# SEL-387E

## Current Differential and Voltage Relay

## Instruction Manual

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SEL SCHWEITZER ENGINEERING LABORATORIES

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# Preface

## Overview

The SEL-387E Relay instruction manual provides specifications and describes installation, setting, testing and operation of the SEL-387E. It also includes detailed information about settings and serial port commands.

An overview of each manual section follows:

Preface. Describes the manual organization and conventions used to present information.

Section 1: Introduction and Specifications. Describes the basic features and functions of the SEL-387E, and lists the specifications.

Section 2: Installation. Describes how to mount and wire the SEL-387E, and illustrates wiring connections.

Section 3: Protection Functions. Describes the protection elements and their associated settings.

Section 4: Control Logic. Describes inputs, the Relay Word, outputs, and logic. Use this section to understand the settings necessary for implementing your logic.

Section 5: Metering and Monitoring. Describes how to retrieve operations data such as metering, DC battery monitor, breaker monitor, and relay status.

Section 6: Settings. Describes settings that are not described in Section 3 or Section 4, for default settings, and for settings sheets.

Section 7: Communications. for a description of the serial port commands used to set the relay for control, obtain target information, and obtain metering information, etc.

Section 8: Front-Panel Operation. Describes how to perform the serial port commands from the front panel.

Section 9: Analyzing Events. Describes event report and sequential events report generation, event report formats, sequential event reports, and report interpretation.

Section 10: Testing and Troubleshooting. Describes test procedures and a troubleshooting guide. You can use this section as a tutorial to check your understanding of the relay's operation.

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

Appendix B: SEL-300 Series Relays Firmware Upgrade Instructions. Describes the procedure to update the firmware stored in Flash memory.

Appendix C: SEL Distributed Port Switch Protocol. Describes how to use the SEL distributed port switch data-link protocol for multidrop applications.

Appendix D: Configuration, Fast Meter, and Fast Operate Commands. Describes the configuration, Fast Meter, and Fast Operate commands provided in the SEL-387E.

Appendix E: Compressed ASCII Commands. Describes the compressed ASCII versions of some of the relay's ASCII commands.

Appendix F: Unsolicited SER Protocol. Describes special binary Sequential Events Recorder (SER) messages that are not included in *Section 9*.

Appendix G: Distributed Network Protocol (DNP3). Describes the DNP3 protocol support provided by the SEL-387E.

Appendix H: IEC 61850 Communications. Describes IEC 61850 implementation in the SEL-387E.

Appendix I: Relay Power Calculations. Describes the SEL-387E Relay power calculations.

Appendix J: Protection Application Examples. Describes transformer winding and CT connection compensation settings examples.

Appendix K: PC Software. Describes PC software solutions that support SEL devices.

SEL-387E Command Summary. Describes the serial port commands that are fully described in *Appendix E: Compressed ASCII Commands*.

# Safety Information

## Dangers, Warnings, and Cautions

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

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

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

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

## Safety Symbols

The following symbols are often marked on SEL products.

| | | |
|---|---|---|
| ⚠ | **⚠CAUTION**<br>Refer to accompanying documents. | **⚠ATTENTION**<br>Se reporter à la documentation. |
| ⏚ | Earth (ground) | Terre |
| ⏚ | Protective earth (ground) | Terre de protection |
| ⎓ | Direct current | Courant continu |
| ∿ | Alternating current | Courant alternatif |

| | | |
|---|---|---|
| | Both direct and alternating current | Courant continu et alternatif |
| | Instruction manual | Manuel d'instructions |

## Safety Marks

The following statements apply to this device.

### General Safety Marks

| | |
|---|---|
| For use in Pollution Degree 2 environment. | Pour l'utilisation dans un environnement de Degré de Pollution 2. |
| **CAUTION**<br>There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children. | **ATTENTION**<br>Une pile remplacée incorrectement pose des risques d'explosion. Remplacez seulement avec un Rayovac no BR2335 ou un produit équivalent recommandé par le fabricant. Voir le guide d'utilisateur pour les instructions de sécurité. La pile utilisée dans cet appareil peut présenter un risque d'incendie ou de brûlure chimique si vous en faites mauvais usage. Ne pas recharger, démonter, chauffer à plus de 100°C ou incinérer. Éliminez les vieilles piles suivant les instructions du fabricant. Gardez la pile hors de la portée des enfants. |

### Other Safety Marks (Sheet 1 of 2)

| | |
|---|---|
| **DANGER**<br>Contact with instrument terminals can cause electrical shock that can result in injury or death. | **DANGER**<br>Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort. |
| **DANGER**<br>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. | **DANGER**<br>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. |
| **WARNING**<br>Before working on a CT circuit, first apply a short to the secondary winding of the CT. | **AVERTISSEMENT**<br>Avant de travailler sur un circuit TC, placez d'abord un court-circuit sur l'enroulement secondaire du TC. |
| **WARNING**<br>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**<br>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. |
| **WARNING**<br>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**<br>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 accès non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès non-autorisé. |
| **WARNING**<br>Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment. | **AVERTISSEMENT**<br>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. |
| **CAUTION**<br>The continuous rating of the current inputs is 3 • $I_{nom}$. For this test, you may want to choose low values of U87P and TAPn, in order to limit the required test current to a safe value. | **ATTENTION**<br>La capacité, en régime permanent, des entrées de courant est 3 • $I_{nom}$. Pour ce test, vous pourriez choisir de valeurs peu élevées pour U87P et TAPn, de façon à limiter le courant de test à une valeur sécuritaire. |

**Other Safety Marks** (Sheet 2 of 2)

| | |
|---|---|
| ⚠CAUTION<br>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. | ⚠ATTENTION<br>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. |
| ⚠CAUTION<br>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. | ⚠ATTENTION<br>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. |

# General Information

## Typographic Conventions

There are three ways to communicate with the SEL-387E:

- Using a command line interface in 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, command options, and command variables typed at a command line interface on a PC. |
| *n*<br>**SUM *n*** | Variables determined based on an application (in bold if part of a command). |
| **<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.<br>The > character indicates submenus. |
| ENABLE | Relay front- or rear-panel labels and pushbuttons. |
| MAIN > METER | Relay front-panel LCD menus and relay responses visible on the PC screen.<br>The > character indicates submenus. |

## Logic Diagrams

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

| NAME | SYMBOL | FUNCTION |
|---|---|---|
| COMPARATOR | A, B, +, –, C | Input A is compared to input B. Output C asserts if A is greater than B. |
| INPUT FLAG | A | Input A comes from other logic. |
| OR | A, B, C | Either input A or input B asserted cause output C to assert. |
| EXCLUSIVE OR | A, B, C | If either A or B is asserted, output C is asserted. If A and B are of the same state, C is deasserted. |
| NOR | A, B, C | If neither A nor B asserts, output C asserts. |
| AND | A, B, C | Input A and input B must assert to assert output C. |
| AND W/ INVERTED INPUT | A, B, C | If input A is asserted and input B is deasserted, output C asserts. Inverter "O" inverts any input or output on any gate. |
| NAND | A, B, C | If A and/or B are deasserted, output C is asserted. |
| TIME DELAYED PICK UP AND/OR TIME DELAYED DROP OUT | A, X, Y, B | 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 | A, X, Y, B | 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 | S, R, Q | Input S asserts output Q until input R asserts. Output Q deasserts or resets when R asserts. |
| FALLING EDGE | A, B | B asserts at the falling edge of input A. |

## Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

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# Section 1

# Introduction and Specifications

## Introduction

Use this relay to protect two- to three-winding power transformers, buses, reactors, generators, large motors, or other multiterminal power apparatus. Three- or four-terminal applications permit separate connection of current transformers from two breakers connected to the same transformer winding, such as in ring-bus or breaker-and-a-half schemes. The relay settings permit you to use wye- or delta-connected current transformers with virtually any type of transformer winding connection.

The SEL-387E Differential Relay provides three differential elements with dual slope characteristics. The second slope provides security against CT saturation for heavy through faults. Be sure to conduct detailed analysis of CT performance under worst-case saturation conditions to set the relay characteristic correctly for bus protection applications. For assistance with CT selection, obtain SEL Application Guide *AG99-07: Bus Protection Using a Four-Winding Low-Impedance Percentage Differential Relay* from the SEL website (selinc.com).

### Instruction Manual Overview

This instruction manual applies to the SEL-387E Relay. If you are unfamiliar with this relay, we suggest that you read the following sections in the outlined order.

*Section 1: Introduction and Specifications* for an introduction, instruction manual overview, relay functional overview, and specifications.

*Section 3: Protection Functions* to understand the protection elements and their associated settings.

*Section 4: Control Logic* to understand inputs, the Relay Word, outputs, and logic. Use this section to understand the settings necessary for implementing your logic.

*Section 6: Settings* to understand settings that are not described in *Section 3* or *Section 4*, for default settings, and for settings sheets.

*Section 7: Communications* for a description of the serial port commands used to set the relay for control, obtain target information, and obtain metering information, etc.

*Section 8: Front-Panel Operation* for a description of how to perform the serial port commands from the front panel.

*Section 5: Metering and Monitoring* to learn how to retrieve operations data such as metering, DC battery monitor, breaker monitor, and relay status.

*Section 9: Analyzing Events* for a description of event report and sequential events report generation, event report formats, sequential event reports, and report interpretation.

*Section 2: Installation* to learn how to configure, install, and wire your relay.

*Section 10: Testing and Troubleshooting* for test procedures and a troubleshooting guide. You can use this section as a tutorial to check your understanding of the relay's operation.

# Relay Functions

| ANSI NUMBERS/ACRONYMS AND FUNCTIONS | |
|---|---|
| 24 | Volts/Hertz |
| 27 | Undervoltage |
| 50 (P, G, Q) | Overcurrent (Phase, Ground, Neg. Seq.) |
| 51 (P, G, Q) | Time-Overcurrent (Phase, Ground, Neg. Seq.) |
| 59 | Overvoltage |
| 81 (O, U) | Over-/Underfrequency |
| 87 | Current Differential |
| DFR | Event Reports |
| HMI | Operator Interface |
| LGC | SELOGIC® Control Equations |
| MET | High-Accuracy Metering |
| REF | Restricted Earth Fault |
| SER | Sequential Events Recorder |

| ADDITIONAL FUNCTIONS | |
|---|---|
| BRM | Breaker Wear Monitor |
| SBM | Station Battery Monitor |
| TRM | Transformer Monitor |

* Optional Feature

**Figure 1.1 SEL-387E Relay Functional Overview**

## Current Differential Protection

The SEL-387E includes independent restrained and unrestrained current differential elements. The restrained element has a dual-slope, variable-percentage restraint characteristic. Use the fifth-harmonic element to prevent relay misoperation during allowable overexcitation conditions. Even-harmonic elements (second- and fourth-harmonic) provide security against inrush currents during transformer energization, complemented by the dc element which measures the dc offset. The even-harmonic element offers the choice between harmonic blocking and harmonic restraint. In the blocking mode, the user selects either blocking on an individual phase basis or on a common basis, as per application and philosophy. The second-, fourth-, and fifth-harmonic thresholds are set independently, and the dc blocking and harmonic restraint features are enabled independently. A separate unrestrained differential element provides faster clearance of high-magnitude internal faults.

## Restricted Earth Fault Protection

The SEL-387E provides sensitive detection of internal ground faults via the Restricted Earth Fault (REF) protection element. The Winding 3 inputs are used for introduction of neutral CT polarizing current. Operating current is

derived from the residual current calculated for the protected winding. A directional element determines whether the fault is internal or external. Tripping is supervised by zero-sequence current thresholds and a positive-sequence current restraint setting. The REF function is applicable to a single grounded wye winding or an autotransformer with one breaker and set of CTs at one terminal and one breaker and set of CTs at the other terminal. Because the Winding 3 inputs are used for the neutral CT, only two of the winding inputs may be used for normal differential or overcurrent protection purposes.

## Overcurrent Protection

The SEL-387E provides nondirectional overcurrent elements for each winding/terminal:

- Phase Overcurrent: Three-level instantaneous; definite-time; inverse-time
- Residual Overcurrent: Instantaneous; definite-time; inverse-time
- Negative-Sequence Overcurrent: Instantaneous; definite-time; inverse-time

In addition, the SEL-387E has two special overcurrent functions:

- Combined overcurrent (inverse-time, phase, and ground) for summed currents from Windings 1 and 2
- Restricted Earth Fault (REF) protection for sensitive ground fault detection in grounded wye-connected windings

Overcurrent element pickup settings and operating characteristics are independent of the differential element settings. Most elements can be torque controlled.

## Volts-per-Hertz Protection

The SEL-387E provides sensitive dual-level elements to detect voltage overexcitation. Level 1 volts-per-hertz elements provide instantaneous and definite-time operation for alarm or trip. Level 2 elements provide one of three selectable inverse-time/definite-time composite characteristics, or one user-definable inverse-time characteristic, for alarm or trip. Both volts-per-hertz protection levels may be torque controlled.

## Overvoltage and Undervoltage Protection

The SEL-387E provides eight overvoltage and undervoltage elements. Elements include phase undervoltage and overvoltage elements, phase-to-phase undervoltage and overvoltage elements, as well as positive-sequence, negative-sequence, and residual overvoltage elements. Phase and phase-to-phase elements operate when any individual phase exceeds the respective setting. Combine these elements with SELOGIC control equations to provide time delays for up to 999999 cycles. The elements have many applications in protection, control, and indication.

### Frequency Protection

The SEL-387E provides six levels of over-/underfrequency elements. Each element can operate as either an underfrequency or as an overfrequency element, depending on its pickup setting. Should any phase voltage fall below a user-defined value, the relay disables all frequency elements, providing security against loss-of-potential conditions. The relay tracks the system frequency from 40.1 to 65 Hz to provide measurement of frequency excursions over a wide range. Apply the elements readily to underfrequency load shedding and restoration control systems.

### Through-Fault Event Monitor

Through faults are a major cause of transformer damage and failure. Fault currents cause cumulative mechanical damage by displacing transformer windings every time a fault occurs. Thermal stress from fault currents damages insulation. The SEL-387E provides a through-fault event monitor to gather fault current level, duration, and date/time for each through fault. The monitor performs a simple $I^2t$ calculation and cumulatively stores calculation results for each phase. Use these through-fault event data to schedule proactive maintenance for transformers and to help justify possible system enhancements to mitigate through faults.

### Programmable Optoisolated Inputs and Output Contacts

The SEL-387E is equipped with enhanced SELOGIC control equations that allow design of a custom tripping or control scheme. SELOGIC control equation functions include independent timers, tripping, closing, event report triggering, and relay output contact control.

## Model Options

### Conventional Terminal Blocks

This model includes hardware that supports nine current inputs, three voltage inputs, six optoisolated inputs, seven programmable output contacts, one alarm contact, three EIA-232 ports, one EIA-485 port, and IRIG-B time code. It uses terminal blocks that support #6 ring terminals. This robust package meets or exceeds numerous industry standard type tests.

This relay is available in a 3.50" (2U) or 5.25" (3U) rack-mount package or 4.9" or 6.65" panel-mount package. Additional optoisolated inputs and programmable output contacts are available with the larger packages.

### Plug-In Connectors (Connectorized®)

This model includes hardware that supports all of the features of the conventional terminal blocks model. It differs in its use of plug-in connectors instead of terminal blocks. In addition, it provides

- Quick connect/release hardware for rear-panel terminals.
- Level-sensitive optoisolated inputs.

This robust package meets or exceeds numerous industry standard type tests. It is available in a 5.25" (3U) rack-mount package or a 6.65" panel-mount package.

### Horizontal or Vertical Mounting

3U versions of the SEL-387E are available with horizontal or vertical mounting. Horizontal mounting provides rack-, panel-, and projection-mount options. Vertical mounting provides rack- and panel-mounting options. Horizontal and vertical relays contain identical features and functions.

# Specifications

## Compliance

Designed and manufactured under an ISO 9001 certified quality management system
UL Listed to U.S. and Canadian safety standards (File E212775; NRGU, NRGU7)
CE Mark
UKCA Mark
RCM Mark

## General

### Terminal Connections

Rear Screw-Terminal Tightening Torque Terminal Block

| | |
|---|---|
| Minimum: | 9 in-lb (1.1 Nm) |
| Maximum: | 12 in-lb (1.3 Nm) |

Connectorized (for further information, see SEL Application Guide *AG2001-03: Installing and Servicing Connectors for Connectorized® Relays*)

| | |
|---|---|
| Minimum: | 5 in-lb (0.6 Nm) |
| Maximum: | 7 in-lb (0.8 Nm) |

Terminals or stranded copper wire. Ring terminals are recommended. Minimum temperature rating of 105°C.

### AC Current Input

| | |
|---|---|
| 5 A Nominal: | 15 A continuous, 500 A for 1 s, linear to 100 A symmetrical, 1250 A for 1 cycle |
| Burden: | 0.27 VA at 5 A, 2.51 VA at 15 A |
| 1 A Nominal: | 3 A continuous, 100 A for 1 s, linear to 20 A symmetrical, 250 A for 1 cycle |
| Burden: | 0.13 VA at 1 A, 1.31 VA at 3 A |

### AC Voltage Inputs

| | |
|---|---|
| Three-Phase, Four-Wire Connection: | 300 $V_{L-N}$ |
| Continuous: | 300 V (connect any voltage from 0 to 300 Vac)<br>600 V for 10 s |
| Burden: | 0.03 VA at 67 V; 0.06 VA at 120 V; 0.8 VA at 300 V |

### Power Supply

| | |
|---|---|
| Rated: | 125/250 Vdc or Vac |
| Range: | 85–350 Vdc or 85–264 Vac |
| Burden: | <25 W |
| Interruption: | 45 ms at 125 Vdc |
| Ripple: | 100% |
| Rated: | 48/125 Vdc or 125 Vac |
| Range: | 38–200 Vdc or 85–140 Vac |
| Burden: | <25 W |
| Interruption: | 160 ms at 125 Vdc |
| Ripple: | 100% |
| Rated: | 28/48 Vdc |
| Range: | 18–60 Vdc polarity-dependent |
| Burden: | <25 W |
| Interruption: | 110 ms at 48 Vdc |
| Ripple: | 100% |

**Note:** Interruption and Ripple per IEC 60255-11 (IEC 255-11):1979

### Output Contacts

Standard

| | |
|---|---|
| Make: | 30 A |
| Carry: | 6 A continuous carry at 70°C<br>4 A continuous carry at 85°C |
| 1s Rating: | 50 A |
| MOV Protected: | 250 Vac/330 Vdc, 40 J |
| Pickup Time: | Less than 5 ms |
| Dropout Time: | Less than 5 ms, typical |

Breaking Capacity (10,000 Operations):

| | | |
|---|---|---|
| 24 V | 0.75 A | L/R = 40 ms |
| 48 V | 0.50 A | L/R = 40 ms |
| 125 V | 0.30 A | L/R = 40 ms |
| 250 V | 0.20 A | L/R = 40 ms |

Cyclic Capacity (2.5 Cycle/Second):

| | | |
|---|---|---|
| 24 V | 0.75 A | L/R = 40 ms |
| 48 V | 0.50 A | L/R = 40 ms |
| 125 V | 0.30 A | L/R = 40 ms |
| 250 V | 0.20 A | L/R = 40 ms |

High-Current Interrupting Option

| | |
|---|---|
| Make: | 30 A |
| Carry: | 6 A continuous carry at 70°C<br>4 A continuous carry at 85°C |
| 1s Rating: | 50 A |
| MOV Protection: | 330 Vdc, 130 J |
| Pickup Time: | Less than 5 ms |
| Dropout Time: | Less than 8 ms, typical |
| Update Rate: | 1/8 cycle |

Breaking Capacity (10,000 Operations):

| | | |
|---|---|---|
| 24 V | 10.0 A | L/R = 40 ms |
| 48 V | 10.0 A | L/R = 40 ms |
| 125 V | 10.0 A | L/R = 40 ms |
| 250 V | 10.0 A | L/R = 20 ms |

Cyclic Capacity (2.5 Cycle/Second):

| | | |
|---|---|---|
| 24 V | 10.0 A | L/R = 40 ms |
| 48 V | 10.0 A | L/R = 40 ms |
| 125 V | 10.0 A | L/R = 40 ms |
| 250 V | 10.0 A | L/R = 20 ms |

**Note:** Do not use hybrid control outputs to switch ac control signals. These outputs are polarity-dependent.
**Note:** Make per IEEE C37.90-1989; Breaking and Cyclic Capacity per IEC 60255-23 (IEC 255-23):1994.

