              float[6]
VSEQ_Z(V)    1128h              float[6]
PS(W)        1134h              float[4]
QS(VAR)      113ch              float[4]
SS(VA)       1144h              float[4]
PT(W)        114ch              float[4]
QT(VAR)      1154h              float[4]
ST(VA)       115ch              float[4]
PU(W)        1164h              float[4]
QU(VAR)      116ch              float[4]
SU(VA)       1174h              float[4]
PW(W)        117ch              float[4]
QW(VAR)      1184h              float[4]
SW(VA)       118ch              float[4]
PX(W)        1194h              float[4]
QX(VAR)      119ch              float[4]
SX(VA)       11a4h              float[4]
PST(W)       11ach              float[4]
QST(VAR)     11b4h              float[4]
SST(VA)      11bch              float[4]
PTU(W)       11c4h              float[4]
QTU(VAR)     11cch              float[4]
STU(VA)      11d4h              float[4]
PUW(W)       11dch              float[4]
QUW(VAR)     11e4h              float[4]
SUW(VA)      11ech              float[4]
PWX(W)       11f4h              float[4]
QWX(VAR)     11fch              float[4]
SWX(VA)      1204h              float[4]
PFS          120ch              float[4]
PFT          1214h              float[4]
PFU          121ch              float[4]
PFW          1224h              float[4]
PFX          122ch              float[4]
PFST         1234h              float[4]
PFTU         123ch              float[4]
PFUW         1244h              float[4]
PFWX         124ch              float[4]
ES(kWh)      1254h              float[4]
ET(kWh)      125ch              float[4]
EU(kWh)      1264h              float[4]
EW(kWh)      126ch              float[4]
EX(kWh)      1274h              float[4]
EST(kWh)     127ch              float[4]
ETU(kWh)     1284h              float[4]
EUW(kWh)     128ch              float[4]
EWX(kWh)     1294h              float[4]

=>>
```

Figure I.1 MAP 1:METER Command Example

Application Example

This direct networking example demonstrates direct networking to the SEL-487E using the Ethernet card. *Figure I.2* shows the Ethernet network topology.

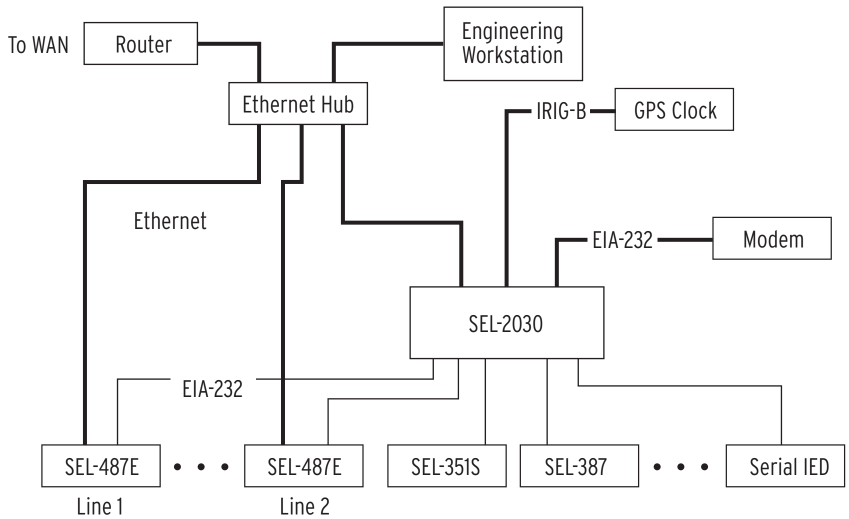

Figure I.2 Example Direct Networking Topology

Application

In this application, all IEDs connect to the Ethernet network. The SEL-487E relays and the SEL-2030 each have an Ethernet card installed. In this example, the Ethernet network is used primarily for an engineering connection to the devices in the substation either across the WAN or from the local computer. The engineer can use FTP to collect settings, oscillography, and other file data directly from the SEL-487E relays. The engineer can also use Telnet to establish a terminal connection to the SEL-487E relays or through the SEL-2030 to one of the serial IEDs in order to configure these devices or obtain diagnostic information.

NOTE: The IRIG-B time signal available from SEL communications processors is not suitable for high-accuracy IRIG (HIRIG) timekeeping mode, which is required for synchrophasor functions.

There is a serial cable from the SEL-2030 to the SEL-487E relays. This cable provides IRIG-B time synchronization from the SEL-2030 that is synchronized by the GPS clock attached to the SEL-2030. The SEL-2030 provides its output synchronization signal from its internal clock, so that loss of the signal from the GPS will not result in a loss of synchronization between substation devices as they will all be synchronized to the SEL-2030 clock. During long periods of loss of synchronization, the SEL-2030 clock drift will become noticeable, but all substation devices will remain synchronized relative to each other and the SEL-2030 clock. The serial cables also allow the SEL-2030 to provide a single point for dial-in communications with the substation IEDs avoiding the high cost of high bandwidth connections (for example, ISDN or DSL) for this backup to the Ethernet network engineering connection.

Settings

This example focuses on the relay labeled Line 1 shown in *Figure I.2*. **PORT 5** settings for the SEL-487E configure the Ethernet card. **PORT 5** settings for this example are shown in *Table I.27*.

Table I.27 SEL-487E PORT 5 Direct Networking Settings (Sheet 1 of 2)

Setting Name	Setting	Description
TIMEOUT	5	Port inactivity time-out in minutes (drops to Access Level 0 on Telnet connections when this expires)
AUTO	N	Automessage disabled because engineering connection will not require unsolicited messages from SEL-2030
FASTOP	N	Fast Operate messages disabled because they are not required on engineering connection
TERTIM1	1	Length of time the channel must be idle before checking for the termination string in seconds
TERSTRN	\005	Transparent communication termination string default of CTRL + E
TERTIM2	0	Length of time the channel must be idle before accepting the termination string in seconds
IPADDR	10.201.0.112	IP network address
SUBNETM	255.255.0.0	IP network subnet mask
DEFRTR	10.201.0.1	Default router
ETCPKA	N	Disable TCP keep-alive functionality (IEC 61850 only)
KAIDLE	10	Length of time to wait with no detected activity before sending a keep-alive packet (must be greater than or equal to KAINTV)
KAINTV	1	Length of time to wait between sending keep-alive packets after receiving no response for the prior keep-alive packet (must be less than or equal to KAI-DLE)
KACNT	6	Maximum number of keep-alive packets to send
NETPORT	A	Primary network port selected to Port A
FAILOVR	N	Automatic fail-over disabled, forcing network operation on Port A only
FTIME	5	Fail over time-out; not used in this application
NETASPD	A	Automatically detect network speed on Port A
NETBSPD	A	Automatically detect network speed on Port B; not used in this application
FTPSERV	Y	FTP sessions enabled
FTPCBAN	FTP SERVER:	FTP connect banner
FTPIDLE	5	FTP connection time-out in minutes
FTPANMS	N	Anonymous log-in disabled so that passwords are required for all FTP users
FTPAUSR	“”	Host user from which anonymous FTP client inherits access rights; not used in this application
T1CBAN	HOST TERMINAL SERVER:	Host Telnet connect banner
T1INIT	N	Telnet session from Ethernet card enable; not used in this application
T1RECV	Y	Telnet session to SEL-487E enable
T1PNUM	23	Host Telnet TCP/IP port

Table I.27 SEL-487E PORT 5 Direct Networking Settings (Sheet 2 of 2)

Setting Name	Setting	Description
T2CBAN	CARD TERMINAL SERVER:	Ethernet card Telnet connect banner
T2RECV	Y	Telnet session to Ethernet card enable
T2PNUM	1024	Ethernet card Telnet TCP/IP port
TIDLE	5	Telnet connection time-out in minutes

FTP Session

Figure I.4 is a screen capture of an FTP session with the relay. The FTP client used for this example is included with the Windows NT® operating system and accessible through a command prompt window. The operator connects to the relay, moves to the SETTINGS directory, and collects the **PORT 5** settings. *Figure I.5* shows a portion of the **PORT 5** settings in the SET_P5.TXT file.

Telnet Session

This section contains screen captures of a Telnet session with the Line 1 SEL-487E. The Telnet application shown is included with the Windows NT operating system. *Figure I.3* shows the log-in dialog box and the entries required to connect to the SEL-487E.

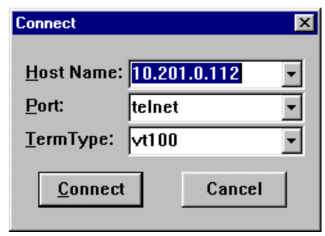

Figure I.3 Telnet Connection Dialog Box

Figure I.6 is a screen capture of a Telnet session with the relay. The operator connects to the relay, and displays the **PORT 5** settings. Only a portion of the **PORT 5** settings are shown.