### Optoisolated Inputs

250 Vdc

| | |
|---|---|
| Pickup: | 200–300 Vdc |
| Dropout: | 150 Vdc |

125 Vdc

| | |
|---|---|
| Pickup: | 105–150 Vdc |
| Dropout: | 75 Vdc |

110 Vdc

| | |
|---|---|
| Pickup: | 88–132 Vdc |
| Dropout: | 66 Vdc |

48 Vdc

| | |
|---|---|
| Pickup: | 38.4–60 Vdc |
| Dropout: | 28.8 Vdc |

24 Vdc

| | |
|---|---|
| Pickup: | 15.0–30 Vdc |

| | |
|---|---|
| Processing Rate: | 1/8 cycle |
| Debounce Time: | Two processing intervals (1/4 cycle) |

**Note:** 24, 48, and 125 Vdc optoisolated inputs draw approximately 4 mA of current, 110 Vdc inputs draw approximately 8 mA of current, and 250 Vdc inputs draw approximately 5 mA of current. All current ratings are at nominal input voltage.

### Routine Dielectric Strength

| | |
|---|---|
| V, I inputs, optoisolated inputs, output contacts: | 2500 Vac for 10 s |
| Power Supply: | 3100 Vdc for 10 s |
| EIA-485 Communications Port: | 2200 Vdc |

### Frequency and Rotation

| | |
|---|---|
| System Frequency: | 50 or 60 Hz |
| Phase Rotation: | ABC or ACB |
| Frequency Tracking: | 40.1–65.0 Hz |

**Note:** $V_A$ required for frequency tracking

### Serial Communications Ports

| | |
|---|---|
| EIA-232: | 1 front and 2 rear |
| EIA-485: | 1 rear, 2100 Vdc isolation |
| Baud Rate: | 300–19200 bps |

### Ethernet Communications Port

Application Protocols

| | |
|---|---|
| FTP to Card: | 1 server session (supports IEC 61850 CID files) |
| Telnet to Card: | 1 server session (supports SEL ASCII) |
| Telnet to Host: | 1 server session (supports SEL ASCII, SEL Compressed ASCII, Fast Meter, and Fast Operate) |
| IEC 61850: | 6 MMS sessions<br>16 incoming GOOSE messages<br>8 outgoing GOOSE messages |
| Web Server: | 3 simultaneous read-only server sessions to host |
| Protocol Stacks: | TCP/IP<br>OSI |

Physical Layer Options (PORT 5 and PORT 6)

| | |
|---|---|
| 10/100BASE-T: | 10/100 Mbps, RJ45 connector |
| 100BASE-FX: | 100 Mbps, LC connector |

Indicators (PORT 5 and PORT 6)

| | |
|---|---|
| Link: | Green LED is on when the link is operational |
| Activity: | Red LED blinks when there is transmit or receive activity |

### Fiber-Optic Ports Characteristics

Port 1 (or 1A, 1B) Ethernet

| | |
|---|---|
| Wavelength: | 1300 nm |
| Optical Connector Type: | LC |
| Fiber Type: | Multimode |
| Link Budget: | 16.1 dB |
| Typical TX Power: | –15.7 dBm |
| RX Min. Sensitivity: | –31.8 dBm |
| Fiber Size: | 62.5/125 µm |
| Approximate Range: | ~6.4 km |
| Data Rate: | 100 Mbps |
| Typical Fiber Attenuation: | –2 dB/km |

### Time-Code Input

Relay accepts demodulated IRIG-B time-code input at Port 1 or 2. Relay is time synchronized to within ±5 ms of time source input.

### Operating Temperature

–40° to +85°C (–40° to +185°F)

### Weight

| | |
|---|---|
| 2U Rack Unit Height: | 6.8 kg (15 lb) |
| 3U Rack Unit Height: | 8 kg (17.75 lb) |

## Type Tests

### Electromagnetic Compatibility Emissions

| | |
|---|---|
| Electromagnetic Emissions: | IEC 60255-25:2000<br>Canada ICES-001 (A) / NMB-001 (A) |

### Electromagnetic Compatibility Immunity

| | |
|---|---|
| Conducted RF Immunity: | ENV 50141:1993, 10 Vrms<br>IEC 61000-4-6: 1996<br>10 Vrms |
| Digital Radio Telephone RF Immunity: | ENV 50204: 1995<br>10 V/m at 900 MHz and 1.89 GHz |
| Electrostatic Discharge Immunity: | IEC 60255-22-2:2008<br>IEC 61000-4-2:2008<br>Level 2, 4, 6, 8 kV contact;<br>Level 2, 4, 8, 15 kV air |
| Fast Transient/Burst Immunity: | IEC 60255-22-4:1992<br>4 kV at 2.5 kHz and 5 kHz<br>IEC 61000-4-4:1995<br>4 kV at 2.5 kHz on power supply;<br>2 kV, 5 kHz on I/O, signal, data, and control lines |
| Generic Immunity: | EN 50082-2:1995 |
| Magnetic Field Immunity: | IEC 61000-4-8:1993<br>800 A/m for 3 s, 100 A/m for 1 min |
| Power Supply Immunity: | IEC 60255-11:1979<br>IEC 61000-4-11:2004 |

| | |
|---|---|
| Radiated Radio Frequency Immunity: | IEC 60255-22-3:1989<br>IEC 61000-4-3:2002<br>ENV 50140:1993<br>10 V/m<br>IEEE C37.90.2-1995<br>35 V/m, no keying test, frequency element accurate to 0.1 Hz |
| Surge Immunity: | IEC 60255-22-5:2002<br>IEC 61000-4-5:2005<br>1 kV Line-to-Line;<br>2 kV Line-to-Earth |
| Surge Withstand Capability: | IEC 60255-22-1:1988<br>2.5 kV peak common mode;<br>2.5 kV peak differential mode<br>IEEE C37.90.1-1989<br>3000 V oscillatory;<br>5000 V fast transient |

### Environmental

| | |
|---|---|
| Cold: | IEC 60068-2-1:1990 + A1:1993 + A2:1994<br>Test Ad, 16 hours at –40ºC |
| Damp Heat, Cycle: | IEC 60068-2-30:1980<br>Test Db, 25° to 55ºC, 6 cycles, 95% humidity |
| Dry Heat: | IEC 60068-2-2:1974 + A1:1993 + A2:1994<br>Test Bd, 16 hours at +85ºC |
| IP Code: | IEC 60529:1989<br>IP30 |
| Vibration: | IEC 60255-21-1:1988<br>Class 1–Endurance<br>Class 2–Response |
| Shock and Bump: | IEC 60255-21-2:1988<br>Class 1–Shock Withstand, Bump<br>Class 2–Shock Response |
| Seismic: | IEC 60255-21-3:1993<br>Class 2 |

### Safety

| | |
|---|---|
| Dielectric Strength: | IEC 60255-5:1977<br>IEEE C37.90-1989<br>2500 Vac on analogs, contact inputs, and contact outputs<br>3100 Vdc on power supply<br>2200 Vdc on EIA-485 comm. port |
| Impulse: | IEC 60255-5:1977<br>0.5 J, 5000 V |

## Sampling Specifications

64 samples per power system cycle

## Processing Specifications

Differential elements, optoisolated inputs, and contact outputs are processed at 1/8-cycle.
Overcurrent elements are processed at 1/8-cycle.

## Metering Accuracy

5 A Model Accuracy Range

| | |
|---|---|
| Phase Currents: | ±1.5% ±0.10 A and ±1.5° |
| Sequence Currents: | ±3.0% ±0.10 A and ±2.0° |
| Differential Quantities: | ±5.0% ±0.10 A |
| 2nd and 5th Harmonic: | ±5.0% ±0.10 A |
| Current Harmonics: | ±5.0% ±0.10 A |

1 A Model Accuracy Range

| | |
|---|---|
| Phase Currents: | ±1.5% ±0.02 A and ±1.5° |
| Sequence Currents: | ±3.0% ±0.02 A and ±2.0° |
| Differential Quantities: | ±5.0% ±0.02 A |
| 2nd and 5th Harmonic: | ±5.0% ±0.02 A |
| Current Harmonics: | ±5.0% ±0.02 A |
| Phase Voltages: | ±1.5% ±0.10 V and ±1.5° |
| Sequence Voltages: | ±3.0% ±0.10 V and ±2.0° |
| Power Quantities: | ±3.0% and ±3.0° for balanced currents and voltages |

## Station DC Battery Monitor

| | |
|---|---|
| Pickup Range: | 20–300 Vdc, 1 Vdc steps |
| Pickup Accuracy: | ±2.0% ±2 Vdc |

## Differential Element

| | |
|---|---|
| Unrestrained Pickup Range: | 1–20 in per unit of tap |
| Restrained Pickup Range: | 0.1–1.0 in per unit of tap |
| Pickup Accuracy | |
| 5 A Model: | ±5% ±0.10 A |
| 1 A Model: | ±5% ±0.02 A |
| Unrestrained Element Pickup Time (Min/Typ/Max): | 0.8/1.0/1.9 cycles |
| Restrained Element (with harmonic blocking) Pickup Time (Min/Typ/Max): | 1.5/1.6/2.2 cycles |
| Restrained Element (with harmonic restraint) Pickup Time (Min/Typ/Max): | 2.62/2.72/2.86 cycles |

## Harmonic Element

| | |
|---|---|
| Pickup Range (% of fundamental): | 5–100% |
| Pickup Accuracy (A secondary) | |
| 5 A Model: | ±5% ±0.10 A |
| 1A Model: | ±5% ±0.02 A |
| Time Delay Accuracy: | ±0.1% ±0.25 cycle |

## Instantaneous/Definite-Time Overcurrent Elements (Winding)

| | |
|---|---|
| Pickup Accuracy (A secondary) | |
| 5 A Model: | 0.25–100.00 A |
| 1A Model: | 0.05–20.00 A |
| 5 A Model Pickup Accuracy (A secondary) | |
| Steady State: | ±3% ±0.10 A |
| Transient: | ±5% ±0.10 A |
| Transient for 50Q: | ±6% ±0.10 A |
| 1 A Model Pickup Accuracy (A secondary) | |
| Steady State: | ±3% ±0.02 A |
| Transient: | ±5% ±0.02 A |
| Transient for 50Q: | ±6% ±0.02 A |

| | |
|---|---|
| Pickup Time (Typ/Max): | 0.75/1.20 cycles |
| Time Delay Range: | 0–16000 cycles |
| Time Delay Accuracy: | ±0.1% ±0.25 cycle |

## Time-Overcurrent Elements (Winding and Combined Current)

| | |
|---|---|
| Pickup Accuracy (A secondary) | |
| 5 A Model: | 0.50–16.00 A |
| 1A Model: | 0.10–3.20 A |
| 5 A Model Pickup Accuracy (A secondary) | |
| Steady State: | ±3% ±0.10 A |
| Transient: | ±5% ±0.10 A |
| Transient for 50Q: | ±6% ±0.10 A |
| 1 A Model Pickup Accuracy (A secondary) | |
| Steady State: | ±3% ±0.02 A |
| Transient: | ±5% ±0.02 A |
| Transient for 50Q: | ±6% ±0.02 A |
| Curve | U1 = U.S. Moderately Inverse<br>U2 = U.S. Inverse<br>U3 = U.S. Very Inverse<br>U4 = U.S. Extremely Inverse<br>U5 = U.S. Short-Time Inverse<br>C1 = IEC Class A (Standard Inverse)<br>C2 = IEC Class B (Very Inverse)<br>C3 = IEC Class C (Extremely Inverse)<br>C4 = IEC Long-Time Inverse<br>C5 = IEC Short-Time Inverse |
| Time-Dial Range | |
| U.S. Curves: | 0.50–15.00 |
| IEC Curves: | 0.05–1.00 |
| Timing Accuracy: | ±4% ±1.5 cycles for current between 2 and 30 multiples of pickup. Curves operate on definite time for current greater than 30 multiples of pickup. |

**Note:** For the combined current elements, 30 multiples of pickup is the sum of the currents in the two windings.

| | |
|---|---|
| Reset Characteristics: | Induction-disk reset emulation or 1 cycle linear reset |

## Over-/Undervoltage Elements

| | |
|---|---|
| Pickup Range: | 0.00–300.00 V, 0.01 V steps |
| Steady-State Pickup Accuracy: | ±5% ±2 V |
| Transient Overreach: | ±5% of pickup |

## Frequency Element

| | |
|---|---|
| Pickup Range: | 40.10–65.00 Hz, 0.01 Hz steps |
| Steady-State plus Transient Overshoot: | ±0.01 Hz |
| Time Delay: | 0.04–300.00 s, 0.01 s steps |
| Timer Accuracy: | ±0.1% ±0.0042 s |
| Frequency Change Caused by Temperature: | $f_{sys} = f_{sys} \cdot (0.04 \cdot 10^{-6})\ (T - 25°C)^2$ where T = temperature of relay via **STATUS** command |

## Volts/Hertz Element

### Definite-Time Element

| | |
|---|---|
| Pickup Range: | 100–200% |
| Steady-State Pickup Accuracy: | ±1% of set point |
| Pickup Time: | 25 ms at 60 Hz (Max) |
| Time-Delay Range: | 0.00–400.00 s |
| Time-Delay Accuracy: | ±0.1% ±4.2 ms at 60 Hz |
| Reset Time Range: | 0.00–400.00 s |

### Inverse-Time Element

| | |
|---|---|
| Pickup Range: | 100–200% |
| Steady-State Pickup Accuracy: | ±1% of set point |
| Pickup Time: | 25 ms at 60 Hz (Max) |
| Curve: | 0.5, 1.0, or 2.0 |
| Factor: | 0.1–10.0 s |
| Timing Accuracy: | ±4% ±25 ms @ 60 Hz, for V/Hz above 1.05 multiples (Curve 0.5 and 1.0) or 1.10 multiples (Curve 2.0) of pickup setting, and for operating times greater than 4 s |
| Reset Time Range: | 0.00–400.00 s |
| Composite-Time Element: | Combination of Definite-Time and Inverse-Time specifications |

### User-Definable Curve Element

| | |
|---|---|
| Pickup Range: | 100–200% |
| Steady-State Pickup Accuracy: | ±1% of set point |
| Pickup Time: | 25 ms at 60 Hz (Max) |
| Reset Time Range: | 0.00–400.00 s |

# Section 2

# Installation

## Overview

Design your installation using the mounting and connection information in this section. Options include rack or panel mounting and terminal block or plug-in connector (Connectorized®) wiring. This section also includes information on configuring the relay for your application.

## Relay Mounting

### Rack Mount

We offer the SEL-387E Relay in a rack-mount version that bolts easily into a standard 19-inch rack (see *Figure 2.1*). From the front of the relay, insert four rack screws (two on each side) through the holes on the relay mounting flanges.

Reverse the relay mounting flanges to cause the relay to project 69.9 mm (2.75 in) 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

We also offer the SEL-387E in a panel-mount version for a clean look. Panel-mount relays have sculpted front-panel molding that covers all installation holes (see *Figure 2.1*). Cut your panel and drill mounting holes according to the dimensions in *Figure 2.1*. Insert the relay into the cutout, aligning four 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 69.9 mm (2.75 in) 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. Projection panel-mount is not available in vertically mounted relays.

# Dimensions and Cutout

| DIMENSION | MAIN BOARD ONLY (2U) | ONE I/O BOARD (3U) |
|---|---|---|
| A | 3.47 (88.1) | 5.22 (132.6) |
| B | 3.00 (76.2) | 2.25 (57.2) |
| C | 4.90 (124.5) | 6.65 (168.9) |
| D | 3.60 (91.4) | 5.35 (135.9) |

* ADD 0.65 (16.5) FOR CONNECTORIZED RELAYS

**Figure 2.1 Relay Dimensions and Panel-Mount Cutout**

**Figure 2.2 Front-Panel Drawings—Models 0387Ex0xxxH and 0387Ex1xxxH**

**Figure 2.3 Front-Panel Drawings—Models 0387Ex0xxx3 and 0387Ex1xxx3**

**Figure 2.4 Front-Panel Drawings—Vertical Mount Models 0387Ex1xxx4 (Panel) and 0387Ex1xxxV (Rack)**

# Rear-Panel Connections

We provide two options for secure connection of wiring to the relay rear panel. One of these is the conventional terminal block, in which you use size #6-32 screws to secure rear-panel wiring. The other option uses plug-in (Connectorized) connections that offer robust connections while minimizing installation and replacement time.

Connectorized rear-panel connections reduce repair time dramatically in the unlikely event that a relay should fail. These connections greatly simplify routine bench testing; connecting and disconnecting rear-panel wiring takes only a few minutes.

Connectorized relays use a current shorting connector for current inputs, a plug-in terminal block that provides maximum wiring flexibility for inputs and outputs, and a quick disconnect voltage rated connector for voltage inputs. The manufacturers of these connectors have tested them thoroughly, and many industry applications have proven the performance of these connectors. In addition, we have tested these connectors thoroughly to ensure that they conform to our standards for protective relay applications.

## Terminal Block

Make terminal block connections with size #6-32 screws using a Phillips or slotted screwdriver. You may request locking screws from the factory. Refer to *Figure 2.5* and *Figure 2.6* to make all terminal block connections.

## Connectorized

To use the Connectorized version of the SEL-387E, ask your SEL sales or customer service representative for the appropriate model option table and order wiring harness kit WA0387E0Y*xxx*A, where *x* designates wire sizes and length. You can find the model option table at selinc.com. Refer to *Figure 2.7* to make all Connectorized connections.

**Figure 2.5 Rear-Panel Drawings—Models 0387Ex0xxxxX and 0387Ex1xxxx2**

**Figure 2.6 Rear-Panel Drawings—Models 0387Ex1xxxx4 and 0387Ex1xxxx6**

**Figure 2.7 Rear-Panel Drawings—Models 0387ExYxxxx2 and 0387ExYxxxx6**

**Figure 2.8 SEL-387E Relay 3U Typical Rear-Panel Drawings Showing 10/100BASE-T and 100BASE-FX Ethernet**

### Prewired Connectors

The wiring harness kit contains several prewired connectors for relay current inputs, power, and ground connections. These prewired connectors include the following:

- (3) six-position CT shorting connectors for current inputs IAW1, IBW1, and ICW1; IAW2, IBW2, and ICW2; and IAW3, IBW3, and ICW3. For these connectors select a wire size from AWG 16 to 10.
- (1) four-position connector for PT wiring. Plug the connector into terminals **Z19** through **Z22**. The connector is keyed uniquely and locks in place upon insertion.
- (1) connector for **POWER** inputs (+ and –). For these connectors select a wire size from AWG 18 to 14.
- (1) spade connector for chassis **GROUND** connection.

### Unwired Connectors

With the wiring harness kit are the following unwired connectors for the relay optoisolated inputs, output contacts, and EIA-485 communications port connections:

**NOTE:** These unwired connectors accept wire sizes AWG 24 to 12. To install these connectors, you will need a wire stripping tool and small, slotted-tip screwdriver. Strip 8 mm (0.31 in) insulation from the wires and install the wires in the connectors. Secure each connector to the relay chassis with the screws located on each connector end.

- (2) eight-position female plug-in connectors for output contacts OUT101 through OUT104 and OUT105 through ALARM.
- (2) six-position female plug-in connectors for optoisolated inputs IN101 through IN103 and IN104 through IN106.
- (1) eight-position female plug-in connector for the EIA-485 serial port connection Port 1 and the demodulated IRIG-B input. Alternatively, you can bring IRIG-B through Port 2.
- (4) six-position female plug-in connectors for interface board output contacts OUT201 through OUT203, OUT204 through OUT206, OUT207 through OUT209, and OUT210 through OUT212.
- (2) eight-position female plug-in connectors for interface board optoisolated inputs IN201 through IN204 and IN205 through IN208.

## Connections

### Frame Ground

For safety and performance, ground the relay chassis at terminal **GND** (Z27). Connectorized relays provide a 0.250 inch by 0.023 inch spade connector for this connection. If the tab on the chassis is removed, the chassis ground connection can be made with the size #6-32 screw. The grounding terminal of either relay version connects directly to relay chassis ground.

## Power Supply

Connect rear-panel terminals marked **+** (Z25) and **–** (Z26) to a source of control voltage. Control power passes through these terminals to a fuse(s) and to the switching power supply. The control power circuitry is isolated from the frame ground. The 24/48 V power supply is polarity sensitive. Refer to *Section 1: Introduction and Specifications* for power supply voltage ranges.

## Current Transformer Inputs

**⚠WARNING**
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

**NOTE:** When installing CT shorting connectors, ensure that you secure each connector to the relay chassis with the screws at each connector end. When removing a CT shorting connector, pull it straight away from the relay rear panel. Removing a shorting connector causes internal mechanisms within the connector to individually short out each power system current transformer.

Connect current inputs to the three sets of current input terminals. Note that the CT shorting connectors providing current connections to Connectorized relays install in only one orientation. Note also that the current input terminals on both terminal block and Connectorized relays have a mark at one terminal per phase to indicate polarity. Each current input is independent of the other two inputs. Current inputs are designated IAW1, IBW1, ICW1; IAW2, IBW2, ICW2; and IAW3, IBW3, ICW3.

## Potential Transformer Inputs

Any of the single-phase voltage inputs (i.e., VA-N, VB-N, or VC-N) can be connected to voltages as high as 300 V RMS continuous. *Figure 2.10* shows an example of wye-connected voltages. Frequency is determined from the voltages connected to terminal VA-N. Volts/hertz is determined from the largest per-winding volts/hertz measurement (see *Volts/Hertz Element on page 3.62*).

Note the signal labels (**VA**, **VB**, **VC**, **N**) on terminals Z19 through Z22. *Figure 2.10* shows the internal connection for terminals VA, VB, VC, and VN.

## Optoisolated Inputs

Connect control input wiring to the six standard inputs IN101–IN106 and to any of the interface board optoisolated inputs IN201–IN208 you need for your application.

All control inputs are dry optoisolated inputs and are not polarity-dependent. Specify a nominal rated control voltage of 48, 110, 125, or 250 Vdc for level-sensitive and 24 Vdc for nonlevel-sensitive when ordering. To assert an input, apply nominal rated control voltage to the terminals assigned to that input. A terminal pair is brought out for each input. Refer to *Specifications on page 1.5* for optoisolated input ratings. There are no internal connections between inputs. ON and OFF values normally are within one volt of each other, in the indicated range.

## Output Contacts

Connect output wiring to the SEL-387E main board eight standard independent output contacts, OUT101 through OUT107 and ALARM. Standard independent dry output contacts are not polarity-dependent; the left side of *Figure 2.9* shows these contacts as they would appear on a terminal block version.

**Figure 2.9 Standard Independent Output Contact Representation**

Connect output wiring to any of the additional output contacts OUT201–OUT212 you need for your application. On the additional interface board, you have the option of either standard or high-current interrupting contacts. *High-current interrupting contacts are polarity-dependent.* A plus polarity mark next to the terminal requiring positive dc voltage identifies these contacts on a relay rear panel. The right side of *Figure 2.9* shows this polarity mark for high-current interrupting contacts. Ensure correct polarity; reversed polarity causes a short circuit to appear across the contact terminals.

## Communications Port

Refer to *Table 2.1* for a list of cables that you can purchase from SEL for various communication applications. Refer to *Section 7: Communications* for detailed cable diagrams for selected cables.

**NOTE:** Listing of devices not manufactured by SEL is for the convenience of our customers. SEL does not specifically endorse or recommend such products nor does SEL guarantee proper operation of those products, or the correctness of connections, over which SEL has no control.

The relay rear panel provides pin definitions for Ports 1, 2, 3, and 4. Refer also to *Section 7: Communications* for more serial port details. Port 1 is an EIA-485 protocol connection on the rear of the relay. Port 1 accepts a pluggable terminal block that supports wire sizes from 24 AWG to as large as 12 AWG. The connector comes with the relay. Ports 2, 3, and 4 are EIA-232 protocol connections with Ports 2 and 3 on the rear of the relay and Port 4 on the front of the relay. These female connectors are 9-pin, D-subminiature connectors. You can use any combination of these ports or all of them simultaneously for relay communication.

For example, to connect the SEL-387E Ports 2, 3, or 4 to the 9-pin male connector on a laptop computer, order cable number SEL-C234A and specify the length needed. Standard length is 2.44 m (8 ft). To connect the SEL-387E Port 2 to the SEL-2032, SEL-2030, or SEL-2020 Communications Processor that supplies the communication link and the time synchronization signal, order cable number SEL-C273A and specify the length needed. For connecting devices at more than 30.48 m (100 ft), fiber-optic transceivers are available. The SEL-2800 family of transceivers provides fiber-optic links between devices for electrical isolation and long-distance signal transmission. Call the factory for further information on these products.

**Table 2.1 SEL-387E Communication Cable Numbers** (Sheet 1 of 2)

| SEL-387E Port # | Connect to Device (gender refers to the device) | SEL Cable # |
|---|---|---|
| 2, 3, 4 | PC, 25-Pin Male (DTE) | SEL-C227A |
| 2, 3, 4 | PC, 9-Pin Male (DTE) | SEL-C234A |
| 2, 3 | SEL 2032, SEL-2030, or SEL-2020 without IRIG-B | SEL-C272A |
| 2 | SEL 2032, SEL-2030, or SEL-2020 with IRIG-B | SEL-C273A |
| 2 | SEL IDM, Ports 2 through 11 | Requires an SEL-C254 and SEL-C257 cable |

**Table 2.1 SEL-387E Communication Cable Numbers** (Sheet 2 of 2)

| SEL-387E Port # | Connect to Device (gender refers to the device) | SEL Cable # |
|---|---|---|
| 2, 3 | Modem, 5 Vdc Powered (pin 10) | SEL-C220[a] |
| 2, 3 | Standard Modem, 25-Pin Female (DCE) | SEL-C222 |

[a] The 5 Vdc serial port jumper must be installed to power the modem using an SEL-C220 cable (see EIA-232 Serial Port Jumpers on page 2.19).

### Clock Synchronization, IRIG-B

Refer to *Table 2.1* for a list of cables that you can purchase from SEL for various time-synchronizing applications.

The SEL-387E accepts a demodulated IRIG-B format signal for synchronizing an internal clock to some external source such as the SEL-2032, SEL-2030, or SEL-2020 Communications Processor, SEL-IDM, or satellite time clock. Connect the IRIG-B source to the relay through the connectors for serial Ports 1 or 2. Refer to the port pin definition of each port for the appropriate connection.

## Typical AC/DC Connection Diagrams

*Figure 2.10* and *Figure 2.14* represent the ac and dc connections for a typical three-winding transformer application. The transformer is an autotransformer with a delta tertiary whose terminals also have been brought out through bushings and are included in the differential zone of protection. Referring to *Figure 2.10*, the current transformers for all windings are wye-connected, with their polarity marks facing away from the transformer. Their outputs are taken to the polarity ends of the relay current inputs, with the nonpolarity ends of the inputs connected to the CT neutral and ground. A single safety-ground point should be used, as shown. If current transformers are delta-connected, the nonpolarity ends of the relay current inputs must be wired together and should be connected to the common ground point/neutral.

This transformer example is used later for calculating relay settings; see *Section 6: Settings*. This example forms the basis for most of the factory default settings stored in the relay before shipment.

**Figure 2.10 Example AC Connections (Three-Winding Transformer; Wye-Connected Voltages)**

**Figure 2.11 Example AC Connections (Three-Winding Transformer; Open-Delta-Connected Voltages)**

**Figure 2.12 Example AC Connections (Two-Winding Transformer; REF With LV Compensated Earthing; Wye-Connected Voltages)**

**Figure 2.13 Example AC Connections (Two-Winding Transformer; HV REF; Wye-Connected Voltages)**

In the dc connection diagram, *Figure 2.14*, tripping control of the three power circuit breakers is illustrated. This includes three 52a input contacts to define breaker status (open or closed) and a separate 86 lockout relay for group tripping on a differential operation. Individual breaker trips occur for overcurrent operation.

ALARM and annunciation functions are also shown. ALARM is factory wired as a Form B contact, so that it closes under conditions of complete relay power failure. If breaker closing control were desired, the Trip Annunciator contact (OUT105) would be one of the three separate output contacts used for connection to the breaker closing coils. That is, for this case the breaker trip and close functions together would require all seven standard output contacts.

**Figure 2.14 Example DC Connections (Basic Version)**

# Circuit Board Configuration

In this section we describe (1) how to remove the relay circuit boards so you can change circuit board jumpers or replace the clock battery and (2) how to replace the circuit boards in the relay.

## Accessing the Relay Circuit Boards

Step 1. De-energize the relay by removing the connections to rear-panel terminals **+** (Z25) and **–** (Z26). Accomplish this easily on Connectorized relays by removing the connector at rear-panel terminals **+** (Z25) and **–** (Z26).

Step 2. Remove any cables connected to serial ports on the front and rear panels.

Step 3. Loosen the six front-panel screws (they remain attached to the front panel) and remove the relay front panel.

Step 4. Each circuit board corresponds to a row of rear-panel terminal blocks or connectors and is affixed to a drawout tray. Identify which drawout tray needs to be removed. An SEL-387E model 0387E*x*0 has only a main board. A Model 0387E*x*1 or 0387E*x*Y relay has an extra interface board below the main board.

**⚠CAUTION**
The relay contains devices sensitive to electrostatic discharge (ESD). When working on the relay with the front or top cover removed, work surfaces and personnel must be properly grounded or equipment damage may result.

Step 5. Disconnect circuit board cables as necessary so you can remove the board and drawout tray you want. To remove the extra interface board, first remove the main board. Remove ribbon cables by pushing the extraction ears away from the connector. Remove the six-conductor power cable by grasping the wires near the connector and pulling away from the circuit board.

Step 6. Grasp the drawout assembly of the board and pull the assembly from the relay chassis.

Step 7. Locate the jumper(s) or battery to be changed. Make the desired changes. Note that the output contact jumpers are soldered in place.

Step 8. When finished, slide the drawout assembly into the relay chassis. Reconnect the cables you removed in *Step 5*. Replace the relay front-panel cover.

Step 9. Replace any cables previously connected to serial ports.

Step 10. Re-energize the relay by reconnecting wiring to rear-panel terminals **+** (Z25) and **–** (Z26). On Connectorized versions, replace the power connector at rear-panel terminals **+** (Z25) and **–** (Z26).

# Main Board

## Output Contact Jumpers

Refer to *Figure 2.15* to see the layout of the main board and locate the solder jumpers to the rear of the output contacts. Select the contact type for the output contacts. With a jumper in the A position, the corresponding output contact is an “a” output contact. An “a” output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. With a jumper in the B position, the corresponding output contact is a “b” output contact. A “b” output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized. These jumpers are soldered in place but may be changed in the field.

Note that the ALARM output contact is a “b” contact and that the other output contacts are all “a” contacts. This is the normal configuration of these jumpers in a standard relay shipment. The additional interface boards have slightly different layout locations for the jumpers relative to the corresponding output contacts.

## Second ALARM Contact Jumper

Note the locations of main board jumper **JMP23** and output contact OUT107 in *Figure 2.15*, and refer to *Table 2.2* to understand the relationship between the jumper and output contact. The jumper **JMP23** controls the operation of output contact OUT107. **JMP23** provides the option of a second alarm output contact by changing the signal that drives output contact OUT107.

**Table 2.2 SEL-387E Second ALARM Contact Jumper Position**

| JMP23 Position | | Output Contact OUT107 Operation |
|---|---|---|
| | Bottom (Pins 1 & 2) | Second Alarm output contact (operated by alarm logic/circuitry). Relay Word bit OUT107 has no effect on output contact OUT107 when jumper **JMP23** is in this position. |
| | Top (Pins 2 & 3) | Regular output contact OUT107 (operated by Relay Word bit OUT107). Jumper **JMP23** comes in this position in a standard relay shipment. |
| | Neither | Disable output contact OUT107. If **JMP23** is not installed, output contact OUT107 is not functional and will remain in its de-energized state. |

If jumper **JMP23** is installed on the two bottom pins and both output contacts OUT107 and ALARM are the same output contact type (a or b), they will be in the same state (closed or open). If jumper **JMP23** is installed on the two bottom pins and output contacts OUT107 and ALARM are different output contact types (one is an "a" and one is a "b"), they will be in opposite states (one is closed and one is open).

## Password and Breaker Jumpers

Refer to *Figure 2.15* and note the password and breaker jumpers identified as JMP6. To change these jumpers, remove the relay front panel and main board according to the steps outlined in *Accessing the Relay Circuit Boards on page 2.17*.

Put password jumper **JMP6A** (left-most jumper) in place to disable serial port and front-panel password protection. With the jumper removed, password security is enabled. View or set the passwords with the **PASSWORD** command (see *Section 7: Communications*).

Put breaker jumper **JMP6B** in place to enable the serial port commands **OPEN**, **CLOSE**, and **PULSE**. The relay ignores these commands while you remove **JMP6B**. Use these commands primarily to assert output contacts for circuit breaker control or testing purposes (see *Section 7: Communications*).

Do not install jumpers in position **JMP6C** or **JMP6D**. If a jumper is in position **JMP6D** and you lose dc power to the relay, the relay will turn on in SELBOOT when power is restored. The front panel will show `SELBoot` and then a warning to remove the jumper when you attempt serial port communication.

## EIA-232 Serial Port Jumpers

Refer to *Figure 2.15*. Jumpers **JMP1** and **JMP2** are toward the rear of the main board, near the rear-panel EIA-232 serial communications ports. These jumpers connect or disconnect +5 Vdc to Pin 1 on the EIA-232 serial communications Ports 2 and 3. SEL normally ships relays with these jumpers removed (out of place) so that the +5 Vdc is not connected to Pin 1 on the EIA-232 serial communications ports. **JMP1** controls the +5 Vdc for Port 3, and **JMP2** controls the +5 Vdc for Port 2 (see *Table 7.1*). If these jumpers are installed, be certain not to short the power supply with an incorrect communication cable. The +5 Vdc connections supply current as high as 1 A.

Solder jumpers **JMP3** and **JMP4** allow connection of an IRIG-B source to Port 2. Removal of **JMP3** and **JMP4** will cause Port 2 to no longer accept an IRIG-B signal. The Port 1 connector always accepts an IRIG-B signal. Port 2 and Port 1 IRIG-B circuits are in parallel; therefore, connect only one IRIG-B source at a time.

### Condition of Acceptability for North American Product Safety Compliance

To meet product safety compliance for end-use applications in North America, use an external fuse rated 3 A or less in-line with the +5 Vdc source on pin 1. SEL fiber-optic transceivers include a fuse that meets this requirement.

## Other Jumpers

Additional main board jumpers **JMP5A** through **JMP5D**, located near **JMP6**, are not functional in the SEL-387E. Originally they were installed for developmental testing purposes but are not used in the production version of the relay. Jumpers must not be installed in any **JMP5** position.

## Low-Level Analog Interface

SEL designed the SEL-387E main board to accept low-level analog signals as an optional testing method. *Section 10: Testing and Troubleshooting* contains a more detailed discussion of the patented Low-Level Test Interface; and *Figure 10.1* shows the pin configuration. The SEL-RTS (Relay Test System) interfaces with the relay through a ribbon cable connection on the main board. With the front panel removed, the low-level interface connector is on the front edge at the far right of the top board (see *Figure 2.15*). Remove the ribbon cable from the main board (top board), and connect the SEL-RTS ribbon cable to the main board. This removes the connection from the transformers in the bottom of the relay chassis and connects the SEL-RTS system for low-level testing. Refer to the SEL-RTS Instruction Manual for system operation. For normal operation, be sure to properly reinstall the ribbon cable that connects the transformers in the bottom of the chassis to the main board.

## Clock Battery

Refer to *Figure 2.15* for clock battery B1 location. This lithium battery powers the relay clock (date and time) if the external power source is lost or removed. The battery is a 3 V lithium coin cell. At room temperature (25°C) the battery will operate nominally for 10 years at rated load.

Because little self-discharge of the battery occurs when an external source powers the relay, battery life can extend well beyond the nominal 10 years. The battery cannot be recharged.

**⚠CAUTION**
There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. See Owner's Manual for safety instructions. The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not recharge, disassemble, heat above 100°C or incinerate. Dispose of used batteries according to the manufacturer's instructions. Keep battery out of reach of children.

If the relay does not maintain the date and time after power loss, replace the battery. Follow the instructions previously described in *Accessing the Relay Circuit Boards on page 2.17* to remove the relay main board.

Remove the battery from beneath the clip and install a new one. The positive side (+) of the battery faces up. Reassemble the relay as described in *Accessing the Relay Circuit Boards*. Set the relay date and time via serial communications port or front panel (see *Section 7: Communications* or *Section 8: Front-Panel Operation*).

## Additional Interface Board

We offer versions of the SEL-387E in a taller case size (3U) to accommodate one additional circuit board. The additional board mounts below the main board and above the analog input (transformer) board.

Three interface board types are available. Interface Board 2 has 12 standard output contacts and 8 optoisolated inputs. Interface Board 4 has 4 standard output contacts and 16 optoisolated inputs. Interface Board 6 has 12 hybrid high-current interrupting output contacts and 8 optoisolated inputs. These latter contacts can interrupt as much as 10 A of dc current, as indicated in the *Specifications on page 1.5*.

### Jumpers

**NOTE:** The level-sensitive optoisolated inputs on both interface boards have no jumpers. You must specify control voltage at the time of order.

As on the main board, the output contacts of Interface Boards 2 and 6 have solder jumpers for configuring the output as either a Form A (normally open) or Form B (normally closed) contact. When removing the board to change jumpers, follow the procedure outlined in *Accessing the Relay Circuit Boards*. Take precautions related to protection of components from damage due to electrostatic discharge (ESD).

### Board Layout

*Figure 2.16*, *Figure 2.17*, and *Figure 2.18* show the layout of Interface Board 2, Interface Board 4, and Interface Board 6 (conventional terminal block), respectively. *Figure 2.19* and *Figure 2.20* show the layout of Interface Board 2 and Interface Board 6 (Connectorized), respectively. The only difference between the two is the row of electronic components that form the interruption circuits of the high-current interrupting contacts on Interface Board 6.

**Figure 2.15 Main Board Jumpers, Connections, and Battery Locations**

| Output Contacts K1 – K12 | |
|---|---|
| Solder Jumper Position | Operation |
| A | Contact closes when asserted |
| B | Contact opens when asserted |

**Figure 2.16 Interface Board 2 Component Layout (Conventional Terminal Block)**

**Figure 2.17 Interface Board 4 Component Layout (Conventional Terminal Block)**

**Figure 2.18 Interface Board 6 Component Layout (Conventional Terminal Block)**

| Output Contacts K1 – K4 | |
|---|---|
| Solder Jumper Position | |
| A | Contact closes when asserted |
| B | Contact opens when asserted |

**Figure 2.19 Interface Board 2 Component Layout (Connectorized)**

**Figure 2.20 Interface Board 6 Component Layout (Connectorized)**

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# Section 3

# Protection Functions

## Introduction

This section describes general applications and operating characteristics for the current differential, restricted earth fault (REF), overcurrent, over- and undervoltage, frequency, and volts/hertz protection elements. The section also contains application guidelines for the differential and overcurrent elements and setting calculation information for the differential elements and restricted earth fault elements.

## Differential Element

### Application Description

Protect your apparatus with dual-slope percentage differential protection. Percentage differential protection provides more sensitive and secure protection than traditional differential protection; the dual-slope characteristic compensates for CT ratio mismatches, CT ratio errors, CT saturation, and errors because of tap changing.

The relay provides a choice between harmonic blocking and harmonic restraint, both providing stability during transformer inrush conditions. Even-numbered harmonics (second and fourth), augmented by dc blocking provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions.