```
C:\>ftp 10.201.5.11 <Enter>

Connected to 10.201.5.11.
220 FTP SERVER:
User (10.201.5.11:(none)): 2AC
331 User name okay, need password.
Password:
230 User logged in, proceed.
ftp> ls
200 PORT Command okay.
150 File status okay; about to open data connection.
RELAY_1
SEL-2702
DD01_RELAY_1
CFG.XML
ERR.TXT
SET_61850.CID
226 Closing data connection.
ftp: 66 bytes received in 0.02Seconds 4.13Kbytes/sec.
ftp> cd RELAY_1
250 CWD  requested file action okay, completed.
ftp> ls
200 PORT Command okay.
150 File status okay; about to open data connection.
CFG.TXT
EVENTS
REPORTS
SETTINGS
SYNCHROPHASORS
226 Closing data connection.
ftp: 52 bytes received in 0.05Seconds 1.11Kbytes/sec.
ftp> cd SETTINGS
250 CWD  requested file action okay, completed.
ftp> ls
200 PORT Command okay.
150 File status okay; about to open data connection.
CARD
ERR.TXT
SET_A1.TXT
SET_A10.TXT
SET_A2.TXT
SET_A3.TXT
SET_A4.TXT
SET_A5.TXT
SET_A6.TXT
SET_A7.TXT
SET_A8.TXT
SET_A9.TXT
SET_ALL.TXT
SET_B1.TXT
SET_D1.TXT
SET_F1.TXT
SET_G1.TXT
SET_L1.TXT
SET_L2.TXT
SET_L3.TXT
SET_L4.TXT
SET_L5.TXT
SET_L6.TXT
SET_M1.TXT
SET_N1.TXT
SET_O1.TXT
SET_P1.TXT
SET_P2.TXT
SET_P3.TXT
SET_P5.TXT
SET_PF.TXT
SET_R1.TXT
SET_S1.TXT
SET_S2.TXT
SET_S3.TXT
SET_S4.TXT
SET_S5.TXT
SET_S6.TXT
SET_T1.TXT
226 Closing data connection.
ftp: 461 bytes received in 0.20Seconds 2.27Kbytes/sec.
ftp> get set_p5.txt
200 PORT Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
ftp: 3086 bytes received in 0.80Seconds 3.88Kbytes/sec.
ftp> quit <Enter>
221 Goodbye.
C:\>
```

Figure I.4 Example FTP Session

```
[INFO]
RELAYTYPE=SEL-487E
FID=SEL-487E-X084-V0-Z001001-D20080506
BFID=SLBT-4XX-X027-V0-Z001002-D20080418
PARTNO=0487E0141112C2B4H70X44X
[IOBOARDS]
INT4_E, , , 24, 15, 0, 0, 2
[COMCARDS]
SEL-2702, SEL-2702-X066-V2-Z001001-D20080409, SLBT-2701-R102-V0-Z000000-D20051107, 1
[P5]
"TIMEOUT",5
"AUTO",Y
"FASTOP",N
"TERTIM1",1
"TERSTRN","\005"
"TERTIM2",0
"FMRENAB",Y
"FMRLCL",N
"FMRMTR",Y
"FMRDMND",Y
"FMRTAR",Y
"FMRHIS",N
"FMRBRKR",N
"FMRSTAT",N
"FMRANA",Y
"FMRSER",N
"FMRD1",N
"IPADDR","10.201.5.11"
"SUBNETM","255.255.0.0"
"DEFRTR","10.201.0.1"
"ETCPKA","N"
"KAIDLE",10
"KAINTV",1
.
.
.
"PMOUDP1",4713
"PMOTS2","OFF"
"PMOIPA2",""
"PMOTCP2",4722
"PMOUDP2",4713
#001 Transfer Complete

=>>
```

Figure I.5 Partial Contents of SET_P5.TXT

```
HOST TERMINAL SERVER:

Relay 1                                    Date: 05/08/2008  Time: 08:21:14.448
Station A                                  Serial Number: 0000000000

?
=?ACC <Enter>
?
Relay 1                                    Date: 05/08/2008  Time: 08:21:19.283
Station A                                  Serial Number: 0000000000

Level 1
??
=>?2AC <Enter>
?
Relay 1                                    Date: 05/08/2008  Time: 08:21:23.462
Station A                                  Serial Number: 0000000000

Level 2
??
=>>?SHO P 5 <Enter>
?Port 5

SEL Protocol Settings

TIMEOUT := 5        AUTO    := Y        FASTOP  := N        TERTIM1 := 1
TERSTRN := "\005"
TERTIM2 := 0

Fast Message Read Data Access

FMRENAB := Y        FMRLCL  := N        FMRMTR  := Y        FMRDMND := Y
FMRTAR  := Y        FMRHIS  := N        FMRBRKR := N        FMRSTAT := N
FMRANA  := Y        FMRSER  := N        FMRD1   := N