### Operating Characteristic

The SEL-387E Relay has three differential elements (87R-1, 87R-2, and 87R-3). These elements employ Operate (IOP) and Restraint (IRT) quantities that the relay calculates from the winding input currents. *Figure 3.1* shows the relay characteristic. You can set the characteristic as either a single-slope, percentage-differential characteristic or as a dual-slope, variable-percentage differential characteristic. Tripping occurs if the Operate quantity is greater than the curve value for the particular restraint quantity. A minimum pickup level for the Operate quantity must also be satisfied. The four settings that define the characteristic are:

O87P = minimum IOP level required for operation

SLP1 = initial slope, beginning at the origin and intersecting O87P at IRT = O87P • 100/SLP1

IRS1 = limit of IRT for SLP1 operation; intersection where SLP2 begins

SLP2 = second slope, if used; must be greater than or equal to SLP1

By careful selection of these settings, the user can duplicate closely the characteristics of existing differential relays that have been in use for many years.

**Figure 3.1 Percentage Restraint Differential Characteristic**

*Figure 3.2*, *Figure 3.3*, and *Figure 3.4* illustrate how input currents are acquired and used in the unrestrained and restrained differential elements. Data acquisition, filtering, tap scaling, and transformer and CT connection compensation for Winding 1 are shown in *Figure 3.2*.

Four digital band-pass filters extract the fundamental, second, fourth, and fifth (not shown) harmonics of the input currents. A dc filter (not shown) forms one-cycle sums of the positive and negative values.

Using the transformer MVA rating as a common reference point, TAP scaling converts all secondary currents entering the relay from the three windings to per-unit values, thus changing the ampere values into dimensionless multiples of TAP. Throughout the text, the term "TAP" refers to the per-unit value common to all three windings, whereas "TAP*n*" refers to the ampere value of a particular winding(s); TAPmin and TAPmax refer to the least and greatest of the three TAP*n* values. This method ensures that, for full-load through-current conditions, all incoming current multiples of tap sum to 1.0 and all outgoing current multiples of tap sum to –1.0, with a reference direction into the transformer windings.

Transformer and CT connection compensation adjusts the sets of three-phase currents for the phase angle and phase interaction effects introduced by the winding connection of the transformer and CTs. Settings W1CTC through W3CTC determine the mathematical corrections to the three-phase currents for Winding 1 through Winding 3, respectively. CTC1 is shown in *Figure 3.2* as the phase angle and sequence quantity adjustment for Winding 1.

I1W1C1, I2W1C1, and I3W1C1 are the fundamental frequency A-phase, B-phase, and C-phase compensated currents for Winding 1. Similarly, I1W1C2, I2W1C2, and I3W1C2 are the second-harmonic compensated currents for Winding 1. The dc, fourth-harmonic, and fifth-harmonic compensated currents use similar names. The I1 compensated currents are used with Differential Element 87-1, I2 with Element 87-2, and I3 with Element 87-3.

**Figure 3.2 Winding 1 Compensated Currents**

*Figure 3.3* illustrates how the IOP1 (operate), IRT1 (restraint), IHRT1 (harmonic restraint), I1HB2 (second harmonic), and I1HB4 (fourth harmonic) quantities are calculated for the 87-1 element. IOP1 is generated by summing the winding currents in a phasor addition. IRT1 is generated by summing the magnitudes of the winding currents in a simple scalar addition and dividing by two. The 87-2 and 87-3 quantities are calculated in a similar manner.

For each restraint element (87R-1, 87R-2, 87R-3), the quantities are summed as phasors and the magnitude becomes the Operate quantity (IOP*n*). For a through-current condition, IOP*n* should calculate to about 1 + (–1) = 0, at rated load. Calculation of the Restraint quantity (IRT*n*) occurs through a summation of all current magnitudes and then division by two. For a through-current condition, this will calculate to about (| 1 | + | –1 |) / 2 = 2 / 2 = 1, at rated load.

**Figure 3.3 Differential Element (87-1) Quantities**

*Figure 3.4* shows how the differential element quantities are used to generate the unrestrained 87U*n* (87U1, 87U2, 87U3) and restrained 87R*n* (87R1, 87R2, 87R3) elements. These elements are combined to form differential element targets (87-1, 87-2, 87-3).

Unrestrained elements (87U1, 87U2, and 87U3) compare the IOP quantity to a setting value (U87P), typically about 10 times TAP, and trip if this level is exceeded. Elements 87U1, 87U2, and 87U3 are combined to form element 87U as shown in the lower right corner of *Figure 3.4*. Harmonic blocking is not performed on the unrestrained elements. Use these elements to protect your transformer bushings and end windings while maintaining security for inrush and through-fault conditions. Operating current elements 87O*n* (87O1, 87O2, 87O3) are provided for testing purposes.

Restrained elements (87R1, 87R2, and 87R3) determine whether the IOP quantity is greater than the restraint quantity using the differential characteristic shown in *Figure 3.1*. Set HRSTR = Y (harmonic restraint) to modify this characteristic as a function of the second- and fourth-harmonic content in the input currents.

In element 87R*n*, for example, the IOP*n* and IRT*n* quantities determine whether the relay trips. The logic enclosed within the dotted line of *Figure 3.4* implements the *Figure 3.1* characteristic. The differential element calculates a threshold as a function of IRT*n*. IOP*n* must exceed this threshold to produce tripping. The function uses the SLP1, SLP2, and IRS1 setting values, along with IRT*n*, to calculate the IOP value. The differential element decision logic compares the calculated value, denoted f(IRT*n*), to the actual IOP*n*. If IOP*n* is greater, one input of the AND gate at the right receives a logic 1. Comparison of IOP*n* with the O87P setting determines the second AND input. If IOP*n* is greater than O87P, Relay Word bit 87O*n* asserts. The AND gate condition then is satisfied, and Relay Word bit 87R*n* asserts, indicating operation of the restrained differential element, *n*. This does not, as yet, produce a trip. The relay still needs the results of the harmonic and dc blocking decision logic, which is described later.

**Figure 3.4 Differential Element Decision Logic**

### Harmonic Restraint

Consider the harmonic restraint feature (HRSTR = Y) if your practices require independent harmonic restraint. When HRSTR = Y, the relay setting IHBL is not used. It also disables second- and fourth-harmonic blocking because it adds the second- and fourth-harmonic quantities to the differential characteristic restraint quantity. Blocking features are discussed in more detail later in this section.

For harmonic blocking, the harmonic content of the differential current must exceed the individual (PCT2 or PCT4) threshold values, i.e., the thresholds are treated as independent measurements of each harmonic value. For harmonic restraint, the values of the second- and fourth-harmonic currents are summed, and that value is used in the relay characteristic. Consider, for example, the simple case of Slope 1, i.e., a straight line through the origin. The general equation for a line is:

$$Y = m \bullet x + c$$

More specifically, in the SEL-387E:

$$IOP = SLP\ 1 \bullet IRT + c$$

where:

$$c = (100/PCT2 \bullet \Sigma 1W\mathit{n}c2) + (100/PCT4 \bullet \Sigma 1W\mathit{n}C4)$$

Because the line starts at the origin, the value of c is normally zero. The sum of the second- and fourth-harmonic currents now forms the constant c in the equation, raising the relay characteristic proportionally to the harmonic values.

## Blocking

While the restrained differential elements are making decisions, a parallel blocking decision process occurs regarding the magnitudes of specific harmonics in the IOP quantities.

### Common (Cross) or Independent Blocking

Use common or independent blocking elements (87BL1, 87BL2, and 87BL3) to supervise the restrained differential elements. Common blocking disables all restrained elements if any blocking element is picked up. *Figure 3.5* shows how independent blocking disables the restrained element associated with the blocking element.

If IHBL is set to N (No), the logic shown in *Figure 3.5* to the left of the vertical line, IHBL = N, is enabled. In this, case all 87R*n* elements enter one OR gate, and all 87BL*n* elements enter another OR gate, whose output is negated at the upper AND gate. If the 87R*n* OR output asserts but the 87BL*n* OR output does not, the 87R Relay Word bit asserts and tripping can take place. In other words, with IHBL = N, blocking within ANY differential element will prevent operation and tripping of ALL the restrained differential elements.

**Figure 3.5 Differential Element Harmonic Blocking Logic**

If IHBL is set to Y (Yes), the logic shown in *Figure 3.5* to the right of the vertical line, IHBL = Y, is enabled. Here, the logic pairs 87R1 with negated 87BL1, 87R2 with negated 87BL2, and 87R3 with negated 87BL3 at separate AND gates. In this logic, blocking in a given element will only disable tripping of that element. In general, this mode of operation might only be used where three single-phase transformers are used to make up a three-phase bank, and independent-pole breaker operation is possible, in the harmonic blocking mode. When harmonic restraint is selected, the relay operates only in the individual blocking mode.

Relay Word bits 87R and 87U are high-speed elements that must trip all breakers. Our example assigns 87R and 87U to trip variable setting TR4. If either bit asserts, this variable asserts bit TRIP4, which drives contact OUT104. OUT104 connects to an 86 lockout device, which trips all breakers via multiple sets of contacts.

## Harmonic Blocking

*Figure 3.6* shows how the 87BL1 blocking element will pick up if the second-, fourth-, or fifth-harmonic operating current, as a percentage of fundamental operating current, is greater than the 2PCT, 4PCT, or 5PCT setting threshold, respectively. The blocking element will also pick up if the ratio of positive and negative dc exceeds a threshold as shown in *Figure 3.7*. The blocking prevents improper tripping during transformer inrush or allowable overexcitation conditions.

Elements 4HB1, 4HB2, and 4HB3 are combined to form element 4HBL as shown at the bottom of *Figure 3.6*. 4HBL is available as a Relay Word bit but elements 4HB1, 4HB2, and 4HB3 are not.

An additional alarm function for 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.

**Figure 3.6 Differential Element (87BL1) Blocking Logic**

## DC Ratio Blocking

*Figure 3.7* shows the dc blocking logic for Winding 1. Elements DCBL1, DCBL2, and DCBL3 are combined to form element DCBL as shown at the bottom of *Figure 3.6*. DCBL is available as a Relay Word bit but elements DCBL1, DBL2, and DCBL3 are not.

The dc ratio blocking feature applies to inrush cases with little harmonic content, but a high dc offset. The measurement principle is that of waveshape recognition, distinguishing between the time constants for inrush current that typically are longer than the time constants for an internal fault.

**Figure 3.7 DC Blocking (DCBL1) Logic**

## Setting Descriptions

### Differential Element Enable (E87W1–E87W3)

**Range:** Y, N, Y1

The SEL-387E has three sets of three-phase current inputs. Depending on the application, you may not need all of these inputs for the differential zone of protection. You can configure any unused terminals for standalone overcurrent protection. The E87W*n* setting specifies which of the terminals the relay is to include in the differential calculation. An independent setting, EOC*n*, exists to enable the overcurrent and demand metering elements. Selecting Y for E87W*n* enables differential element settings for the corresponding winding. Selecting N for E87W*n* disables differential element settings for the corresponding winding; the relay hides the settings, and they are unavailable for use.

Selecting Y1 makes the fourth-harmonic (PCT4), dc ratio blocking (DCRB), and harmonic restraint (HRSTR) settings available. This is the only difference between Y and Y1 selection.

### CT Connection (W1CT–W3CT)

**Range:** D, Y

To perform calculations for TAP*n* values, the relay uses information on whether the CTs are connected in delta (D) or wye (Y) for each winding. If the CTs are connected in delta, the relay raises the TAP value by a factor of 1.732.

Also, if the CTs on a particular winding *n* are connected in delta (W*n*CT = D), then the secondary currents into the corresponding SEL-387E current inputs (IAW*n*, IBW*n*, and ICW*n*) are modified before being displayed or used in:

- breaker monitoring (**BRE** command)
- instantaneous metering (**METER** command)
- demand metering (**METER D** and **METER P** commands)
- through-fault event monitoring (**TFE** command)

For delta-connected CTs, the secondary currents into the SEL-387E current inputs are phase-to-phase difference currents (e.g., phase-to-phase difference current IA–IB flows into current input IAW*n*). To create a pseudo phase-neutral value for display or use in algorithms, these phase-to-phase difference currents are divided by $\sqrt{3}$ (divided by 1.732).

### CT Ratio (CTR1–CTR3)

**Range:** 1–50000

Determine the CT ratio by dividing the nominal primary CT current by the nominal secondary CT current. If, for example, the nominal primary CT current is 2000 A and the nominal secondary CT current is 5 A, the ratio is 2000/5 or 400. For this example, enter a value of 400.

## Maximum Transformer Capacity, Three-Phase MVA (MVA)

**Range:** OFF, 0.2–5000 MVA, in 0.1 MVA steps

Use the highest expected transformer rating, such as the FOA (Forced Oil and Air cooled) rating or a higher emergency rating, when setting the maximum transformer capacity.

## Internal Winding/CT Connection Compensation (ICOM)

**Range:** Y, N

This Yes/No variable 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, the relay permits the user, in the next group of settings, to define the amount of shift needed to properly align the secondary currents for the differential calculation.

## Connection Compensation (W1CTC Through W3CTC)

**Range:** 0, 1, …, 12

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 removal of zero-sequence current components.

## Line-to-Line Voltage, kV (VWDG1 Through VWDG3)

**Range:** 1–1000 kV, in 0.01 kV steps

Enter the nominal line-to-line transformer terminal voltages. If the transformer differential zone includes a load tap-changer, assume that it is in the neutral position. The setting units are kilovolts.

## Current TAP (TAP1 Through TAP3)

**Range:** 1 A: 0.1–31 A, secondary, in 0.01 A steps
5 A: 0.5–155 A, secondary, in 0.01 A steps

**Note:** $TAP_{MAX}/TAP_{MIN}$ must be less than or equal to 7.5

When a value is entered in the 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 automatically calculates the TAP*n* values.

You can also directly enter tap values. Set MVA = OFF, and enter the TAP1 through TAP3 values directly, along with the other pertinent settings.

## Restrained Element Operating Current Pickup (O87P)

**Range:** 0.10–1.00 • TAP

**Note:** $TAP_{MIN}$ • O87P ≥ 0.1 $I_n$

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.

## Restraint Slope Percentage (SLP1, SLP2)

**Range:** SLP1: 5–100%, in 1% steps; SLP2: OFF, 25–200%

Use restraint slope percentage settings to discriminate between internal and external faults. Set SLP1 or SLP2 to accommodate current differences from power transformer tap-changer, CT saturation, CT errors, and relay error.

## Restraint Current Slope 1 Limit (IRS1)

**Range:** 1.0–20.0, in 0.1 steps • TAP

**Note:** 1 A: $TAP_{MAX}$ • IRS1 ≤ 31.0

5 A: $TAP_{MAX}$ • IRS1 ≤ 155.0

A two-slope, or variable-percentage differential application, improves sensitivity in the region where CT error is less and increases security in the high-current region where CT error is greater. We must define both slopes, as well as the slope 1 limit or point IRS1, where SLP1 and SLP2 intersect.

## Unrestrained Element Current Pickup (U87P)

**Range:** 1.0–20.0, in 0.1 steps • TAP

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 10 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, IRS1, PCT2, PCT5, or IHBL settings. Thus, you must set the element pickup level high enough so as not to react to large inrush currents.

## Second-Harmonic Blocking Percentage of Fundamental (PCT2)

**Range:** OFF, 5–100%, in 1% steps

Energization of a transformer causes a temporary large flow of magnetizing inrush current into one terminal of a transformer, without other terminals seeing this current. Thus, it appears as a differential current that could cause improper relay operation. Magnetizing inrush currents contain greater amounts of second-harmonic current than do fault currents. This second-harmonic current can be used to identify the inrush phenomenon and to prevent relay misoperation. The SEL-387E measures the amount of second-harmonic current flowing in the transformer. You can set the relay to block the percentage restrained differential element if the ratio of second-harmonic current to fundamental current (IF2/IF1) is greater than the PCT2 setting.

## Fourth-Harmonic Blocking Percentage of Fundamental (PCT4)

**Range:** OFF, 5–100%, in 1% steps

Set E87W*x* = Y1 to make the fourth-harmonic, (PCT4), dc ratio blocking (DCRB), and harmonic restraint (HRSTR) settings available. Energization of a transformer causes a temporary large flow of magnetizing inrush current into one terminal of a transformer, without other terminals seeing this current. Thus, it appears as a differential current that could cause improper relay operation. Magnetizing inrush currents contain greater amounts of even-harmonic current than do fault currents. This even-harmonic current can be used to identify the inrush phenomenon and to prevent relay misoperation. The SEL-387E measures the amount of fourth-harmonic current flowing in the transformer. You can set the relay to block the percentage restrained differential element if the ratio of fourth-harmonic current to fundamental current (IF4/IF1) is greater than the PCT4 setting.

## Fifth-Harmonic Blocking Percentage of Fundamental (PCT5)

**Range:** OFF, 5–100%, in 1% steps

According to industry standards (ANSI/IEEE C37.91, C37.102), overexcitation occurs when the ratio of the voltage to frequency (V/Hz) applied to the transformer terminals exceeds 1.05 per unit at full load or 1.1 per unit at no load. This ratio is a measure of the core flux density. Transformer overexcitation produces odd-order harmonics, which can appear as differential current to a transformer differential relay.

Unit-generator step-up transformers at power plants are the primary users of fifth-harmonic blocking. Transformer voltage and generator frequency may vary somewhat during startup, overexciting the transformers.

## Fifth-Harmonic Alarm Threshold (TH5P)

**Range:** OFF, (0.02–3.2), in 0.01 steps • TAP

**Note:** 1 A: $TAP_{MIN} \cdot TH5P \geq 0.05$

$TAP_{MAX} \cdot TH5P \leq 31.0$

5 A: $TAP_{MIN} \cdot TH5P \geq 0.25$

$TAP_{MAX} \cdot TH5P \leq 155.0$

You may use the presence of fifth-harmonic differential current to assert an alarm output during startup. This alarm indicates that the rated transformer excitation current is exceeded. You may also consider triggering an event report if fifth-harmonic current exceeds the fifth-harmonic threshold that you set.

## Fifth-Harmonic Alarm Time Delay Pickup (TH5D)

**Range:** 0–8000 cycles, in 0.125-cycle steps

With this pickup, you can delay assertion of an alarm for excessive fifth-harmonic differential current.

## DC Ratio Blocking (DCRB)

Set E87W*x* = Y1 to make the fourth-harmonic, (PCT4), dc ratio blocking (DCRB), and harmonic restraint (HRSTR) settings available. Some magnetizing inrush cases contain very little harmonic content but contain a dc offset. The SEL-387E can detect the dc offset and use it in the blocking (not restraint) logic. Enable this function by setting DCRB = Y.

## Harmonic Restraint (HRSTR)

Set E87W*x* = Y1 to make the fourth-harmonic, (PCT4), dc ratio blocking (DCRB), and harmonic restraint (HRSTR) settings available. Even harmonics (second and fourth) can be used to provide security against magnetizing inrush currents during transformer energization. Choose between harmonic blocking and harmonic restraint. Harmonic blocking treats the second and fourth harmonics independently and blocks the relay when the second- or fourth-harmonic content (harmonic current as a percentage of the fundamental current) exceeds the PCT2 or PCT4 setting, respectively. For example, assume the following:

> PCT2 = PCT4 = 20 percent, and the harmonics in the differential current are: second harmonic = 15 percent, fourth harmonic = 7 percent

In this case, the relay does not block because neither harmonic content exceeds its particular setting. But when the second-harmonic content increases to 21 percent, the relay blocks, regardless of the value of the fourth-harmonic content present in the differential current. Increasing the fourth-harmonic content to exceed the PCT4 setting while the second-harmonic content remains lower than the PCT2 setting yields the same result.

Harmonic restraint is more secure than harmonic blocking because it adds the values of the second- and fourth-harmonic currents together and raises the relay characteristic by the sum of the two values. In the example, second-harmonic content + fourth-harmonic content = 15 percent + 7 percent = 22 percent and relay tripping is restrained when it would not have been blocked.

Set HRSTR = Y to select the harmonic restraint function and automatically enable Independent Harmonic Blocking (IHBL).

## Independent Harmonic Blocking (IHBL)

**Range:** Y, N

Upon energization of a three-phase transformer, at least two phase currents will contain inrush harmonics. In traditional single-phase relays each relay compares the harmonic current flowing through the phase for that relay. The SEL-387E performs harmonic blocking in two ways:

1. Independent Harmonic Blocking (IHBL = Y) blocks the percentage differential element for a particular phase if the harmonic (second or fifth) in that phase exceeds the block threshold. No blocking occurs on other differential elements.
2. Common Harmonic Blocking (IHBL = N) blocks all of the percentage differential elements if the harmonic magnitude of any one phase is greater than the blocking threshold.