Protocol Card Settings

IPADDR  := "10.201.5.11"
SUBNETM := "255.255.0.0"
DEFRTR  := "10.201.0.1"
ETCPKA  := "N"
KAIDLE  := 10       KAINTV  := 1        KACNT   := 6
NETPORT := "A"
FAILOVR := "Y"
FTIME   := 5
.
.
.
ECLASSA := 2        ECLASSB := 1        ECLASSC := 0        DECPL   := 0
ANADB   := 0
16BIT   := "16"
STIMEO  := 1.0
DNPPAIR := "N"
DNPINA  := 120      NUMEVE  := 10       AGEEVE  := 2        ETIMEO  := 2
URETRY  := 3        UTIMEO  := 60
EPMIP   := "N"
PMOTS1  := "OFF"
PMOIPA1 := ""
PMOTCP1 := 4712     PMOUDP1 := 4713
PMOTS2  := "OFF"
PMOIPA2 := ""
PMOTCP2 := 4722     PMOUDP2 := 4713??
=>>?qui

Host connection terminated, terminating Network connection.
```

Figure I.6 Example Telnet Session (Partial Data)

Glossary

a Contact A breaker auxiliary contact (ANSI Standard Device Number 52A) that closes when the breaker is closed and opens when the breaker is open.

a Output A relay control output that closes when the output relay asserts.

b Contact A breaker auxiliary contact (ANSI Standard Device Number 52B) that opens when the breaker is closed and closes when the breaker is open.

b Output A relay control output that opens when the output relay asserts.

c Contact A breaker auxiliary contact that can be set to serve either as an a contact or as a b contact.

c Output An output with both an a output and b output sharing a common post.

6U, 7U The designation of the vertical height of a device in rack units. One rack unit, U, is approximately 1.75 inches or 44.45 mm.

A Abbreviation for amps or amperes; unit of electrical current flow.

ABS Operator An operator in math SELOGIC® control equations that provides absolute value.

AC Ripple The peak-to-peak ac component of a signal or waveform. In the station dc battery system, monitoring ac ripple provides an indication of whether the substation battery charger has failed.

Acceptance Testing Testing that confirms that the relay meets published critical performance specifications and requirements of the intended application. Such testing involves testing protection elements and logic functions when qualifying a relay model for use on the utility system.

Access Level A relay command level with a specified set of relay information and commands. Except for Access Level 0, you must have the correct password to enter an access level.

Access Level 0 The least secure and most limited access level. No password protects this level. From this level, you must enter a password to go to a higher level.

Access Level 1 A relay command level you use to monitor (view) relay information. The default access level for the relay front panel.

Access Level 2 The most secure access level where you have total relay functionality and control of all settings types.

Access Level A A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Automation, Alias, Global, Front Panel, Report, Port, and DNP settings.

Access Level B A relay command level you use for Access Level 1 functions plus circuit breaker control and data.

Access Level O A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Output, Alias, Global, Front Panel, Report, Port, and DNP settings.

Access Level P A relay command level you use to access all Access Level 1 and Access Level B (Breaker) functions plus Protection, SELOGIC, Alias, Global, Group, Breaker Monitor, Front Panel, Report, Port, and DNP settings.

ACSELERATOR Architect® **ACSELERATOR** Architect is an add-on to the ACSELERATOR QuickSet Suite that utilizes the IEC 61850 Substation Configuration Language to configure SEL IEDs.

ACSELERATOR QuickSet® ACSELERATOR QuickSet SEL-5030 software program: A Windows®-based program that simplifies settings and provides analysis support.

ACSI Abstract Communications Service Interface for the IEC 61850 protocol. Defines a set of objects, a set of services to manipulate and access those objects, and a base set of data types for describing objects.

Active Settings Group The settings group that the SEL-487E is presently using from among six settings groups available in the relay.

Analog Quantities Variables represented by such fluctuating measurable quantities as temperature, frequency, current, and voltage.

AND Operator Logical AND. An operator in Boolean SELOGIC control equations that requires fulfillment of conditions on both sides of the operator before the equation is true.

ANSI Standard Device Numbers A list of standard numbers used to represent electrical protection and control relays. The standard device numbers used in this instruction manual include the following:

24	Volts/Hertz element
27	Undervoltage Element
32	Power Elements
49	Thermal Element
50	Overcurrent Element
51	Inverse-Time Overcurrent Element
52	AC Circuit Breaker
59	Overvoltage Element
67	Directional Element
86	Breaker Failure Lockout
89	Disconnect

These numbers are frequently used within a suffix letter to further designate their application. The suffix letters used in this instruction manual include the following:

P	Phase Element
G	Residual/Ground Element
N	Neutral/Ground Element
Q	Negative-Sequence (3I2) Element

Anti-Aliasing Filter A low pass filter that blocks frequencies too high for the given sampling rate to accurately reproduce.

Apparent Power, S Complex power expressed in units of volt-amps (VA), kilovolt-amps (kVA), or megavolt-amps (MVA). Accounts for both real (P) and reactive (Q) power dissipated in a circuit: S = P + jQ. This is power at the fundamental frequency only; no harmonics are included in this quantity.

ASCII Abbreviation for American Standard Code for Information Interchange. Defines a standard set of text characters. The SEL-487E uses ASCII text characters to communicate using front-panel and rear-panel EIA-232 serial ports on the relay and through virtual serial ports.

ASCII Terminal A terminal without built-in logic or local processing capability that can only send and receive information.

Assert To activate. To fulfill the logic or electrical requirements needed to operate a device. To set a logic condition to the true state (logical 1) of that condition. To apply a closed contact to an SEL-487E input. To close a normally open output contact. To open a normally closed output contact.

AT Modem Command Set Dialing String Standard The command language standard that Hayes Microcomputer Products, Inc. developed to control auto-dial modems from an ASCII terminal (usually EIA-232 connected) or a PC (personal computer) containing software allowing emulation of such a terminal.

Autoconfiguration The ability to determine relay type, model number, metering capability, port ID, baud rate, passwords, relay elements, and other information that an IED (an SEL communications processor) needs to automatically communicate with relays.

Automatic Messages Messages including status failure and status warning messages that the relay generates at the serial ports and displays automatically on the front-panel LCD.

Automation Variables Variables that you include in automation SELOGIC control equations.

Autotransformer A transformer with at least two common windings.

AX-S4 MMS "Access for MMS" is an IEC 61850, UCA2, and MMS client application produced by SISCO, Inc., for real-time data integration in Microsoft Windows-based systems supporting OPC and DDE. Included with AX-S4 MMS is the interactive MMS Object Explorer for browser-like access to IEC 61850 / UCA2 and MMS device objects.

Bandpass Filter A filter that passes frequencies within a certain range and blocks all frequencies outside this range.

Bay Primary plant including disconnects, circuit breaker, CTs, PTs, power transformer, ect.

Bay Control Front-panel control (open and close) of the transformer circuit breakers and disconnects (isolators).

Best Choice Ground Directional Supervision™ Logic An SEL logic that determines the directional element that the relay uses for ground faults.

Bit Label The identifier for a particular bit.

Bit Value Logical 0 or logical 1.

Bolted Fault A fault with essentially zero impedance or resistance between the shorted conductors.

Boolean Logic Statements Statements consisting of variables that behave according to Boolean logic operators such as AND, NOT, and OR.

Breaker Auxiliary Contact An electrical contact associated with a circuit breaker that opens or closes to indicate the breaker position. A form-a breaker auxiliary contact (ANSI Standard Device Number 52A) closes when the breaker is closed and opens when the breaker is open. A form-b breaker auxiliary contact (ANSI Standard Device Number 52B) opens when the breaker is closed and closes when the breaker is open.