Common Harmonic Blocking is more secure but may slightly delay percentage differential element operation because harmonics in all three phases must drop below the thresholds for the three phases.

## Setting Calculation

### Connection Compensation Settings

The relay offers connection compensation settings, W*n*CTC (*n* = 1, 2, 3, or 4), to compensate for the phase shift across the transformer. These settings offer a range, 0–12, that represents 3x3 matrices, CTC(0)–CTC(12), permitting compensation from 0 degrees to 360 degrees, in increments of 30 degrees, respectively. The general expression for current compensation is as follows:

$$\begin{bmatrix} \mathrm{I1W}n\mathrm{C} \\ \mathrm{I2W}n\mathrm{C} \\ \mathrm{I3W}n\mathrm{C} \end{bmatrix} = [\mathrm{CTC}(m)] \bullet \begin{bmatrix} \mathrm{IAW}n \\ \mathrm{IBW}n \\ \mathrm{ICW}n \end{bmatrix}$$

where IAW*n*, IBW*n*, and ICW*n* are the three-phase currents entering terminal "*n*" of the relay; I1W*n*C, I2W*n*C, and I3W*n*C are the corresponding phase currents after compensation the relay uses to calculate the operate and restraint quantities; and CTC(*m*) is the three-by-three compensation matrix corresponding to the W*n*CTC setting. The complete list of compensation matrices (*m* = 0–12) and the corresponding correction compensation they result in are shown in *Table 3.1*.

**Table 3.1 WnCTC Setting: Corresponding Phase and Direction of Correction** (Sheet 1 of 2)

| WnCTC Setting[a] | Matrix | Compensation Matrices | Amount and Direction of Correction | |
|---|---|---|---|---|
| | | | ABC Phase Rotation | ACB Phase Rotation |
| 0 | CTC(0) | $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ | 0° | 0° |
| 1 | CTC(1) | $\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$ | 30° CCW | 30° CW |
| 2 | CTC(2) | $\frac{1}{3} \bullet \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & 1 \end{bmatrix}$ | 60° CCW | 60° CW |
| 3 | CTC(3) | $\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix}$ | 90° CCW | 90° CW |
| 4 | CTC(4) | $\frac{1}{3} \bullet \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix}$ | 120° CCW | 120° CW |

**Table 3.1 WnCTC Setting: Corresponding Phase and Direction of Correction** (Sheet 2 of 2)

| WnCTC Setting[a] | Matrix | Compensation Matrices | Amount and Direction of Correction | |
|---|---|---|---|---|
| | | | ABC Phase Rotation | ACB Phase Rotation |
| 5 | CTC(5) | $\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$ | 150° CCW | 150° CW |
| 6 | CTC(6) | $\frac{1}{3} \bullet \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix}$ | 180° CCW | 180° CW |
| 7 | CTC(7) | $\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix}$ | 210° CCW | 210° CW |
| 8 | CTC(8) | $\frac{1}{3} \bullet \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix}$ | 240° CCW | 240° CW |
| 9 | CTC(9) | $\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{bmatrix}$ | 270° CCW | 270° CW |
| 10 | CTC(10) | $\frac{1}{3} \bullet \begin{bmatrix} 1 & 1 & -2 \\ -2 & 1 & 1 \\ 1 & -2 & 1 \end{bmatrix}$ | 300° CCW | 300° CW |
| 11 | CTC(11) | $\frac{1}{\sqrt{3}} \bullet \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$ | 330° CCW | 330° CW |
| 12 | CTC(12) | $\frac{1}{3} \bullet \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$ | 0° (360°) CCW | 0° (360°) CW |

[a] n = 1, 2, 3, 4.

Compensation matrix CTC(0) is intended to create no changes at all in the currents and merely multiplies them by an identity matrix. 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 current, as do all of the matrices with non-zero values of *m*.

Use the following guidelines to determine correct compensation settings for each winding.

Step 1. Determine the phase shift as seen by the relay. The following information is required to accurately determine this phase shift.

- ➢ Transformer winding connection diagram (transformer nameplate)
- ➢ Three-line connection diagram showing: (1) system phase-to-transformer bushing connections, (2) current transformer (CT) connections, and (3) CT-to-relay connections

Step 2. Choose one of the relay current inputs as the reference winding.

- ➢ If a delta winding exists and is wired into the relay, choose it as the reference. Select matrix CTC(0) for the compensation of the delta winding.
- ➢ If a delta winding does not exist, select matrix CTC(11) for the compensation of one of the wye windings.

Step 3. With the winding in *Step 2* as a reference, determine the required compensation settings for all other windings. Use odd matrices for compensating wye windings. Avoid the use of even matrices when possible.

Refer to *Appendix J: Protection Application Examples* for more details on application of these guidelines in determining correct compensation settings.

## Winding Line-to-Line Voltages

Enter the nominal line-to-line transformer terminal voltages. If a load tap changer is included in the transformer differential zone, assume that it is in the neutral position. The setting units are kilovolts.

## Current TAP

The relay uses a standard equation to set TAP*n*, based on settings entered for the particular winding. (*n* denotes the winding number.)

$$\mathrm{TAPn} = \frac{\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet \mathrm{VWDGn} \bullet \mathrm{CTRn}} \bullet \mathrm{C} \qquad \textbf{Equation 3.1}$$

where:

C = 1 if W*n*CT setting = Y (wye-connected CTs)

C = $\sqrt{3}$ if W*n*CT setting = D (delta-connected CTs)

MVA = maximum power transformer capacity setting (must be the same for all TAP*n* calculations)

VWDG*n* = winding line-to-line voltage setting, in kV

CTR*n* = current transformer ratio setting

The relay calculates TAP*n* with the following limitations:

- ➤ The tap settings are within the range $0.1 \bullet I_N$ and $31 \bullet I_N$
- ➤ The ratio $TAP_{MAX}/TAP_{MIN} \leq 7.5$

## Restrained Element Operating Current Pickup

The O87P setting range is 0.1 to 1.0; we suggest an O87P setting of 0.3. The setting must be at a minimum for increased sensitivity but high enough to avoid operation because of steady-state CT error and transformer excitation current. The setting must also yield an operating current greater than or equal to $0.1 \bullet I_N$, when multiplied by the smallest of TAP1 through TAP3. Stated another way,

$$O87P_{MIN} \geq (0.1 \bullet I_N) / TAP_{MIN}$$

## Restraint Slope Percentage

Example:

The current transformer error, e, is equal to ±10 percent. In per unit:

$$e = 0.1$$

The voltage ratio variation of the power transformer load tap-changer, LTC, 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 as well as being offset by maximum LTC variation. Therefore, the maximum differential current expected for through-current conditions is:

$$Id\ max = (1 + e) \bullet \sum_{IN} IWn - \frac{(1 - e)}{(1 + a)} \bullet \sum_{OUT} IWn$$ **Equation 3.2**

where the summation terms are the total input and output power transformer secondary currents, after tap compensation. Because these summations must be equal for external faults and load current, we can express the maximum differential current as a percentage of winding current:

$$(1 + e) - \frac{(1 - e)}{(1 + a)} = \frac{2 \bullet e + a + e \bullet a}{1 + a} \bullet 100\% = 28.18\%$$ **Equation 3.3**

In addition to the error calculated above, we have to consider additional errors from transformer excitation current (≈3 percent) and relay measurement error (≤ 5 percent). The maximum total error comes to 36 percent. Therefore, if we use only one slope, a conservative slope setting, SLP1, is about 40 percent. This represents a fixed percentage differential application and is a good average setting to cover the entire current range.

A two-slope, or variable-percentage differential application, improves sensitivity in the region where CT error is small and increases security in the high-current region where CT error is great. We must define both slopes, as well as the slope 1 limit or crossover point, IRS1. If we assume CT error to be only 1 percent, we can set SLP1 at about 25 percent. A good choice for IRS1 is about 3.0 per unit of tap, while the SLP2 setting should probably be in the 50 percent to 60 percent range to avoid problems with CT saturation at high currents. A 60 percent SLP2 setting covers CT error to as great as 20 percent.

## Unrestrained Element Current Pickup

**NOTE:** U87P must be set lower than $31 \cdot I_{nom}/TAP_{max}$, where $TAP_{max}$ is the largest of the TAP settings.

The instantaneous unrestrained current element is intended to react quickly to very heavy current levels that clearly indicate an internal fault. Set the pickup level (U87P) to about 10 times TAP. The unrestrained differential element only responds to the fundamental frequency component of the differential operating current. It is not affected by the SLP1, SLP2, IRS1, PCT2, PCT5, or IHBL settings. Thus, it must be set high enough so as not to react to large inrush currents.

## Second-Harmonic Blocking

Transformer simulations show that magnetizing inrush current usually yields more than 30 percent of IF2/IF1 in the first cycle of the inrush. A setting of 15 percent usually provides a margin for security. However, some types of transformers, or the presence within the differential zone of equipment that draws a fundamental current of its own, may require setting the threshold as low as 7 percent. For example, the additional fundamental frequency charging current of a long cable run on the transformer secondary terminals could "dilute" the level of second harmonic seen at the primary to less than 15 percent.

## Fourth-Harmonic Blocking

Transformer magnetizing inrush currents are generated during transformer energization when the current contains a dc offset due to point-on-wave switching. Inrush conditions typically are detected using even harmonics and are used to prevent misoperations due to inrush. The largest even-harmonic current component is usually the second harmonic followed by the fourth harmonic. Use fourth-harmonic blocking to provide additional security against inrush conditions; set PCT4 less than PCT2.

## Fifth-Harmonic Blocking

Fourier analysis of transformer currents during overexcitation indicates that a 35 percent fifth-harmonic setting is adequate to block the percentage differential element. To disable fifth-harmonic blocking, set PCT5 to OFF.

You may use the presence of fifth-harmonic differential current to assert an alarm output during startup. This alarm indicates that the rated transformer excitation current is exceeded. At full load, a TH5P setting of 0.1 corresponds to 10 percent of the fundamental current. A delay, TH5D, that can be set by the user prevents the relay from indicating transient presence of fifth-harmonic currents.

You may consider triggering an event report if transformer excitation current exceeds the fifth-harmonic threshold.

There are two criteria for setting TH5P:

- $TH5P \cdot TAP_{MIN} \geq 0.05 \cdot I_{nom}$, and
- $TH5P \cdot TAP_{MAX} \leq 31 \cdot I_{nom}$

where $TAP_{MIN}$ and $TAP_{MAX}$ are the least and greatest of the tap settings.

## Independent Harmonic Blocking Element (IHBL)

When a three-phase transformer is energized, inrush harmonics are present in at least two phase currents. In traditional single-phase relays, each relay performs a comparison of the harmonic current flowing through its phase. The SEL-387E can perform harmonic blocking two ways:

- Independent Harmonic Blocking (IHBL = Y) blocks the percentage differential element for a particular phase if the harmonic (second or fifth) in that phase is greater than the block threshold. Other differential elements are not blocked.
- Common Harmonic Blocking (IHBL = N) blocks all of the percentage differential elements if any one phase has a harmonic magnitude greater than the blocking threshold.

Common Harmonic Blocking is a more secure scheme but may slightly delay percentage differential element operation because harmonics in all three phases must drop below their thresholds.

## Example of Setting the SEL-387E for a Three-Winding Transformer

In this section we use an example that forms the basis of the default differential settings we entered at the factory before shipping the relay. The example represents a typical three-winding transformer application and demonstrates the use of CT compensation settings and tap calculations.

*Figure 2.10* illustrates the application. The transformer is a 230 kV to 138 kV autotransformer with a 13.8 kV delta tertiary whose terminals we have brought out and included in the differential zone of protection. The transformer primary and secondary have a maximum rating of 100 MVA, while the tertiary has a rating of 30 MVA. All three windings have wye-connected current transformers, with ratios of 600/5 A at 230 kV, 1200/5 A at 138 kV, and 2000/5 A at 13.8 kV. We have connected the transformer per IEEE standards, with the low-voltage delta lagging the high-voltage wye by 30 degrees.

Step 1. Enable the differential settings as follows:

E87W1 = Y  E87W2 = Y  E87W3 = Y

These settings enable Windings 1, 2, and 3.

Step 2. Select settings for the current transformer connection and ratio for each winding. All CTs connect in wye. The ratios are equal to primary current divided by secondary current. The settings are as follows:

| **230 kV** | **138 kV** | **13.8 kV** |
|---|---|---|
| W1CT = Y | W2CT = Y | W3CT = Y |
| CTR1 = 120 | CTR2 = 240 | CTR3 = 400 |

Step 3. Set the transformer maximum rating. We use this rating for all windings in the later tap calculation:

MVA = 100

Step 4. Determine compensation settings. Because the CTs on either side of the transformer (wye and delta sides) are wye-connected, we must adjust for the phase angle shift. In the "traditional" differential relay connection, the wye transformer windings have their CTs connected in delta to produce a shift in the same direction as that produced in the transformer. Using the guidelines in *Steps to Determine the Compensation Settings (WnCTC) on page J.5*, it can be determined that the phase-to-transformer bushing connections are standard. The primary delta current Ia lags the system primary wye current IA by 30 degrees. The CT connections are standard, which results in IAW3 leading IAW1 and IAW2 by 150 degrees as seen by the relay. Primary currents and secondary currents as measured by the relay are shown in *Figure 3.8*. For simplicity, only Terminal 1 and Terminal 3 currents are shown. Terminal 2 currents are the same as Terminal 1.

**Figure 3.8 Primary Currents and Secondary Currents as Measured by the Relay**

Further, select the delta winding as the reference. The delta current is connected to Terminal W3 of the SEL-387E Relay. Therefore, set W3CTC = 0. The wye currents are connected to Terminal W1 and W2 of the SEL-387E Relay, so W1CTC and W2CTC must be determined. IAW1 and IAW2 must be rotated 330 degrees (11 multiples of 30 degrees) in the counterclockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW3. Therefore, set W1CTC = 11 and W2CTC = 11. The resulting compensation settings are:

ICOM = Y (choose to define the CT compensation)

W1CTC = 11 W2CTC = 11 W3CTC = 0

The relay multiplies the wye CT currents from the wye transformer windings by the CTC(11) matrix to give the same results as the physical DAC CT connection.

Step 5. Enter winding line-to-line voltages. The relay needs these voltages for the tap calculation. Voltages are in units of kV. For this example we enter the following values:

VWDG1 = 230 VWDG2 = 138 VWDG3 = 13.8

The relay now calculates each tap current, using the formula stated previously:

$$TAPn = \frac{MVA \bullet 1000}{\sqrt{3} \bullet VWDGn \bullet CTRn} \bullet C \qquad \textbf{Equation 3.4}$$

(C = 1 for wye CTs)

Thus, we have the following:

$$TAP1 = \frac{100\ MVA \bullet 1000}{\sqrt{3} \bullet 230\ kV \bullet 120} \bullet 1$$

TAP1 = 2.09 A

$$TAP2 = \frac{100\ MVA \bullet 1000}{\sqrt{3} \bullet 138\ kV \bullet 240} \bullet 1$$

TAP2 = 1.74 A

$$TAP3 = \frac{100\ MVA \bullet 1000}{\sqrt{3} \bullet 13.8\ kV \bullet 400} \bullet 1$$

TAP3 = 10.46 A

The relay calculates these taps automatically if MVA is given. If MVA is set to OFF, the user must calculate the taps and enter them individually.

The relay will check to see if a violation of the maximum tap ratio has occurred, and will notify the user of the violation. That is, it will divide the greatest TAP*n*, in this case 10.46, by the least TAP*n*, here 1.74, to get a ratio of 6.01. Because this is below 7.5, adjustment of the CT ratio is unnecessary.

Step 6. Set the differential element characteristic. Select the settings according to our suggestions in the earlier setting descriptions. For this example, we have selected a two-slope, variable-percentage differential characteristic for maximum sensitivity at low currents and greater tolerance for CT saturation on external high-current faults. The settings are as follows:

| | | |
|---|---|---|
| O87P = | 0.3 | (Operate current pickup in multiple of tap) |
| SLP1 = | 25 | (25 percent initial slope) |
| SLP2 = | 50 | (50 percent second slope) |
| IRS1 = | 3.0 | (limit of slope 1, Restraint current in multiple of tap) |
| U87P = | 10 | (unrestrained differential Operate current level, multiple of tap) |
| PCT4 = | 15 | (block operation if fourth harmonic is above 15 percent) |
| PCT5 = | 35 | (block operation if fifth harmonic is above 35 percent) |
| TH5P = | OFF | (no fifth-harmonic alarm) |
| DCRB = | N | (dc ratio blocking disabled) |
| HRSTR = | N | (harmonic restraint disabled) |

Remember that the O87P setting must yield an operating current value of at least 0.1 • $I_N$, at the least tap. In this case O87PMIN = (0.1 • $I_N$)/$TAP_{MIN}$ = 0.5/1.74 = 0.287. Therefore, the O87P setting of 0.3 is valid.

The differential unit settings are complete for this specific application. At this point you can also choose to set backup overcurrent elements which we discuss at the end of this section.

## Application Guidelines

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 Arrangements

Use separate relay restraint circuits for each power source to the relay. In the SEL-387E, you may apply two to four restraint inputs to the relay. You may connect CT secondary windings in parallel only if both circuits meet the following criteria:

- They are connected at the same voltage level.
- Both have CTs that are matched in ratio, C voltage ratings, and core dimensions.

### 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.

As a rule of thumb, CT performance will be satisfactory if the CT secondary maximum symmetrical external fault current multiplied by the total secondary burden in ohms is less than half of the C voltage rating of the CT. The following CT selection procedure uses this second guideline.

### 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 (e.g., CTR1) 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 $\sqrt{3}$ • $I_{HS}$. Select the nearest standard ratio such that $I_{REL}$ is between 0.1 • $I_N$ and 1.0 • $I_N$ A secondary, where $I_N$ is the relay nominal secondary current, 1 A or 5 A.

Step 3. Select the remaining CT ratios (e.g., CTR2–CTR3) 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 this rating is much smaller than the rating of the largest winding, you may violate the tap ratio limit for the SEL-387E (see *Step 4* and *Step 5*). As before, for wye-connected CTs $I_{REL}$ equals $I_{LS}$. For delta-

connected CTs $I_{REL}$ equals $\sqrt{3}$ • $I_{LS}$. Select the nearest standard ratio such that $I_{REL}$ is between 0.1 • $I_N$ and 1.0 • $I_N$ A secondary.

Step 4. The SEL-387E calculates settings TAP1 through TAP3 if the ratio $TAP_{MAX}/TAP_{MIN}$ is less than or equal to 7.5. When the relay calculates the tap settings, it reduces CT mismatch to less than 1 percent. Allowable tap settings are in the range (0.1–31) • $I_N$.

Step 5. If the ratio $TAP_{MAX}/TAP_{MIN}$ is greater than 7.5, 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 • $I_N$. If necessary, reselect the CT ratios and repeat *Step 2* through *Step 6*.

Step 7. For each CT, multiply the burdens calculated in *Step 1* by the magnitude, in secondary amperes, of the expected maximum symmetrical fault current 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.

Please note that the effective C voltage rating of a CT is lower than the nameplate rating if a tap other than the maximum is used. Derate the CT C voltage rating by a factor of ratio used/ratio max.

# Restricted Earth Fault Element

## Application Description

Use the Restricted Earth Fault (REF) element to provide sensitive protection against ground faults in your wye-connected transformer winding. The element is “restricted” in the sense that protection is restricted to ground faults within a zone defined by neutral and line CT placement.

## Operating Characteristic

Restricted Earth Fault (REF) protection is a technique for sensitive detection of ground faults in a grounded wye-connected transformer winding. Because it employs a neutral CT at one end of the winding and the normal set of three CTs at the line end of the winding, REF protection can detect only ground faults within that particular wye-connected winding. For REF to function, the line-end CTs must also be connected in wye, because the technique uses comparison of zero-sequence currents. Delta-connected CTs cancel out all zero-sequence components of the currents, eliminating one of the quantities the REF element needs for comparison.

The REF implementation in the SEL-387E uses a directional element (32I) that compares the direction of an operating current, derived from the line-end CTs, with the polarizing current, obtained from the neutral CT. A zero-sequence current threshold and positive-sequence restraint supervise tripping. You can apply REF to a single wye winding in a transformer or to an entire autotransformer winding with as many as two sets of line-end CT inputs. The

neutral CT connects to one of the three current inputs for Winding 3 (IAW3, IBW3, or ICW3), leaving only two three-phase winding inputs for normal differential or overcurrent protection purposes.

*Figure 3.9* shows the REF simplified enable/block logic. The upper logic group determines whether to enable the REF directional element by assertion of the 32IE Relay Word bit. The two enabling quantities are assertion of the E32I equation and a magnitude of the neutral CT secondary current (IRW3) greater than the pickup setting, 50GP. The topmost part of this logic is a blocking function. This function asserts if any of the winding residual currents used in the REF function are less than a positive-sequence current restraint factor, a0, times the positive-sequence current for their respective winding. Such a winding residual current value might occur with "false Io" or if zero sequence current for that winding exceeds 50GP. False Io can occur in cases of CT saturation during heavy three-phase faults. If the blocking logic asserts, the CTS Relay Word bit asserts. To prevent 32IE assertion when CTS asserts, set the E32I setting = !CTS.

The lower logic group adjusts the winding residual currents to a common sensitivity level with the neutral CT, calculates a phasor sum of the appropriate currents, and compares this sum to the 50GP pickup value. The 0.8 multiplier on the 50GP setting is to ensure that 50GC always asserts before I2IE. This is to secure the operation of the 32IF element as shown in *Figure 3.10*. If the sum is greater than the pickup level, Relay Word bit 50GC asserts. This bit indicates that the winding currents are present in sufficient magnitude.

**Figure 3.9 REF Enable/Block Logic**

*Figure 3.10* illustrates the logic of the REF directional element, 32I. It is at this stage that the element decides whether to operate.

**Figure 3.10 REF Directional Element**

The relay enables the 32I directional element if the output of the AND gate at left-center in *Figure 3.10* asserts. This will occur if the two Relay Word bits 32IE and 50GC assert.

The directional element compares the polarizing current to the operating current and indicates forward (internal) fault location or reverse (external) fault location. The internal/forward indication occurs if the fault is within the protected winding, between the line-end CTs and the neutral CT. The relay multiplies each current by the appropriate CT ratio to convert input currents to actual primary amperes. This must be done to properly sum the currents in the autotransformer winding.

The polarizing current, IPOL, is simply the neutral CT current multiplied by the neutral CT ratio, CTR3, to produce a primary current value. The operating current, IOP, is the phasor sum of the winding residual currents, also on a primary basis. The 32IOP setting determines the appropriate IRW*n*, which the relay multiplies by the associated CTR*n*. The relay then sums the products. The 32I element calculates the real part of IOP times IPOL (IPOL complex conjugate). This equates to |IOP| times |IPOL| times the cosine of the angle between them. The result is positive if the angle is within ±90 degrees, indicating a forward or internal fault. The result is negative if the angle is greater than +90 or less than –90 degrees, indicating a reverse or external fault. The relay compares the output of the 32I element to positive and negative thresholds, to ensure security for very small currents or for an angle very near +90 or –90 degrees. If the 32I output exceeds the threshold test, it then must persist for at least 1.5 cycles before the Relay Word bit 32IF (forward) or 32IR (reverse) asserts. Assertion of 32IF constitutes a decision to trip by the REF function.

A second path can also assert the 32IF bit. This path comes from the two-position AND gate at the top-right of *Figure 3.10*. The gate asserts if 32IE is asserted. This assertion indicates that neutral current is above pickup but 50GC is not asserted, indicating no line-end current flow. This logic covers the situation of an internal wye-winding fault with the line-end breaker open.

You can perform tripping directly by inclusion of the Relay Word bit 32IF into one or more of the trip variables, TR*n*, as appropriate. If you want additional security, the relay is programmed to use 32IF to torque control an inverse-time curve for delayed tripping, as discussed below. *Figure 3.11* shows the output of the REF protection function. Timing is on an extremely inverse-time overcurrent curve (curve U4) at the lowest time-dial setting (0.5) and with 50GP as the pickup setting.

**Figure 3.11 REF Protection Output (Extremely Inverse-Time O/C)**

Relay Word bit 32IF (forward fault) torque controls the timing curve, and IRW3 operates the timing function. The curve resets in one cycle if current drops below pickup or if 32IF deasserts. When the curve times out, Relay Word bit REFP asserts. You can use this bit directly as an input to the appropriate trip variables, TR*n*, to trip the breaker or breakers that feed the fault.

## Setting Descriptions

### REF Directional Element Enable (E32I)

**Range:** SELOGIC® control equation

The setting E32I is a SELOGIC control equation setting that uses Relay Word bits to define the conditions under which the relay will enable REF. A logical state of 1 for this control equation enables the other REF settings and satisfies one of the conditions the REF element needs to activate. A logical state of 0 for this control equation disables the other REF settings; the relay hides these settings and they are unavailable for use.

### Operating Quantity from W1, W2 (32IOP)

**Range:** 1, 2, 12

The setting 32IOP tells the relay which winding or combination of windings it should use in calculating residual current, which acts as the Operate quantity for the directional element.

### Positive-Sequence Current Restraint Factor, I0/I1 (a0)

**Range:** 0.02–0.50, in 0.01 steps

For the relay to enable REF, the zero-sequence current at Winding n must be greater than a0 times the positive-sequence current at that input, or $|IRW_n| > a0 \bullet |I1W_n|$. This supervision provides security against “false I0” that may occur because of CT saturation during heavy three-phase faults.

### Residual Current Sensitivity Threshold (50GP)

**Range:** 1 A: 0.05–3 A, in 0.01 A steps
5 A: 0.25–15.00 A, in 0.01 A steps

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 50GP must meet two criteria:

1. 50GP must be greater than any natural residual current (IR) unbalance caused by load conditions.
2. 50GP must be greater than a minimum value determined by the relationship of the CTR*n* values used in the REF function.

You must set the threshold setting, 50GP, at the greater of the two criteria values. Determine criterion 1 for load unbalance. The second criterion relates to the relative sensitivity of the winding CTs compared to the neutral CT.

## Setting Calculation

### Operating Quantity

*Figure 3.14* depicts how to determine the Operate quantity, 32IOP, setting.

**Figure 3.12 REF Function, 32IOP Setting Guide**

If you want to protect a single wye winding in, for example, a delta-wye transformer, set 32IOP at 1, 2, or 12, which is the number of the relay winding input associated with the line-end CTs of the protected winding. The relay

uses residual current from that single winding input as the operate quantity. *Figure 3.12* shows neutral CT input connected to the Winding 3 input of the relay, as it must be for every case where REF protection is to be used.

If you want to protect an autotransformer, set 32IOP at 12 and connect the primary and secondary side CTs to relay Winding Inputs 1 and 2. You could also use this setting for the single winding mentioned above if that winding had two breakers and two sets of CTs at the line end. You would also have to connect these CTs to Winding Inputs 1 and 2. Such a connection would be typical in ring-bus or breaker-and-a-half configurations. With 32IOP set at 12, the relay sums the residual currents from the Winding 1 and Winding 2 inputs to create the operate quantity.

Calculation of the residual current at each relay winding input is as follows:

$$IRWn = IAWn + IBWn + ICWn \quad (n = 1, 2)$$

For the neutral CT connection, the relay uses only one of the three ABC inputs, e.g., IBW3, so the residual current for input 3 would be IRW3 = 0 + IBW3 + 0 = IBW3.

## Residual Current Sensitivity Threshold

The second criterion of 50GP relates to the relative sensitivity of the winding CTs compared to the neutral CT. Use the following equation to determine the minimum second criterion for 50GP:

$$50GPmin \geq 0.05 \bullet I_{nom} \bullet \frac{CTRmax}{CTR3} \qquad \textbf{Equation 3.5}$$

where CTR3 is the neutral CT ratio and CTRmax is the greatest CT ratio among the CTs being used for the REF function.

The 32IOP setting defines which line CTs the relay uses for REF. For example, if 32IOP = 12, CTRmax is the greatest of CTR1 or CTR2.

An example 50GP calculation is as follows, assuming that CTR3 = 40, CTRmax = 160, $I_{nom}$ = 5 A, and load unbalance is 10 percent:

$$50GPmin \geq 0.05 \bullet 5\ A \bullet \frac{160}{40}$$

$$50GPmin \geq 0.25\ A \bullet 4$$

$$50GPmin \geq 1.0\ A$$

Criterion 2 minimum setting of 50GP is 1.0 A. With a 10 percent load unbalance, we can assume the criterion 1 value to be 0.1 • 5 A, or 0.5 A. Because 50GP must be set at the greater of the two criteria values, we would select a setting of 1.0 A.

If you attempt to save a 50GP setting that is too low, the relay will respond (for a 5 A relay), `Minimum 50GP sensitivity is CTRmax/CTR3 • 0.25`. The relay then will prompt you for a new setting.

The relay stores a default setting for the Residual Current Sensitivity Threshold of 5OGP = 0.5 A.

# Overcurrent Element

## Application Description

The SEL-387E provides numerous overcurrent elements, as many as 11 per winding, 33 total. Four levels of phase instantaneous/definite-time elements are available for single- or three-pole feeder protection, breaker failure protection, overcurrent phase selection for targeting, transformer backup protection, etc. Two levels of negative-sequence and residual instantaneous elements provide protection against unbalanced conditions and ground faults. A-phase, negative-sequence, and residual time-overcurrent elements are available for system backup protection.

## Operating Characteristic

Each winding input of the SEL-387E has 11 overcurrent elements (see *Table 3.2*). Nine of these 11 are torque-controlled elements, of which there are one definite-time element, one instantaneous element, and one inverse-time element per each of three categories. These categories are phase, negative-sequence, and residual current. Two of the 11 overcurrent elements, 50P*n*3 and 50P*n*4, are not torque controlled. These two elements are phase instantaneous overcurrent elements that provide output information per phase and, through an OR gate, assert a Relay Word bit if any one of the three phases asserts. These two elements primarily provide level detection, for applications such as trip unlatch logic or phase identification.

In addition to the 11 overcurrent elements, there is one set of inverse-time overcurrent elements that use combined currents from two windings. These phase and residual current elements, one each for Windings 1 and 2, remove circulating current components from two breakers that connect to the same physical transformer winding but whose CT inputs go to separate relay input terminals. These combined overcurrent elements permit more sensitive tripping in ring-bus or breaker-and-a-half schemes. These elements are not torque controlled.

**Table 3.2 Overcurrent Element Summary**

| | Definite-Time Elements | Instantaneous Elements | Inverse-Time Elements |
|---|---|---|---|
| Phase (Ia, Ib, and Ic) | | | |
| Winding 1 | 50P11 | 50P12, 50P13, 50P14 | 51P1 |
| Winding 2 | 50P21 | 50P22, 50P23, 50P24 | 51P2 |
| Winding 3 | 50P31 | 50P32, 50P33, 50P34 | 51P3 |
| Combined (Windings 1 and 2) | | | 51PC1 |
| Negative-Sequence ($IQ = 3 \cdot I_2$) | | | |
| Winding 1 | 50Q11 | 50Q12 | 51Q1 |
| Winding 2 | 50Q21 | 50Q22 | 51Q2 |
| Winding 3 | 50Q31 | 50Q32 | 51Q3 |
| Residual (IR = Ia + Ib +Ic) | | | |
| Winding 1 | 50N11 | 50N12 | 51N1 |
| Winding 2 | 50N21 | 50N22 | 51N2 |
| Winding 3 | 50N31 | 50N32 | 51N3 |
| Combined (Windings 1 and 2) | | | 51NC1 |

## 50Pn1—Phase Definite-Time Element

*Figure 3.13* shows the logic for the 50P*n*1 element. The logic compares the magnitudes of phase input currents IAW*n*, IBW*n*, and ICW*n* to pickup setting 50P*n*1P. If one or more current magnitudes exceed the pickup level, a logic 1 asserts at one input to the AND gate at the center. The torque-control SELOGIC control equation 50P*n*1TC determines the other AND input. If 50P*n*1TC is true, Relay Word bit 50P*n*1 asserts and starts the timer. After the time specified by delay setting 50P*n*1D expires, a second Relay Word bit, 50P*n*1T, asserts. This bit asserts only if the 50P*n*1 bit remains asserted for the duration of 50P*n*1D. When 50P*n*1 deasserts, the timer resets without delay, along with 50P*n*1T if it has asserted.

**Figure 3.13 50Pn1 Phase Definite-Time O/C Element, Torque Controlled**

## 50Pn2—Phase Instantaneous Element

*Figure 3.14* shows the logic for the 50P*n*2 element. The 50P*n*2 element logic compares magnitudes of phase input currents IAW*n*, IBW*n*, and ICW*n* to pickup setting 50P*n*2P. If one or more current magnitudes exceed the pickup level, a logic 1 asserts at one input to the AND gate. The torque-control SELOGIC control equation 50P*n*2TC determines the other AND input. If 50P*n*2TC is true, Relay Word bit 50P*n*2 asserts.

**Figure 3.14 50Pn2 Phase Instantaneous O/C Element, Torque Controlled**

## 50Pn3 and 50Pn4—Phase Instantaneous Element

*Figure 3.15* shows the logic for the two nontorque-controlled phase instantaneous elements. The two elements find application primarily in level detection or phase identification. The logic compares magnitudes of phase input currents IAW*n*, IBW*n*, and ICW*n* to pickup setting 50P*n*3P(4P). Any phase current exceeding the pickup level will assert the appropriate phase-specific Relay Word bit, 50A*n*3(4), 50B*n*3(4), or 50C*n*3(4). These bits enter an OR gate to assert Relay Word bit 50P*n*3(4), indicating "any phase" pickup.

**Figure 3.15 50Pn3 and 50Pn4 Phase Instantaneous O/C Element, Nontorque Controlled**

## 51Pn—Phase Inverse-Time Element

*Figure 3.16* shows the logic for the 51P*n* element. The logic compares the magnitudes of phase input currents IAW*n*, IBW*n*, and ICW*n* to pickup setting 51P*n*P. If one or more current magnitudes exceed the pickup level, a logical 1 asserts at one input to the AND gate at the center. The torque-control SELOGIC control equation 51P*n*TC determines the other AND input. If 51P*n*TC is true, Relay Word bit 51P*n* asserts and the inverse curve begins timing.

**Figure 3.16 51Pn Phase Inverse-Time O/C Element, Torque Controlled**

Four settings define an inverse-time curve: the pickup setting, 51P*n*P, acts as a horizontal scaling factor, because the curve formula uses current multiple of pickup as an input; the curve setting, 51P*n*C, defines the particular curve equation, of which there are 10 (five U.S. and five IEC); the time-dial setting, 51P*n*TD, defines the time dial, which scales the curve in a vertical direction to vary the output timing for a given multiple of pickup; and the reset setting, 51P*n*RS, defines whether the curve resets slowly like an electromechanical disk or instantaneously when current drops below pickup. The phase inverse-time curve looks at all three phase current magnitudes and times on the basis of the greatest current of the three. It updates this maximum phase current selection every quarter-cycle.

If the curve times out, Relay Word bit 51P*n*T asserts. When all phase currents drop below pickup, with or without a curve time-out, 51P*n* deasserts and the element resets according to setting 51P*n*RS. At the completion of the reset, Relay Word bit 51P*n*R asserts. This bit normally will be at logic state 1, when the element is at rest during normal system operation. Use the **TAR** command via a serial port or the front panel to verify the state of this bit. You can use the

Level 2 serial port command **RES** or the front-panel RESET51 function under the **OTHER** button to force this bit to logical 1 during element testing. This saves time if you have chosen electromechanical reset.

## 50Qn1 and 50Nn1—Sequence Current Definite-Time Element Logic

*Figure 3.17* shows the logic for the definite-time 50Q*n*1 negative-sequence element and the definite-time 50N*n*1 residual element.

**Figure 3.17 50Qn1 and 50Nn1 Sequence Definite-Time O/C Element, Torque Controlled**

### 50Qn1 Negative-Sequence Definite-Time Element

The 50Q*n*1 element logic compares the magnitude of calculated negative-sequence current 3I2W*n* to pickup setting 50Q*n*1P. If the calculated negative-sequence current magnitude exceeds the pickup level, a logical 1 asserts at one input to the AND gate at the center. The torque-control SELOGIC control equation, 50Q*n*1TC, determines the other AND input. If 50Q*n*1TC is true, Relay Word bit 50Q*n*1 asserts and the timer starts. After the time specified by delay setting 50Q*n*1D has expired, a second Relay Word bit, 50Q*n*1T, asserts. The 50Q*n*1T bit asserts only if the 50Q*n*1 bit remains asserted for the duration of 50Q*n*1D. When 50Q*n*1 deasserts, the timer resets without delay, along with 50Q*n*1T if it has asserted.

### 50Nn1 Residual Definite-Time Element

The 50N*n*1 element logic compares the magnitude of the calculated residual current, IRW*n*, to the pickup setting, 50N*n*1P. If the calculated residual current magnitude exceeds the pickup level, a logical 1 asserts at one input to the AND gate at the center. The torque-control SELOGIC control equation, 50N*n*1TC, determines the other AND input. If 50N*n*1TC is true, Relay Word bit 50N*n*1 asserts and the timer starts. After the time specified by delay setting 50N*n*1D has expired, a second Relay Word bit, 50N*n*1T, asserts. The 50N*n*1T bit asserts only if the 50N*n*1 bit remains asserted for the duration of 50N*n*1D. When 50N*n*1 deasserts, the timer resets without delay, along with 50N*n*1T if it has asserted.

## 50Qn2 and 50Nn2—Sequence Instantaneous Element Logic

*Figure 3.18* shows the logic for the instantaneous 50Q*n*2 negative-sequence element and the instantaneous 50N*n*2 residual element.

**Figure 3.18 50Qn2 and 50Nn2 Sequence Instantaneous O/C Element, Torque Controlled**

## 50Qn2 Negative-Sequence Instantaneous Element

The 50Q*n*2 element compares the magnitude of the calculated negative-sequence current, 3I2W*n*, to the pickup setting, 50Q*n*2P. If the calculated negative-sequence current exceeds the pickup level, a logical 1 asserts at one input to the AND gate. The torque-control SELOGIC control equation, 50Q*n*2TC, determines the other AND input. If 50Q*n*2TC is true, Relay Word bit 50Q*n*2 asserts.

## 50Nn2 Residual Instantaneous Element

The 50N*n*2 element compares the magnitude of the calculated residual current, IRW*n*, to the pickup setting, 50N*n*2P. If the calculated residual current exceeds the pickup level, a logical 1 asserts at one input to the AND gate. The torque-control SELOGIC control equation, 50N*n*2TC, determines the other AND input. If 50N*n*2TC is true, Relay Word bit 50N*n*2 asserts.

# 51Qn and 51Nn–Sequence Inverse-Time Elements

*Figure 3.21* shows the logic for the inverse-time 51Q*n* negative-sequence element and the instantaneous 51N*n* residual element.

**Figure 3.19 51Qn and 51Nn Sequence Inverse-Time O/C Element, Torque Controlled**

## 51Qn Negative-Sequence Inverse-Time Element

The 51Q*n* element logic compares the magnitude of the calculated negative-sequence current, 3I2W*n*, to the pickup setting, 51Q*n*P. If the calculated negative-sequence current exceeds the pickup level, a logical 1 asserts at one input to the AND gate at the center. The torque-control SELOGIC control equation, 51Q*n*TC, determines the other AND input. If 51Q*n*TC is true, Relay Word bit 51P*n* asserts and the inverse curve begins timing.

As with phase inverse-time element logic, four settings define the curve. In this case 51Q*n*P is the pickup, 51Q*n*C defines the curve equation, 51Q*n*TD defines the time dial, and 51Q*n*RS determines how the curve resets.

Curve time-out causes Relay Word bit 51Q*n*T to assert. When the current drops below pickup, 51Q*n* deasserts and the element resets according to the setting for 51Q*n*RS. At the completion of the reset, Relay Word bit 51Q*n*R asserts. This bit normally is at logic state 1, when the element is at rest during normal system operation. You can use the **TAR** command to verify the state of the bit. You can use the Level 2 serial port command **RES** or the front-panel RESET51 function under the OTHER button to force the bit to a logical 1 during element testing. This saves time if you have chosen electromechanical reset.