Breaker-and-a-half Configuration A switching station arrangement of three circuit breakers per two circuits; the two circuits share one of the circuit breakers.

Buffered Report IEC 61850 IEDs can issue buffered reports of internal events (caused by trigger options data-change, quality-change, and data-update). These event reports can be sent immediately or buffered (to some practical limit) for transmission, such that values of data are not lost due to transport flow control constraints or loss of connection. Buffered reporting provides sequence-of-events (SOE) functionality.

C37.118 IEEE C37.118, Standard for Synchrophasors for Power Systems

Category A collection of similar relay settings.

Checksum A method for checking the accuracy of data transmission involving summation of a group of digits and comparison of this sum to a previously calculated value.

CID Checksum identification of the firmware.

CID File IEC 61850 Configured IED Description file. XML file that contains the configuration for a specific IED.

Circuit Breaker Failure Logic This logic within the SEL-487E detects and warns of failure or incomplete operation of a circuit breaker in clearing a fault or in performing a trip or close sequence.

Circuit Breaker History Report A concise circuit breaker event history that contains as many as 128 events. This breaker history report includes circuit breaker mechanical operation times, electrical operation times, interrupted currents, and dc battery monitor voltages.

Circuit Breaker Report A full report of breaker parameters for the most recent operation. These parameters include interrupted currents, number of operations, and mechanical and electrical operating times among many parameters.

Class The first level of the relay settings structure including Global, Group, Breaker Monitor, Port, Report, Front Panel, DNP settings, Protection SELOGIC control equations, Automation SELOGIC control equations, and Output SELOGIC control equations.

Cold Start Beginning a system from power up without carryover of previous system activities.

Combined Winding Mathematical combination (in the SEL-487E) of currents from two separate sets of CT on the same voltage level, typical of breaker-and-a-half busbar configurations.

Commissioning Assistant Software used during transformer commissioning that checks for typical (single-contingency) wiring errors; uses load current to calculate the correct matrix combinations for up to five windings.

Commissioning Testing Testing that serves to validate all system ac and dc connections and confirm that the relay, auxiliary equipment, and SCADA interface all function as intended with your settings. Perform such testing when installing a new protection system.

Common Data Class IEC 61850 grouping of data objects that model substation functions. Common Data Classes include Status information, Measured information, Controllable status, Controllable analog, Status settings, Analog settings, and Description information.

Common Inputs Relay control inputs that share a common terminal.

Communications Protocol A language for communication between devices.

Communications-Assisted Tripping Circuit breaker tripping resulting from the transmission of a control signal over a communications medium.

Comparison Boolean SELOGIC control equation operation that compares two numerical values. Compares floating-point values such as currents, total counts, and other measured and calculated quantities.

COMTRADE Abbreviation for Common Format for Transient Data Exchange. The SEL-487E supports the IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE C37.111–1999.

Conditioning Timers Timers for conditioning Boolean values. Conditioning timers either stretch incoming pulses or allow you to require that an input take a state for a certain period before reacting to the new state.

Contact Input See Control Input.

Contact Output See Control Output.

Coordination Timer A timer that delays an overreaching element so that a downstream device has time to operate.

Control Input Relay inputs for monitoring the state of external circuits. Connect auxiliary relay and circuit breaker contacts to the control inputs.

Control Output Relay outputs that affect the state of other equipment. Connect control outputs to circuit breaker trip and close coils, breaker failure auxiliary relays, communications-assisted tripping circuits, and SCADA systems.

COS Operator Operator in math SELOGIC control equations that provides the cosine function.

Counter Variable or device such as a register or storage location that either records or represents the number of times an event occurs.

CT Current transformer.

CT Subsidence Current Subsidence current appears as a small exponentially decaying dc current with a long time constant. This current results from the energy trapped in the CT magnetizing branch after the circuit breaker opens to clear a fault or interrupt load.

CTR Current transformer ratio.

Current Compensation Calculations to compensate for the phase shift across a power transformer and/or to remove zero-sequence current components.

Current Transformer Saturation The point of maximum current input to a current transformer; any change of input beyond the saturation point fails to produce any appreciable change in output.

Data Attribute In the IEC 61850 protocol, the name, format, range of possible values, and representation of values being communicated. Data Bit A single unit of information that can assume a value of either logical 0 or logical 1 and can convey control, address, information, or frame check sequence data.

Data Class In the IEC 61850 protocol, an aggregation of classes or data attributes.

Data Label The identifier for a particular data item.

Data Object In the IEC 61850 protocol, part of a logical node representing specific information (status or measurement, for example). From an object-oriented point of view, a data object is an instance of a data class.

DC Offset A dc component of fault current that results from the physical phenomenon preventing an instantaneous change of current in an inductive circuit.

Deadband The range of variation an analog quantity can traverse before causing a response.

Deassert To deactivate. To remove the logic or electrical requirements needed to operate a device. To clear a logic condition to its false state (logical 0). To open the circuit or open the contacts across an SEL-487E input. To open a normally open output contact. To close a normally closed output contact.

Debounce Time The time that masks the period when relay contacts continue to move after closing; debounce time covers this indeterminate state.

Default Data Map The default map of objects and indices that the SEL-487E uses in DNP protocol.

Delta A phase-to-phase series connection of circuit elements, particularly voltage transformers or loads.

Demand Meter A measuring function that calculates a rolling average or thermal average of instantaneous measurements over time.

Distance Protection Protection that compares current(s) that enter a point to current(s) that leave that point using current inputs from at least two sets of CTs. The physical location of the input CTs form a distinct area of protection, and the differential element protects against faults within this area.

DMTC Period The time of the demand meter time constant in demand metering.

DNP (Distributed Network Protocol) Manufacturer-developed, hardware-independent communications protocol.

Dropout Time The time measured from the removal of an input signal until the output signal deasserts. You can set the time, in the case of a logic variable timer, or the dropout time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element dropout time.

DTE Devices Data terminal equipment (computers, terminals, printers, relays, etc.).

EEPROM Electrically Erasable Programmable Read-Only Memory. Nonvolatile memory where relay settings, event reports, SER records, and other nonvolatile data are stored.

EHV Extra high voltage. Voltages greater than 230 kV.

EIA-232 Electrical definition for point-to-point serial data communications interfaces, based on the standard EIA/TIA-232. Formerly known as RS-232.

EIA-485 Electrical standard for multidrop serial data communications interfaces, based on the standard EIA/TIA-485. Formerly known as RS-485.

Electrical Operating Time Time between trip or close initiation and an open phase status change.

Electromechanical Reset Setting of the relay to match the reset characteristics of an electromechanical overcurrent relay.

Energy Metering Energy metering provides a look at imported power, exported power, and net usage over time; measured in MWh (megawatt hours).

Equalize Mode A procedure where substation batteries are overcharged intentionally for a preselected time in order to bring all cells to a uniform output.

ESD (Electrostatic Discharge) The sudden transfer of charge between objects at different potentials caused by direct contact or induced by an electrostatic field.

Ethernet A network physical and data link layer defined by IEEE 802.2 and IEEE 802.3.

Event History A quick look at recent relay activity that includes a standard report header; event number, date, time, and type; fault location; maximum fault phase current; active group at the trigger instant; and targets.

Event Report A text-based collection of data stored by the relay in response to a triggering condition, such as a fault or ASCII **TRI** command. The data show relay measurements before and after the trigger, in addition to the states of protection elements, relay inputs, and relay outputs each processing interval. After an electrical system fault, use event reports to analyze relay and system performance.

Event Summary A shortened version of stored event reports. An event summary includes items such as event date and time, event type, fault location, time source, recloser shot counter, prefault and fault voltages, currents, and sequence current, and MIRRORED BITS® communications channel status (if enabled).

The relay sends an event report summary (if auto messaging is enabled) to the relay serial port a few seconds after an event.

EXP Operator Math SELOGIC control equation operator that provides exponentiation.

F_TRIG Falling-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a falling edge.

Falling Edge Transition from logical 1 to logical 0.

Fast Hybrid Control Output A control output similar to, but faster than, the hybrid control output. The fast hybrid output uses an insulated gate bipolar junction transistor (IGBT) to interrupt (break) high inductive dc currents and to very rapidly make and hold the current until a metallic contact operates, at which time the IGBT turns off and the metallic contact holds the current. Unlike the hybrid control output, this output is not polarity sensitive; reversed polarity causes no misoperations.

Fast Meter SEL binary serial port command used to collect metering data with SEL relays.

Fast Operate SEL binary serial port command used to perform control with SEL relays.

Fast Message SEL binary serial port protocol used for Fast SER, Fast Message Synchrophasors, and RTD communications.

Firmware The nonvolatile program stored in the relay that defines relay operation.

Flash Memory A type of nonvolatile relay memory used for storing large blocks of nonvolatile data.

Flashover A disruptive discharge over the surface of a solid dielectric in a gas or liquid.

Float High The highest charging voltage supplied by a battery charger.

Float Low The lowest charging voltage supplied by a battery charger.

Free-Form Logic Custom logic creation and execution order.

Free-Form SELOGIC Control Equations Free-form relay programming that includes mathematical operations, custom logic execution order, extended relay customization, and automated operation.

FTP File transfer protocol.

Function In IEC 61850, task(s) performed by the substation automation system, i.e., by application functions. Generally, functions exchange data with other functions. Details are dependent on the functions involved.

Functions are performed by IEDs (physical devices). A function may be split into parts residing in different IEDs but communicating with each other (distributed function) and with parts of other functions. These communicating parts are called logical nodes.

Function Code A code that defines how you manipulate an object in DNP3 protocol.

Functional Component Logical Node dedicated to a particular function including status, control, and descriptive tags.

Fundamental Frequency The component of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz. Generally used to differentiate between the normal system frequency and any harmonic frequencies present.

Fundamental Power Power calculated with components of the measured electrical signal with a frequency equal to the normal electrical system frequency, usually 50 Hz or 60 Hz.

GOMSFE Generic Object Model for Substation and Feeder Equipment; a system for presenting and exchanging IED data.

GOOSE IEC 61850 Generic Object Oriented Substation Event. GOOSE objects can quickly and conveniently transfer status, controls, and measured values among peers on an IEC 61850 network.

GPS Global Positioning System. Source of position and high-accuracy time information.

Ground Directional Element Priority The order the relay uses to select directional elements to provide ground directional decisions; relay setting ORDER.

Ground Overcurrent Elements Elements that operate by comparing a residual ground calculation of the three-phase inputs with the residual overcurrent threshold setting. The relay asserts ground overcurrent elements when a relay residual current calculation exceeds ground current setting thresholds.

GUI Graphical user interface.

Hexadecimal Address A register address consisting of a numeral with an “h” suffix or a “0x” prefix.

High-Resolution Data Capture Reporting of 3 kHz low-pass analog filtered data from the power system at each event trigger or trip at high sample rates of 8000 samples/second, 4000 samples/second, 2000 samples/second, and 1000 samples/second.

Harmonics Frequencies that are multiples of the frequency of the power system; 100 Hz is the second harmonic of a 50 Hz power system.

Harmonic Restraint Method by which harmonics are used to desensitize differential elements, thereby avoiding misoperations during inrush conditions.

Harmonic Blocking Method by which harmonics are used to block differential elements thereby avoiding misoperations during inrush conditions.

HMI Human machine interface.

Hybrid Control Output Contacts that use an insulated gate bipolar junction transistor (IGBT) in parallel with a mechanical contact to interrupt (break) high inductive dc currents. The contacts can carry continuous current, while eliminating the need for heat sinking and providing security against voltage transients. These contacts are polarity dependent and cannot be used to switch ac control signals.

IA*k*, IB*k*, IC*k* Measured A-phase, B-phase, and C-phase currents of Winding *k*, (*k* = S, T, U, W, X).

ICD File IEC 61850 IED Capability Description file. XML file that describes IED capabilities, including information on logical node and GOOSE support.

IEC 61850 Internationally standardized method of communications and integration conceived with the goal of supporting systems of multivendor IEDs networked together to perform protection, monitoring, automation, metering, and control.

IED Intelligent electronic device.

IEEE Institute of Electrical and Electronics Engineers, Inc.

IG Residual current, calculated from the sum of the phase currents. In normal, balanced operation, this current is very small or zero.

IGBT Insulated gate bipolar junction transistor.

Independent Zone Timing The provision of separate zone timers for phase and ground distance elements.

Infinite Bus A constant-voltage bus.

Input Conditioning The establishment of debounce time and assertion level.

Instance A subdivision of a relay settings class. Group settings have several subdivisions (Group 1–Group 6), while the Global settings class has one instance.

Instantaneous Meter Type of meter data presented by the SEL-487E that includes the present values measured at the relay ac inputs. The word “Instantaneous” is used to differentiate these values from the measurements presented by the demand, thermal, energy, and other meter types.

IP Address An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the IP address of the destination. The format of an IP address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