### 51Nn Residual Inverse-Time Element

The 51N*n* element compares the magnitude of the calculated residual current, IRW*n*, to the pickup setting, 51N*n*P. If calculated residual current exceeds the pickup level, a logical 1 asserts at one input to the AND gate at the center. The torque-control SELOGIC control equation, 51N*n*TC, determines the other AND input. If 51N*n*TC is true, Relay Word bit 51N*n* asserts and the inverse curve begins timing.

The settings defining the curve in this case are 51N*n*P for the pickup setting, 51N*n*C for the particular curve equation, 51N*n*TD for the time dial, and 51N*n*RS for the curve reset.

Curve time-out causes Relay Word bit 51N*n*T to assert. When the current drops below pickup, 51N*n* deasserts and the element resets according to the setting for 51N*n*RS. At the completion of the reset, Relay Word bit 51N*n*R asserts. This bit normally is at logic state 1, when the element is at rest during normal system operation. You can use the **TAR** command to verify the state of the bit. You can use the Level 2 serial port command **RES** or the front-panel RESET51 function under the OTHER button to force the bit to a logical 1 during element testing.

## 51PC1 and 51NC1 Combined Overcurrent Elements

The combined overcurrent elements operate on summed input currents to two windings. Elements 51PC1 and 51NC1 use phase and residual current from Windings 1 and 2. See *Figure 3.20*.

**Figure 3.20 Combined Overcurrent Example**

## 51PC1 and 51NC1 Element Logic

The logic for the inverse-time combined overcurrent elements 51PC1 and 51NC1 is shown in *Figure 3.21*.

**Figure 3.21 51PC1 and 51NC1 Combined Inverse-Time O/C Elements**

The relay determines whether to assert Relay Word bit 51PC1 by selecting the greater of the two CT ratios, using this ratio as a common base in calculating the combined secondary current, and then comparing this combined secondary current against the 51PC1P pickup setting. This pickup setting is a secondary quantity that the relay calculates by dividing the primary current pickup by the greater of the two CT ratios.

For CTR1 < CTR2, the relay performs the following operation on the secondary quantities it receives from the CTs:

$$(I_n W1 \bullet CTR1/CTR2) + I_n W2,$$

where $n$ = Phase A, Phase B, or Phase C.

The following example illustrates the equivalent operation on the primary quantities entering the CTs:

Assume

CTR1 = 600/5 = 120

CTR2 = 2000/5 = 400

$I_n W1$ = 2000 A (primary)

$I_n W2$ = 1000 A (primary)

Pickup = 8000 A (primary)

where $n$ = Phase A, Phase B, or Phase C.

Then, converting the observed primary values to secondary values, we have

$$\frac{2000\text{A}}{400} + \frac{1000\text{A}}{400} = 7.5\text{A combined secondary current}$$

**NOTE:** Because CTR1 < CTR2, the relay uses CTR2 as the common base.

$$51\text{PC1P} = \frac{8000\text{A}}{400} = 20\text{A secondary}$$

The combined secondary current is less than the 51PC1P setting, so 51PC1 does not assert.

For CTR1 > CTR2, the relay performs the following operation on the secondary quantities it receives from the CTs:

I*n*W1 + (I*n*W2 • CTR2/CTR1),

where *n* = Phase A, Phase B, or Phase C.

The following example illustrates the equivalent operation on the primary quantities entering the CTs:

Assume

CTR1 = 1000/5 = 200

CTR2 = 500/5 = 100

I*n*W1 = 3000 A (primary)

I*n*W2 = 6000 A (primary)

Pickup = 8000 A (primary)

where *n* = Phase A, Phase B, or Phase C.

Then, converting the observed primary values to secondary values, we have

$$\frac{6000\text{A}}{200} + \frac{3000\text{A}}{200} = 45\text{A combined secondary current}$$

**NOTE:** Because CTR1 > CTR2, the relay uses CTR1 as the common base.

$$51\text{PC1P} = \frac{8000\text{A}}{200} = 40\text{A secondary}$$

The combined secondary current value is greater than the 51PC1P setting, so 51PC1 asserts and the time-overcurrent curve begins timing.

The settings defining the curve in this case are 51PC1P for the pickup setting, 51PC1C for the particular curve equation, 51PC1TD for the time dial, and 51PC1RS for the curve reset.

Curve time-out causes the Relay Word bit 51PC1T to assert. When the current drops below pickup, 51PC1 deasserts and the element resets according to the setting 51PC1RS. At the completion of reset, Relay Word bit 51PC1R asserts. This bit normally is at logic state 1, when the element is at rest during normal system operation. You can use the **TAR** command to verify the state of the bit. You can use the Level 2 serial port command **RES** or the front-panel RESET51 function under the OTHER button to force the bit to 1 during element testing. This saves time if you have chosen electromechanical reset.

The relay determines whether to assert Relay Word bit 51NC1 by selecting the greater of the two CT ratios, using this ratio as a common base in calculating the combined secondary current and then comparing this combined secondary current against the 51NC1P pickup setting. This pickup setting is a secondary quantity that the relay calculates by dividing the primary current pickup by the greater of the two CT ratios.

For CTR1 < CTR2, the relay performs the following operation on the secondary quantities it receives from the CTs:

$$(\overrightarrow{IAW1} + \overrightarrow{IBW1} + \overrightarrow{ICW1}) \bullet \frac{CTR1}{CTR2} + (\overrightarrow{IAW2} + \overrightarrow{IBW2} + \overrightarrow{ICW2})$$

**NOTE:** $\overrightarrow{XXXX}$ defines a vector quantity.

The following example illustrates the equivalent operation on the primary quantities entering the CTs:

Assume

CTR1 = 500/5 = 100

CTR2 = 1000/5 = 200

Pickup = 400 A (primary)

| Primary Currents | |
|---|---|
| IAW1 = 3000 ∠2° A | IAW2 = 1545 ∠3° A |
| IBW1 = 3010 ∠–122° A | IBW2 = 1480 ∠–118° A |
| ICW1 = 2950 ∠117° A | ICW2 = 1505 ∠124° A |
| **Secondary Currents** | |
| IAW1 = 30 ∠2° A | IAW2 = 7.725 ∠3° A |
| IBW1 = 30.1 ∠–122° A | IBW2 = 7.4 ∠–118° A |
| ICW1 = 29.5 ∠117° A | ICW2 = 7.525 ∠124° A |

Then,

$$(30 \angle 2° \text{ A} + 30.1 \angle -122° \text{ A} + 29.5 \angle 117° \text{ A}) \bullet \frac{100}{200}$$

$$+ (7.725 \angle 3° \text{ A} + 7.4 \angle -118° \text{ A} + 7.525 \angle 124° \text{ A})$$

$$= 1.071 \angle 70.8° \text{ A}$$

**NOTE:** Because CTR1 < CTR2, the relay uses CTR2 as the common base.

$$51NC1P = \frac{400A}{200} = 2A \text{ secondary}$$

The combined secondary current value is less than the 51NC1P setting, so 51NC1 does not assert.

For CTR1 > CTR2, the relay performs the following operation on the secondary quantities it receives from the CTs:

$$(\overrightarrow{IAW1} + \overrightarrow{IBW1} + \overrightarrow{ICW1}) + (\overrightarrow{IAW2} + \overrightarrow{IBW2} + \overrightarrow{ICW2}) \bullet \frac{CTR2}{CTR1}$$

**NOTE:** $\overrightarrow{XXXX}$ defines a vector quantity.

The following example illustrates the equivalent operation on the primary quantities entering the CTs:

Assume

CTR1 = 1000/5 = 200

CTR2 = 500/5 = 100

Pickup = 400 A (primary)

| Primary Currents | |
|---|---|
| IAW1 = 3000 ∠5° A | IAW2 = 1545 ∠3° A |
| IBW1 = 3010 ∠–123° A | IBW2 = 1480 ∠–118° A |
| ICW1 = 2950 ∠115° A | ICW2 = 1505 ∠124° A |
| **Secondary Currents** | |
| IAW1 = 15 ∠5° A | IAW2 = 15.45 ∠3° A |
| IBW1 = 15.05 ∠–123° A | IBW2 = 14.80 ∠–118° A |
| ICW1 = 14.75 ∠115° A | ICW2 = 15.05 ∠124° A |

Then,

$$(15 \angle 5° \text{ A} + 15.05 \angle -123° \text{ A} + 15.75 \angle 115° \text{ A}) + (15.45 \angle 3° \text{ A} + 14.80 \angle -118° \text{ A} + 15.05 \angle 124° \text{ A}) \bullet \frac{100}{200}$$
$$= 2.1164 \angle 76° \text{ A} + 0.11370 \angle 73° \text{ A} = 2.230 \angle 76° \text{ A}$$

**NOTE:** Because CTR1 > CTR2, the relay uses CTR1 as the common base.

$$51NC1P = \frac{400A}{200} = 2A \text{ secondary}$$

The combined secondary current value is greater than the 51NC1P setting, so 51NC1 asserts and the time-overcurrent curve begins timing.

As with the phase current element, four settings define the curve: 51NC1P is the pickup setting, 51NC1C defines the curve equation, 51NC1TD defines the time dial, and 51NC1RS determines how the curve resets.

Curve time-out causes the Relay Word bit 51NC1T to assert. When the current drops below pickup, 51NC1 deasserts and the element resets according to the setting 51NC1RS. At the completion of the reset, Relay Word bit 51NC1R asserts. This bit normally will be at logic state 1, when the element is at rest during normal system operation. You can verify the state of the bit using the **TAR** command via a serial port or the front panel. You can force this bit to 1 during element testing using the Level 2 serial port command **RES** or the front-panel RESET51 function under the **OTHER** button.

## Setting Descriptions

**NOTE:** All negative-sequence element pickup settings are in terms of $3I_2$.

This subsection contains setting names, setting ranges, and labels for the overcurrent elements associated with Winding 1. Windings 2 and 3 overcurrent element settings have similar names and labels. All windings have identical setting ranges.

### Winding n Overcurrent Element and Demand Threshold Enables (EOCn)

**Range:** Y, N

Set EOC1 = Y to enable overcurrent elements and demand thresholds for Winding 1. The operation is identical for the other three windings. The relay default is for Winding 1–3 overcurrent elements and demand thresholds to be enabled.

## Combined O/C Element Enable (EOCC)

**Range:** Y, N

Set EOCC = Y to enable combined overcurrent elements. A setting of EOCC = N disables the elements.

## Instantaneous and Definite-Time Element Pickups (50PnmP, 50QnmP, 50NnmP)

**Range:** 1 A: OFF, (0.05–20), A secondary, in 0.01 A steps
5 A: OFF, (0.25–100), A secondary, in 0.01 A steps

**NOTE:** n = Winding 1, 2, or 3; m = Level 1, 2, 3, or 4.

Set pickups for the current level above which you want the elements to assert. As the name of the instantaneous elements suggests, assertion occurs almost immediately after current exceeds the threshold you specify. A definite-time element asserts only after current exceeds the level you specify and after a time delay that you specify with the definite-time delay setting.

## Definite-Time Element Delays (50Pn1D, 50Qn1D, 50Nn1D)

**Range:** 0–16000 cycles, in 0.25-cycle steps

Select a time in cycles that you want definite-time elements to wait before asserting.

## Inverse-Time Element Pickups (51PnP, 51QnP, 51NnP, 51PC1P, 51NC1P)

**Range:** 1 A: OFF, (0.1–3.2), A secondary, in 0.01 A steps
5 A: OFF, (0.5–16), A secondary, in 0.01 A steps

The pickup setting acts as a horizontal scaling factor for an inverse-time curve, because the curve formula uses current multiple of pickup as an input.

Set pickups, and the following three settings defining the time-overcurrent curve, to fit the practices of your organization, coordinate with upstream and downstream devices such as fuses and motors, and accommodate transient and fault conditions.

## Curve Shape Settings (51PnC, 51QnC, 51NnC, 51PC1C, 51NC1C)

**Range:** U1, U2, U3, U4, U5
C1, C2, C3, C4, C5

This setting defines a particular curve equation for an inverse-time curve from among five U.S. (U1–U5) and five IEC (C1–C5) curves.

## Time-Dial Settings (51PnTD, 51QnTD, 51NnTD, 51PC1TD, 51NC1TD)

**Range:** U.S. 0.5–15, IEC 0.05–1, in 0.01 steps

The time-dial setting acts to scale an inverse-time curve vertically, to vary the output timing for a given multiple of pickup.

### Electromechanical Reset Settings (51PnRS, 51QnRS, 51NnRS, 51PC1RS, 51NC1RS)

**Range:** Y, N

This setting defines whether an inverse-time curve emulates an electromechanical disk and resets slowly or instantaneously when current drops below pickup. A setting of Y causes the relay to emulate an electromechanical disk. A setting of N causes a full reset of the time-overcurrent element one cycle after current drops below the element pickup setting.

### Torque-Control Settings (50PnmTC, 50QnmTC, 50NnmTC, 51PnTC, 51QnTC, 51NnTC)

**Range:** SELOGIC control equation

**NOTE:** n = Winding 1, 2, or 3; m = Level 1, 2, 3, or 4.

The torque-control setting is an enable setting for which you have three options: a setting of logical 0 disables the associated definite-time element, a logical 1 permits the element to operate, and SELOGIC control equations allow conditional assertion of the element.

## Application Guidelines

### Transformer Overcurrent Protection

Instantaneous overcurrent elements typically provide high-speed protection for high-current, internal transformer faults and coordinated backup protection for faults on the adjacent bus and/or feeders. You may use inverse-time overcurrent elements to prevent transformer damage due to excessive through currents caused by slow clearing external faults. Thermal and mechanical damage curves should be available from the transformer manufacturer for specific transformer designs. You can consult several references, including the IEEE C37.91, *Guide for Protective Relay Applications to Power Transformers*, that provide generic through-current limitations for various classes of transformers.

Set the SEL-387E instantaneous overcurrent elements to detect high-current faults within the transformer differential protection zone. Use definite-time and time-overcurrent elements to detect lower current faults inside and outside the transformer differential protection zone. Use appropriate delays to coordinate with upstream and downstream protection.

Conventional instantaneous overcurrent elements must be set sufficiently high to avoid tripping on transformer magnetizing inrush current, where peak currents may be many times the transformer full-load current. Transformer magnetizing inrush current contains substantial second-harmonic and fourth-harmonic current and often contains a significant dc component. Unlike conventional electromechanical overcurrent elements, the SEL-387E overcurrent elements ignore all but the fundamental frequency current, making them insensitive to the off-fundamental-frequency content of the magnetizing inrush current. The SEL-387E instantaneous, definite-time, and time-overcurrent elements need only be set with regard to expected load and fault conditions.

Where the SEL-387E is applied to a distribution substation transformer serving load centers, expected load conditions include steady-state load as well as transient conditions caused by hot and cold load pickup.

Hot load pickup inrush occurs when a distribution circuit is energized shortly after being de-energized, such as in a feeder trip-reclose cycle. Hot load pickup inrush current that the SEL-387E may see consists primarily of starting current from motor loads, incandescent and fluorescent lighting load inrush, and resistive heating element inrush. The overall effect is an inrush current several times the normal load current that may last for several seconds.

Cold load pickup inrush occurs when a distribution circuit is energized after being de-energized for a relatively long period of time. The cold load pickup includes many of the same inrush characteristics as hot load pickup but is usually more severe and longer lasting because more thermostatically controlled systems need to satisfy their heating or cooling requirements after the prolonged outage.

For these reasons, overcurrent protection must be tailored to meet the protection requirements for the specific transformer, avoid tripping for various types of nonfault transient conditions, and coordinate with upstream and downstream protection devices. These factors constrain the selection of settings and characteristics for the applied overcurrent protection.

## Overcurrent Element Operating Quantities

The SEL-387E phase overcurrent elements respond to the maximum phase current magnitude, Ip, where Ip is the largest value of |Ia|, |Ib|, and |Ic|. Set phase overcurrent element pickup settings greater than the highest expected load current to avoid tripping on normal load current. You may set the pickup lower if you use torque control.

Because you can use the negative-sequence overcurrent elements to detect phase-to-phase faults, you can set the phase overcurrent elements for three-phase fault detection only. This setting selection improves the ratio of the minimum phase fault current to maximum load current required for secure phase overcurrent relay application.

The negative-sequence elements respond to $|3I_2|$ current, where $3I_2 = Ia + Ib \bullet (1 \angle 240) + Ic \bullet (1 \angle 120)$. The negative-sequence overcurrent elements are uniquely suited to detect phase-to-phase faults and are not sensitive to balanced load.

For a phase-to-phase fault:

$$|I_2| = (\sqrt{3}/3) \bullet |I_P|$$

$$3 \bullet |I_2| = \sqrt{3} \bullet |I_P|$$

$$\therefore \ |3I_2|/|I_P| = 1.73$$

where $I_p$ is the maximum phase current

Thus, the negative-sequence element is 1.73 times more sensitive to phase-to-phase faults than a phase-overcurrent element with the same pickup setting.

While negative-sequence overcurrent elements do not respond to balanced load, they do detect the negative-sequence current present in unbalanced load. For this reason, select an element pickup setting greater than the maximum $3I_2$ current expected due to load unbalance.

When applied on the delta side of a delta-wye transformer, negative-sequence relay elements also provide sensitive fault protection for ground faults on the wye side of the transformer. This is not possible using only phase and residual overcurrent elements.

The residual element responds to $3I_0$ current, where $3I_0$ = Ia + Ib + Ic. Residual overcurrent elements detect ground faults and do not respond to balanced load. The residual element is sensitive to unbalanced load, however, and should be set greater than the maximum $3I_0$ current expected due to load unbalance.

When applied on the delta side of a delta-wye transformer, residual overcurrent elements are insensitive to any type of fault on the wye side of the transformer, and can only detect ground faults on the delta side. This eliminates any coordination constraints with protection devices on the wye side of the transformer, permitting very sensitive residual overcurrent element pickup settings.

## Time-Overcurrent Element Settings

The SEL-387E includes time-overcurrent elements for phase, negative-sequence, and residual current. Each element operates using measured current and five settings that define:

- Pickup current, in secondary amperes
- Operating time curve
- Operating time dial
- Element reset characteristic
- Element external torque-control

To disable a time-overcurrent element, set that element pickup setting = OFF. When the pickup setting is OFF, the relay disables the element and you are not required to enter any remaining settings associated with the element.

The residual overcurrent elements are automatically disabled if the CT for the associated winding is connected in delta (W*n*CT = D). The residual element is disabled because the delta-connected CT cannot deliver any residual operating current.

### Time-Overcurrent Pickup

Set the phase time-overcurrent element to provide sensitive detection and coordinated time-overcurrent protection for balanced and unbalanced fault conditions. Use the negative-sequence time-overcurrent element to provide sensitive detection and coordinated time-overcurrent protection for unbalanced fault conditions including phase-to-phase, phase-to-ground and phase-to-phase-to-ground faults. Set the residual time-overcurrent element to provide sensitive detection and coordinated time-overcurrent protection for phase-to-ground faults.

### Time-Overcurrent Curve and Time-Dial

Select the element curve and time-dial settings individually to coordinate with downstream phase, negative-sequence, and residual time-overcurrent elements. Refer to the time-overcurrent equations and curves in this section for the specific time-overcurrent characteristic equations.

### Time-Overcurrent Element Reset Characteristic

You can set the relay time-overcurrent element to emulate an induction disk relay reset characteristic by setting the 51*xn*RS (*x* = P, Q, or N; *n* = winding number) setting equal to Y. With this setting, the relay emulates the spring-torque-governed disk reset action of an induction time-overcurrent unit. Make this setting when the SEL-387E time-overcurrent element must coordinate with upstream electromechanical time-overcurrent relays during trip-reclose cycles.

When you set 51*xn*RS = N, the relay fully resets the time-overcurrent element one cycle after current drops below the element pickup setting. Make this setting when the relay time-overcurrent element must coordinate with upstream static or microprocessor-based time-overcurrent elements that have fast reset characteristics.