IRIG-B A time code input that the relay can use to set the internal relay clock.

Jitter Time, amplitude, frequency, or phase-related abrupt, spurious variations in duration, magnitude, or frequency.

L/R Circuit inductive/resistive ratio.

Latch Bits Nonvolatile storage locations for binary information.

LED Light-emitting diode. Used as indicators on the relay front panel.

Left-Side Value LVALUE. Result storage location of a SELOGIC control equation.

Line Impedance The phasor sum of resistance and reactance in the form of positive-sequence, negative-sequence, and zero-sequence impedances of the protected line.

LN Operator Math SELOGIC control equation operator that provides natural logarithm.

Local Bits The Relay Word bit outputs of local control switches that you access through the SEL-487E front panel. Local control switches replace traditional panel-mounted control switches.

Lockout Relay An auxiliary relay that prevents operation of associated devices until it is reset either electrically or by hand.

Logical 0 A false logic condition, dropped out element, or deasserted control input or control output.

Logical 1 A true logic condition, picked up element, or asserted control input or control output.

Logical Node In IEC 61850, the smallest part of a function that exchanges data. A logical node (LN) is an object defined by its data and methods. Each logical node represents a group of data (controls, status, measurements, etc.) associated with a particular function.

Loss of Potential Loss of one or more phase voltage inputs to the relay secondary inputs.

Low-Level Test Interface An interface that provides a means for interrupting the connection between the relay input transformers and the input processing module and allows inserting reduced-scale test quantities for relay testing.

MAC Address The Media Access Control (hardware) address of a device connected to a shared network medium, most often used with Ethernet networks.

Maintenance Testing Testing that confirms that the relay is measuring ac quantities accurately and verifies correct functioning of auxiliary equipment, scheme logic, and protection elements.

Math Operations Calculations for automation or extended protection functions.

Math Operators Operators that you use in the construction of math SELOGIC control equations to manipulate numerical values and provide a numerical base-10 result.

Maximum Dropout Time The maximum time interval following a change of input conditions between the deassertion of the input and the deassertion of the output.

Mechanical Operating Time Time between trip initiation or close initiation and the change in status of an associated circuit breaker auxiliary 52A normally open contacts.

MIRRORED BITS® Communications Patented relay-to-relay communications technique that sends internal logic status, encoded in a digital message, from one relay to the other. Eliminates the need for some communications hardware.

MMS Manufacturing Messaging Specification, a data exchange protocol used by IEC 61850.

Model Model of device (or component of a device) including the data, control access, and other features in UCA protocol.

Motor Running Time The circuit breaker motor running time. Depending on your particular circuit breaker, you can use the motor running time to monitor the charge time of the circuit breaker springs or the running time of the compressor motor.

MOV Metal-oxide varistor.

MVA Mega Volt-Ampere. Typical unit for expressing the capacity of a power transformer, e.g., 100MVA.

Negation Operator A SELOGIC control equation math operator that changes the sign of the argument. The argument of the negation operation is multiplied by –1.

Negative-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°, and have clockwise phase rotation with current and voltage maxima that occur differently from that for positive-sequence configuration. If positive-sequence maxima occur as ABC, negative-sequence maxima occur as ACB.

Negative-Sequence Current Supervision Pickup
An element allowed to operate only when a negative-sequence current exceeds a threshold.

Negative-Sequence Directional Element
An element that provides directivity by the sign, plus or minus, of the measured negative-sequence impedance.

Negative-Sequence Impedance
Impedance of a device or circuit that results in current flow with a balanced negative-sequence set of voltage sources.

Negative-Sequence Overcurrent Elements
Elements that operate by comparing a negative-sequence calculation of the three-phase secondary inputs with negative-sequence overcurrent setting thresholds. The relay asserts these elements when a relay negative-sequence calculation exceeds negative-sequence current setting thresholds.

Negative-Sequence Voltage-Polarized Directional Element
These directional elements are 32QG and 32Q. 32QG supervises the ground distance elements and residual directional overcurrent elements; 32Q supervises the phase distance elements.

NEMA
National Electrical Manufacturers' Association.

Neutral Impedance
An impedance from neutral to ground on a device such as a generator or transformer.

Nonvolatile Memory
Relay memory that persists over time to maintain the contained data even when the relay is deenergized.

NOT Operator
A logical operator that produces the inverse value.

Operate Current
Differential current (vector sum) between current(s) that enter a point, and current(s) that leave that point.

OR Operator
Logical OR. A Boolean SELOGIC control equation operator that compares two Boolean values and yields either a logical 1 if either compared Boolean value is logical 1 or a logical 0 if both compared Boolean values are logical 0.

OSI
Open Systems Interconnect. A model for describing communications protocols. Also an ISO suite of protocols designed to this model.

Over/Underpower Elements
Elements that calculate the forward and reverse power flow and compare the result against settable thresholds.

Over/Undervoltage Elements
Elements that calculate the system voltage and compare the result against settable thresholds.

Over/Underfrequency Elements
Elements that calculate the power system frequency and compare the result against settable thresholds.

Override Values
Test values you enter in Fast Meter, DNP, and communications card database storage.

Parentheses Operator
Math operator. Use paired parentheses to control the execution of operations in a SELOGIC control equation.

PC Personal computer.

Peak Demand Metering Maximum demand and a time stamp for phase currents, negative-sequence and zero-sequence currents, and powers. The SEL-487E stores peak demand values and the date and time these occurred to nonvolatile storage once per day, overwriting the previously stored value if the new value is larger. Should the relay lose control power, the relay restores the peak demand information saved at 23:50 hours on the previous day.

Phase Overcurrent Element Elements that operate by comparing the phase current applied to the secondary current inputs with the phase overcurrent setting. The relay asserts these elements when any combination of the phase currents exceeds phase current setting thresholds.

Phase Rotation The sequence of voltage or current phasors in a multiphase electrical system. In an ABC phase rotation system, the B-phase voltage lags the A-phase voltage by 120°, and the C-phase voltage lags B-phase voltage by 120°. In an ACB phase rotation system, the C-phase voltage lags the A-phase voltage by 120°, and the B-phase voltage lags the C-phase voltage by 120°.

Pickup Time The time measured from the application of an input signal until the output signal asserts. You can set the time, as in the case of a logic variable timer, or the pickup time can be a result of the characteristics of an element algorithm, as in the case of an overcurrent element pickup time.

Pinout The definition or assignment of each electrical connection at an interface. Typically refers to a cable, connector, or jumper.

Polarizing Memory A circuit that provides a polarizing source for a period after the polarizing quantity has changed or gone to zero.

Pole-Open Logic Logic that determines the conditions that the relay uses to indicate an open circuit breaker pole.

Port Settings Communications port settings such as Data Bits, Speed, and Stop Bits.

Positive-Sequence A configuration of three-phase currents and voltages. The currents and voltages have equal magnitude and a phase displacement of 120°.

Positive-Sequence Current Restraint Factor, a2 This factor compensates for highly unbalanced systems with many untransposed lines and helps prevent misoperation during current transformer saturation. The a2 factor is the ratio of the magnitude of negative-sequence current to the magnitude of positive-sequence current (I2/I1).

Positive-Sequence Current Supervision Pickup An element that operates only when a positive-sequence current exceeds a threshold.

Positive-Sequence Impedance Impedance of a device or circuit that results in current flow with a balanced positive-sequence set of voltage sources.

Power Factor The cosine of the angle by which phase current lags or leads phase voltage in an ac electrical circuit. Power factor equals 1.0 for power flowing to a pure resistive load.

Protection and Automation Separation Segregation of protection and automation processing and settings.

Protection Settings Group Individual scheme settings for as many as six different schemes (or instances).

Protection-Disabled State Suspension of relay protection element and trip/close logic processing and deenergization of all control outputs.

PT Potential transformer. Also referred to as a voltage transformer or VT.

PTR Potential transformer ratio.

Quadrilateral Characteristic A distance relay characteristic on an R-X diagram consisting of a directional measurement, reactance measurement, and two resistive measurements.

Qualifier Code Specifies type of range for DNP3 objects. With the help of qualifier codes, DNP master devices can compose the shortest, most concise messages.

R_TRIG Rising-edge trigger. Boolean SELOGIC control equation operator that triggers an operation upon logic detection of a rising edge.

RAM Random Access Memory. Volatile memory where the relay stores intermediate calculation results, Relay Word bits, and other data.

Real Power Power that produces actual work. The portion of apparent power that is real, not imaginary.

Relay Word Bit A single relay element or logic result. A Relay Word bit can equal either logical 1 or logical 0. Logical 1 represents a true logic condition, picked up element, or asserted control input or control output. Logical 0 represents a false logic condition, dropped out element, or deasserted control input or control output. Use Relay Word bits in SELOGIC control equations.

Remapping The process of selecting data from the default map and configuring new indices to form a smaller data set optimized to your application.

Remote Bit A Relay Word bit with a state that is controlled by serial port commands, including the **CONTROL** command, a binary Fast Operate command, DNP binary output operation, or a UCA control operation.

Report Settings Event report and Sequential Events Recorder settings.

Residual Current The sum of the measured phase currents. In normal, balanced operation, this current is very small or zero.

Residual Directional Overcurrent Element A residual overcurrent element allowed to operate in only the forward or reverse direction.

Residual Overcurrent Protection Overcurrent protection that operates at conditions exceeding a threshold of system unbalance ($3I_0 = I_A + I_B + I_C$).

Restraint Current Sum of the absolute values of current(s) entering a point, and leaving that point. Used as basis to calculate the reference (setting) value for differential elements.

Restricted Earth Fault Differential element that augments the phase differential element by providing sensitive protection against ground faults close to the neutral of a grounded-wye transformer. The element compares the phase angle of zero-sequence quantities from the transformer neutral with zero-sequence quantities from up to five line CTs.

Retrip A subsequent act of attempting to open the contacts of a circuit breaker after the failure of an initial attempt to open these contacts.

Rising Edge Transition from logical 0 to logical 1, or the beginning of an operation.

RMS Root-mean-square. This is the effective value of the current and voltage measured by the relay, accounting for the fundamental frequency and higher-order harmonics in the signal.

Rolling Demand A sliding time-window arithmetic average in demand metering.

RTD Resistance Temperature Detector

RTU Remote Terminal Unit.

RXD Received data.

SCADA Supervisory control and data acquisition.

SCD File IEC 61850 Substation Configuration Description file. XML file that contains information on all IEDs within a substation, communications configuration data, and a substation description.

SCL IEC 61850 Substation Configuration Language. An XML-based configuration language that supports the exchange of database configuration data among different software tools that can be from different manufacturers. There are four types of SCL files used within IEC 61850: CID, ICD, SCD, and SSD.

Self-Description A feature of GOMSFE in the UCA2 protocol. A master device can request a description of all of the GOMSFE models and data within the IED.

Self-Test A function that verifies the correct operation of a critical device subsystem and indicates detection of an out-of-tolerance condition. The SEL-487E has self-tests that validate the relay power supply, microprocessor, memory, and other critical systems.

SELOGIC Expression Builder A rules-based editor within the ACSELERATOR QuickSet software program for programming SELOGIC control equations.

SELOGIC Math Variables Math calculation result storage locations.

SELOGIC Control Equation A relay setting that allows you to control a relay function (such as a control output) using a logical combination of relay element outputs and fixed logic outputs.

Sequencing Timers Timers designed for sequencing automated operations.

Sequential Events Recorder A relay function that stores a record of the date and time of each assertion and deassertion of every Relay Word bit in a list that you set in the relay. SER provides a useful way to determine the order and timing of events of a relay operation.

SER Sequential Events Recorder or the relay serial port command to request a report of the latest 1000 sequential events.

Series-Compensated Line A power line on which the addition of series capacitance compensates for excessive inductive line impedance.

Settle/Settling Time Time required for an input signal to result in an unvarying output signal within a specified range.

SIN Operator Operator in math SELOGIC control equations that provides the sine function.

SQRT Operator Math SELOGIC control equation operator that provides square root.

SSD File IEC 61850 System Specification Description file. XML file that describes the single-line diagram of the substation and the required logical nodes.

Status Failure A severe out-of-tolerance internal operating condition. The relay issues a status failure message and enters a protection-disabled state.

Status Warning Out-of-tolerance internal operating conditions that do not compromise relay protection, yet are beyond expected limits. The relay issues a status warning message and continues to operate.

Subnet Mask The subnet mask divides the local node IP address into two parts, a network number and a node address on that network. A subnet mask is four bytes of information and is expressed in the same format as an IP address.

Subsidence Current See CT subsidence current.

Synchronized Phasor A phasor calculated from data samples using an absolute time signal as the reference for the sampling process. The phasors from remote sites have a defined common phase relationship. Also known as Synchrophasor.

TAP Full-load secondary current that the relay uses to convert Ampere values to dimensionless per-unit values.

TAP Tappings on some power transformer windings, used for voltage/reactive power flow control.

Telnet An Internet protocol for exchanging terminal data that connects a computer to a network server and allows control of that server and communication with other servers on the network.

Terminal Transformer winding, synonymous with “winding.”

Terminal Emulation Software Software such as Microsoft® HyperTerminal® or ProComm Plus® that can be used to send and receive ASCII text messages and files via a computer serial port.

Thermal Demand Thermal demand is a continuous exponentially increasing or decreasing accumulation of metered quantities; used in demand metering.

Thermal Withstand Capability The capability of equipment to withstand a predetermined temperature value for a specified time.

Three-Phase Fault A fault involving all three phases of a three-phase power system.

Three-Pole Trip A circuit breaker operation that occurs when the circuit breaker opens all three poles at the same time.

Time Delay on Pickup The time interval between initiation of a signal at one point and detection of the same signal at another point.

Time Dial (Time Multiplier) A control that governs the time scale of the time-overcurrent characteristic of a relay. Use the time-dial setting to vary relay operating time.

Time-Delayed Tripping Tripping that occurs after expiration of a pre-determined time.

Time Error A measurement of how much time an ac powered clock would be ahead or behind a reference clock, as determined from system frequency measurements.

Time-Overcurrent Element An element that operates according to an inverse relationship between input current and time, with higher current causing faster relay operation.

Time Quality An indication from a GPS clock receiver that specifies the maximum error in the time information. Defined in IEEE C37.118.

Torque Control A method of using one relay element to supervise the operation of another.

Total Clearing Time The time interval from the beginning of a fault condition to final interruption of the circuit.

Transformer Impedance The resistive and reactive parameters of a transformer looking in to the transformer primary or secondary windings. Use industry accepted open-circuit and short-circuit tests to determine these transformer equivalent circuit parameters.

TVE Total Vector Error. A measurement of accuracy for phasor quantities that combines magnitude and angle errors into one quantity. Defined in IEEE C37.118.

TXD Transmitted data.

Unbalanced Current Element Element that calculates the percentage difference between the three phase currents.

Unbuffered Report IEC 61850 IEDs can issue immediate unbuffered reports of internal events (caused by trigger options data-change, quality-change, and data-update) on a “best efforts” basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

User ST Region in GOOSE for user-specified applications.

VA, VB, VC Measured A-phase-to-neutral, B-phase-to-neutral, and C-phase-to-neutral voltages.

VAB, VBC, VCA Measured or calculated phase-to-phase voltages.

Virtual Terminal Connection A mechanism that uses a virtual serial port to provide the equivalent functions of a dedicated serial port and a terminal.

Volatile Storage A storage device that cannot retain data following removal of relay power.

VT Voltage transformer. Also referred to as a potential transformer or PT.

Warm Start The reset of a running system without removing and restoring power.

Winding Transformer winding, synonymous with “terminal.”

Wye A phase-to-neutral connection of circuit elements, particularly voltage transformers or loads. To form a wye connection using transformers, connect the nonpolarity side of each of three voltage transformer secondaries in common (the neutral), and take phase to neutral voltages from each of the remaining three leads. When properly phased, these leads represent the A-phase-, B-phase-, and C-phase-to-neutral voltages. This connection is frequently called ‘four-wire wye,’ alluding to the three phase leads plus the neutral lead.

XML Extensible Markup Language. This specification developed by the W3C (World Wide Web Consortium) is a pared-down version of SGML designed especially for web documents. It allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data among applications and organizations.

Zero-Sequence A configuration of three-phase currents and voltages with currents and voltages that occur simultaneously, are always in phase, and have equal magnitude ($3I_0 = I_A + I_B + I_C$).

Zero-Sequence Impedance Impedance of a device or circuit resulting in current flow when a single voltage source is applied to all phases.

Zero-Sequence Overcurrent Element Overcurrent protection that operates at conditions exceeding a threshold of system unbalance.

Zero-Sequence Voltage-Polarized Directional Element An element that provides directionality by the sign, plus or minus, of the measured zero-sequence impedance.

Z Number That portion of the relay FID string that identifies the proper ACSELERATOR QuickSet software relay driver version and HMI driver version when creating or editing relay settings files.

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D

SEL-487E Command Summary

Command[a,b]	Description
2ACCESS	Go to Access Level 2 (complete relay monitoring and control)
89CLOSE *m*	Disconnect *m* **CLOSE** command (*m* = 1–8)
89OPEN *m*	Disconnect *m* **OPEN** command
AACCESS	Go to Access Level A (automation control)
ACCESS	Go to Access Level 1 (monitor relay)
BACCESS	Go to Access Level B (monitor relay and control circuit breakers)
BNAME	ASCII names of all relay status bits (Fast Meter)
BREAKER *k*	Display Circuit Breaker *k* report (*k* = S, T, U, W, X)
CASCII	Generate the Compressed ASCII response configuration message
CBREAKER	Compressed ASCII Circuit Breaker *k* report
CEVENT	**EVENT** command for the Compressed ASCII response
CHISTORY	**HISTORY** command for the Compressed ASCII response
CLOSE *k*	Circuit Breaker *n* **CLOSE** command
COMM *c*	Display relay-to-relay MIRRORED BITS® communications or remote synchrophasor data and synchrophasor clients (*c* = A is channel A; *c* = B is channel B; *c* = M is either enabled single channel; *c* = RTC for remote synchrophasors)
CONTROL *nn*	Set, clear, or pulse an internal remote bit (*nn* is the remote bit number from 01–96)
COPY	Copy settings between instances in the same class
CPR	Displays signed profile data
CSER	**SER** command for the Compressed ASCII response
CSTATUS	**STATUS** command for the Compressed ASCII response
CSUMMARY	**SUMMARY** command for the Compressed ASCII response
DATE	Display and set the date
DNAME X	ASCII names of all relay digital I/O (Fast Meter)
DNP	Access or modify serial port DNP 3.00 settings (similar to **SHOW D** and **SET D**)
EVENT	Display and acknowledge event reports
FILE	Transfer data between the relay and external software
GROUP	Display the active group number or select the active group
HELP	Display available commands or command help at each access level
HISTORY	View event summaries/histories; clear event data
ID	Display the firmware id, user id, device code, part number, and configuration information
LOOPBACK	Connect MIRRORED BITS data from transmit to receive on the same port
MAP 1	Analyze the communications card database
METER	Display metering data and internal relay operating variables
OACCESS	Go to Access Level O (output control)
OPEN *n*	Open the circuit breaker (*n* = 1–18)
PACCESS	Go to Access Level P (protection control)
PASSWORD	Change relay passwords

Command[a,b]	Description
PORT	Connect to a remote relay via MIRRORED BITS® virtual terminal (for port number *p* = 1–3 and F), or to the Ethernet card (port *p* = 5)
PROFILE	Displays signal profile data
PULSE	Pulse a relay control output
QUIT	Reduce access level to Access Level 0 (exit relay control)
RTC	Display configuration of received remote synchrophasors
SER	View Sequential Events Recorder reports
SET[c]	Enter relay settings
SHOW[c]	Display relay settings
SNS	Display Sequential Events Recorder settings name strings (Fast SER)
STATUS	Report or clear relay status and SELOGIC® control equation errors
SUMMARY	View summary event reports
TARGET	Display relay elements for a row in the Relay Word table
TEST DB	Display or place values in the communications card database (useful for Ethernet protocol read tests)
TEST DNP	Display or place values in the serial port DNP 3.00 object map
TEST FM	Display or place values in metering database (Fast Meter)
TFE	Display, set, and clear through-fault data
THE	Display transformer thermal report
TIME	Display and set the internal clock
TRIGGER	Initiate a data capture and record an event report
VERSION	Display the relay hardware and software configurations
VIEW	View data from the communications card database

[a] See Section 13: ASCII Command Reference.
[b] For help on a specific command, type **HELP [command] <Enter>** at an ASCII terminal communicating with the relay.
[c] See the table below for **SET/SHOW** options.

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