## Instantaneous and Definite-Time Overcurrent Elements

The SEL-387E includes instantaneous and definite-time overcurrent elements for phase, negative-sequence, and residual current. There are three separate phase instantaneous elements, which can be used for various tripping or supervisory functions defined by the user. Each element operates using measured current, a pickup setting and, for the definite-time elements, a time delay setting.

## Instantaneous and Definite-Time Element Pickup and Time Delay Settings

Use the instantaneous overcurrent elements to provide fast tripping for heavy internal transformer faults. Set the element pickup settings high enough to prevent tripping for faults outside the protection zone. Both definite-time and instantaneous phase overcurrent elements are sensitive to load, but should, based on other setting constraints, be set well above the maximum expected loading.

Use the definite-time delayed overcurrent elements to provide fast backup protection for downstream instantaneous elements. Allow sufficient time delay to coordinate with downstream breakers, reclosers, or other protection.

## Overcurrent Element External Torque-Control

The SEL-387E allows you to either enable or block selected overcurrent elements using a SELOGIC control equation. You may wish, for example, to control an overcurrent element using an external contact from a toggle switch, control switch, external directional relay, or recloser. Or, you may wish to use some combination of relay elements to enable or block the overcurrent element. These choices are easily accomplished by creating a SELOGIC control equation that describes what is needed, and storing the equation as the setting for the specific overcurrent element's torque-control variable. For example, to torque control the inverse-time phase overcurrent element for Winding 1, an equation is needed for the setting 51PTC. A few simple possibilities might include:

- To enable the element with an external contact input IN104, set 51PTC = IN104.
- To block the element with this same input, set 51PTC = !IN104 (i.e., NOT IN104).

- To enable the element with IN104, but only if Breaker 3 is open, set 51PTC = IN104*!IN106 (i.e., IN104 AND NOT IN106, where IN106 was previously defined as representing the 52a-3 contact input)
- To enable the element continuously (default setting), set 51PTC = 1.

## Overcurrent Settings for Example Application

The differential settings for the example transformer application (see *Figure 2.16*) were defined earlier. Overcurrent settings were chosen to complete the protection settings package. These settings are listed at the end of this section of the instruction manual.

Before setting of any overcurrent elements can occur, these must be enabled by the configuration settings EOC1 through EOC3. EOC1, EOC2, and EOC3 are set to Y.

For the 230 kV primary winding (Winding 1), three elements are set for overcurrent tripping of 230 kV Breaker 1. The phase definite-time element, 50P11, is set for 20 A secondary, with a five-cycle trip delay time. The phase and negative-sequence inverse-time elements, 51P1 and 51Q1, are set to pick up at 4 A and 6 A, respectively, both using the U2 or U.S. Inverse curve, on Time-Dial 3, with electromechanical reset characteristics. One of the phase instantaneous elements, 50P13, is set very low at 0.5 A, along with 50P23 and 50P33 on the other two windings. These elements are employed in a supervisory mode for the Unlatch Trip function, effectively defining when the breaker has opened by the dropping of phase current below the element setting. The 50P14 phase instantaneous element has been set at 4 A and is used in an internal supervision function (LED targeting).

For the 138 kV secondary winding (Winding 2), tripping is set for the phase and negative-sequence inverse-time elements, 51P2 and 51Q2. These are set at lower pickup values of 3.5 and 5.25 A secondary, using the same curves as Winding 1, but at a higher Time Dial of 3.5. Tripping is done for the 138 kV Breaker 2. Phase instantaneous elements 50P23 and 50P24 are used for supervision, as with Winding 1, set at 0.5 A and 3.5 A, respectively.

For the 13.8 kV tertiary, Winding 3, tripping is by the definite-time element, 50P31, set as an instantaneous element at 7 A and zero time delay, and by the phase inverse-time element 51P3. 51P3 is set for 4 A, at Time Dial 1.3 of the U2 inverse curve, with electromechanical reset. Tripping is for the 13.8 kV Breaker 3. The 50P33 and 50P34 phase instantaneous elements are used for supervision, set at 0.5 A and 4 A.

## Time-Overcurrent Curve Reference Information

tp = operating time in seconds

tr = electromechanical induction-disk emulation reset time in seconds (if electromechanical reset setting is made)

TD = time-dial setting

M = applied multiples of pickup current [for operating time (tp), M > 1; for reset time (tr), M ≤ 1]

U.S. Moderately Inverse Curve: U1

$$tp = TD \bullet \left[0.0226 + \frac{0.0104}{M^{0.02} - 1}\right]$$

$$tr = TD \bullet \left[\frac{1.08}{1 - M^2}\right]$$

U.S. Inverse Curve: U2

$$tp = TD \bullet \left[0.180 + \frac{5.95}{M^2 - 1}\right]$$

$$tr = TD \bullet \left[\frac{5.95}{1 - M^2}\right]$$

U.S. Very Inverse Curve: U3

$$tp = TD \bullet \left[0.0963 + \frac{3.88}{M^2 - 1}\right]$$

$$tr = TD \bullet \left[\frac{3.88}{1 - M^2}\right]$$

U.S. Extremely Inverse Curve: U4

$$tp = TD \bullet \left[0.0352 + \frac{5.67}{M^2 - 1}\right]$$

$$tr = TD \bullet \left[\frac{5.67}{1 - M^2}\right]$$

U.S. Short-Time Inverse Curve: U5

$$tp = TD \bullet \left[0.00262 + \frac{0.00342}{M^{0.02} - 1}\right]$$

$$tr = TD \bullet \left[\frac{0.323}{1 - M^2}\right]$$

IEC Class A Curve (Standard Inverse): C1

$$tp = TD \bullet \left[\frac{0.14}{M^{0.02} - 1}\right]$$

$$tr = TD \bullet \left[\frac{13.5}{1 - M^2}\right]$$

IEC Class B Curve (Very Inverse): C2

$$tp = TD \bullet \left[\frac{13.5}{M - 1}\right]$$

$$tr = TD \bullet \left[\frac{47.3}{1 - M^2}\right]$$

IEC Class C Curve (Extremely Inverse): C3

$$tp = TD \bullet \left[\frac{80.0}{M^2 - 1}\right]$$

$$tr = TD \bullet \left[\frac{80.0}{1 - M^2}\right]$$

IEC Long-Time Inverse Curve: C4

$$tp = TD \bullet \left[\frac{120.0}{M - 1}\right]$$

$$tr = TD \bullet \left[\frac{120.0}{1 - M}\right]$$

IEC Short-Time Inverse Curve: C5

$$tp = TD \bullet \left[\frac{0.05}{M^{0.04} - 1}\right]$$

$$tr = TD \bullet \left[\frac{4.85}{1 - M^2}\right]$$

**Figure 3.22 U.S. Moderately Inverse Curve: U1**

**Figure 3.23 U.S. Inverse Curve: U2**

**Figure 3.24 U.S. Very Inverse Curve: U3**

**Figure 3.25 U.S. Extremely Inverse Curve: U4**

**Figure 3.26 U.S. Short-Time Inverse Curve: U5**

**Figure 3.27 IEC Class A Curve (Standard Inverse): C1**

**Figure 3.28 IEC Class B Curve (Very Inverse): C2**

**Figure 3.29 IEC Class C Curve (Extremely Inverse): C3**

**Figure 3.30 IEC Long-Time Inverse Curve: C4**

**Figure 3.31 IEC Short-Time Inverse Curve: C5**

# Over-/Undervoltage Element

## Application Description

The SEL-387E offers the following overvoltage and undervoltage elements for protection, indication, and control functions:

- Two levels of phase undervoltage
- Two levels of phase-to-phase undervoltage
- One level of positive-sequence undervoltage (V1)
- Two levels of phase overvoltage
- Two levels of residual overvoltage (3V0)
- One level of negative-sequence overvoltage (V2)
- One level of positive-sequence overvoltage
- Two levels of phase-to-phase overvoltage

## Operating Characteristic

Phase overvoltage elements operate using the maximum of the measured phase voltage magnitudes. Residual overvoltage elements operate using the sum of the three-phase voltage (3V0) measurements. The positive- (V1) and negative-sequence (V2) overvoltage elements operate when their respective measurements exceed their set thresholds. The phase-to-phase overvoltage element operates when the maximum phase-to-phase voltage exceeds the set threshold.

Phase undervoltage elements operate using the minimum of the measured phase voltage magnitudes, operating if any single-phase measurement falls below the set threshold. The phase-to-phase undervoltage element operates using the minimum of the measured phase-to-phase voltages. The positive-sequence (V1) undervoltage element operates when the measured positive-sequence voltage falls below the set threshold.

*Figure 3.34* and *Figure 3.35*, respectively, diagram the logic for the overvoltage and undervoltage elements.

**Figure 3.32 Overvoltage Element Logic Diagram**

**Figure 3.33 Undervoltage Element Logic Diagram**

## Setting Descriptions

### Undervoltage Element Enable (E27)

**Range:** Y, N

Set E27 = Y to enable the 27P1, 27P2, 27PP1, 27PP2, and 27V1 undervoltage elements. If you do not need these elements, set E27 = N. When E27 = N, the relay hides the undervoltage elements and you do not need to enter the pickup settings. Settings DELTA_Y and TPVI also affect whether these elements are available.

### Overvoltage Element Enable (E59)

**Range:** Y, N

Set E59 = Y to enable the 59P1, 59P2, 59G1, 59G2, 59Q, 59V1, 59PP1, and 59PP2 overvoltage elements. If you do not need any of these elements, set E59 = N. When E59 = N, the relay hides the overvoltage elements and you do not need to enter the pickup settings. Settings DELTA_Y and TPVI also affect whether these elements are available.

## Phase Undervoltage Element Pickups (27PnP)

**Range:** OFF, 0.1–300.0 V

Set pickups for the phase voltage value below which you want the elements to assert. Note that *n* represents one of two pickup levels, 1 or 2.

## Phase-to-Phase Undervoltage Element Pickups (27PPn)

**Range:** OFF, 0.1–520.0 V

Set pickups for the phase-to-phase voltage value below which you want the elements to assert. Note that *n* represents one of two pickup levels, 1 or 2.

## Positive-Sequence Undervoltage Element Pickup (27V1P)

**Range:** OFF, 0.1–100.0 V

Set the pickup for the positive-sequence voltage value below which you want the element to assert.

## Phase Overvoltage Element Pickups (59PnP)

**Range:** OFF, 0.0–300.0 V

Set pickups for the phase voltage value above which you want the elements to assert. Note that *n* represents one of two pickup levels, 1 or 2.

## Residual Overvoltage Element Pickups (59GnP)

**Range:** OFF, 0.0–300.0 V

Set pickups for the residual voltage value above which you want the elements to assert. Note that *n* represents one of two pickup levels, 1 or 2.

## Negative-Sequence Overvoltage Element Pickup (59QP)

**Range:** OFF, 0.0–100.0 V

Set the pickup for the negative-sequence voltage value above which you want the element to assert.

## Phase-to-Phase Overvoltage Element Pickups (59PPn)

**Range:** OFF, 0.0–520.0 V

Set pickups for the phase-to-phase voltage value above which you want the elements to assert. Note that *n* represents one of two pickup levels, 1 or 2.

## Positive-Sequence Overvoltage Element Pickup (59V1P)

**Range:** OFF, 0.0–100.0 V

Set the pickup for the positive-sequence voltage value above which you want the element to assert.

### Definite-Time Characteristic

None of the elements is equipped with a definite-time delay. If you want a definite-time characteristic, use a SELOGIC control equation variable and corresponding built-in time-delay pickup and dropout timers.

# Frequency Element

## Application Description

The SEL-387E provides six levels of over-/underfrequency elements. Each element can operate as an overfrequency or as an underfrequency element, depending on its pickup setting. If the element pickup setting 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.

## Operating Characteristic

**NOTE:** All frequency elements are disabled if any phase voltage is less than a settable voltage, 27B81P. Use the relay frequency elements for simple abnormal frequency protection.

The SEL-387E determines system frequency using the A-phase voltage.

Six frequency elements are available. The desired number of frequency elements are enabled with the E81 enable setting:

E81 = N (none), 1 through 6

as shown in *Figure 3.34*. Frequency is determined from the voltage connected to voltage terminals VA-N.

**Figure 3.34 Undervoltage Block for Frequency Elements**

Instantaneous frequency element Relay Word bits 81D1–81D6 should not be used for applications other than testing.

**Figure 3.35 Frequency Element Logic**

## Setting Descriptions

### Frequency Element Enable (E81)

**Range:** N, 1–6

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.

### Phase Undervoltage Block (27B81P)

**Range:** 20.00–150.00 Vsec

Set the phase voltage value below which all frequency elements will be disabled.

### Frequency Element Pickups (81DnP)

**Range:** OFF, 40.10–65.00 Hz

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 of 60 Hz, the element operates as an underfrequency element. For a value greater than 60 Hz, the element operates as an overfrequency element. Note that *n* can be one of six levels, 1–6.

### Frequency Element Time Delays (81DnD)

**Range:** 0.04–300.00 seconds

Select a time in seconds that you want frequency elements to wait before asserting. Note that *n* can be one of six levels, 1–6.

# Volts/Hertz Element

## Application Description

Overexcitation occurs when a transformer magnetic core becomes saturated. When this happens, stray flux is induced in nonlaminated components, causing overheating. In the SEL-387E a volts/hertz element detects overexcitation. The SEL-387E provides a sensitive definite-time volts/hertz element, plus a tripping element with a composite operating time. The relay calculates the present transformer volts/hertz as a percent of nominal, based on the present and nominal voltages and frequencies. The settings VNOM and NFREQ define the nominal transformer voltage and frequency, respectively.

## Operating Characteristic

If the torque-control 24TC SELOGIC control equation is true and the present volts/hertz exceed the 24D1P setting, the relay asserts the 24D1 Relay Word bit and starts the 24D1D timer. If the condition remains for 24D1D seconds, the relay asserts the 24D1T Relay Word bit. Typically, you should apply this element as an overexcitation alarm.

For volts/hertz tripping the relay provides a time-integrating element with a settable operating characteristic. You can set the element to operate as an inverse-time element; a user-defined curve element (using the SEL-5806 PC Software); a composite element with an inverse-time characteristic and a

**NOTE:** When TPVI = N, the relay assumes the voltage applied to the A-phase terminal is a line-to-neutral voltage. Therefore, if a phase-to-phase voltage is applied to the A-phase terminal, the volts/hertz element calculation does not result in the expected value.

definite-time characteristic; or as a dual-level, definite-time element. In any case, the element provides a linear reset characteristic with a settable reset time. This element also is supervised by the 24TC torque-control setting.

The volts/hertz tripping element has a percent-travel operating characteristic similar to that employed by an induction-disk time-overcurrent element. This characteristic coincides well with the heating effect that overexcitation has on transformer components.

The element compares the three phase voltages and uses the highest of the values for the volts/hertz magnitude calculations. The relay tracks the frequency over the range of 40.1 to 65 Hz, but only on the A-phase voltage.

Volts/hertz tripping elements are usually used to trip the transformer breaker. Volts/hertz logic is discussed in the following section. For more detail and for examples of tripping SELOGIC control equations, refer to *Section 4: Control Logic*.

*Figure 3.36*, following, diagrams the logic of the volts/hertz elements.

**Figure 3.36 Volts/Hertz Element Logic Diagram**

The figures below are similar to *IEEE C37.102: 1987 IEEE Guide for AC Generator Protection Figure 4.5.4-1 and Figure 4.5.4-2*.

**Figure 3.37 Dual-Level Volts/Hertz Time-Delay Characteristic 24CCS = DD**

**Figure 3.38 Composite Inverse/Definite-Time Overexcitation Characteristic, 24CCS = ID**

## Setting Descriptions

### Recommendations

Collect this information before calculating volts/hertz element settings:

- Transformer manufacturer's overexcitation limit curve
- Transformer nominal phase-to-phase voltage

Select the transformer winding that is most likely to suffer overexcitation. The relay voltage input should be from a source that most reliably reflects that winding voltage.

Use the Level 1 volts/hertz element as an overexcitation alarm. Set 24D1P equal to or greater than 105 percent, but less than the minimum pickup of the Level 2 element. Use a 24D1D time delay of 1.0 second to allow time for correction of an overexcitation condition prior to an alarm.

Use the Level 2 volts/hertz element as an overexcitation tripping element. Select the dual-level, composite inverse, simple inverse, or user-defined operating time characteristic (using the SEL-5806 Curve Designer Software) to conform to the transformer manufacturer's recommendations.

## Phase Potential Connection (DELTA_Y)

Use **SET G <Enter>** to access the DELTA_Y setting. Set DELTA_Y = D for open-delta PT connections (*Figure 2.11*), otherwise, set it to Y. See *Phase Potential Connection (DELTA_Y) on page 6.8* for more information on this type of PT connection.

## Volts/Hertz Protection Enable (E24)

**Range:** (Y, N)

Set E24 = Y to enable volts/hertz protection elements. If you do not need volts/hertz protection, set E24 = N. When E24 = N, the 24TC, 24D1, 24D1T, 24C2, 24C2T, and 24CR Relay Word bits are inactive. The relay hides corresponding settings; you do not need to enter these settings.

## Protected Winding Line-to-Line Voltage (VNOM)

**Range:** (0.20–800.00 kV)

VNOM is the rated transformer line-to-line voltage in kV at the protected winding. Consider the transformer tap when determining this setting. For example, a 345 kV transformer set on the 327.75 kV TAP would have VNOM = 327.75.

## Power Transformer Winding Connection (24WDG)

**Range:** (D, Y)

When three PTs are available, the most common PT winding connection is to connect both HV and LV sides in wye, leaving the power transformer winding connections as the only variable. For wye-connected power transformer windings, the power transformer phase-to-neutral voltage is readily measured through wye-wye connected PTs. Set 24WDG = Y. When the power transformer windings are delta-connected, the relay cannot measure the phase voltage directly, but needs to calculate the voltage values. The relay calculates the differences between the voltages presented to the relay from the wye-wye connected PTs and thus the voltage connected to the power transformer windings. Set 24WDG = D. Thus, voltage values selection to calculate the volts/hertz protection and sequence components is based on the 24WDG selection; phase-to-phase for 24WDG = D and phase-to-neutral for 24WDG = Y.

## Level 1 Volts/Hertz Element Pickup (24D1P)

**Range:** 100–200%

Apply the Level 1 element as an overexcitation alarm. The 24D1P setting defines the percent volts/hertz alarm pickup. The 24D1 Relay Word bit asserts without time delay when the measured transformer volts/hertz exceeds the 24D1P setting.

## Level 1 Time Delay (24D1D)

**Range:** 0.04–400.00 s

The 24D1T Relay Word bit asserts 24D1D seconds after 24D1 assertion if the measured volts/hertz remains greater than the 24D1P setting.

## Level 2 Composite Curve Shape (24CCS)

**Range:** OFF, DD, ID, I, U

The 24CCS setting defines the overexcitation tripping element time-delay characteristic or disables the element when set to OFF.

Set 24CCS = OFF if you do not require Level 2 volts/hertz protection. When 24CCS = OFF, the other Level 2 settings are hidden and do not need to be entered.

### When 24CCS = DD

The element operates with a dual-level, definite-time characteristic.

**Level 2 Pickups (24D2P1 and 24D2P2)**

**Range:** 100–200% (for 24D2P1)

**Range:** 101–200% (for 24D2P2)

The SEL-387E asserts the 24C2 Relay Word bit without time delay when the transformer volts/hertz exceeds either the 24D2P1 or 24D2P2 setting.

**Level 2 Time-Delays (24D2D1 and 24D2D2)**

**Range:** 0.04–400.00 s

If the volts/hertz percentage is greater than the 24D2P1 setting, but less than the 24D2P2 setting, the relay asserts the 24C2T Relay Word bit in 24D2D1 seconds.

When the volts/hertz percentage is greater than the 24D2P2 setting, the relay asserts the 24C2T Relay Word bit in 24D2D2 seconds. The setting 24D2P1 must be less than the setting for 24D2P2.

### When 24CCS = ID

The element operates with a composite inverse-time and definite-time characteristic.

**Level 2 Inverse-Time Pickup (24IP)**

**Range:** 100–200%

The 24IP setting defines the pickup point of the inverse-time portion of the operating time curve. The SEL-387E asserts the 24C2 Relay Word bit without time delay when the transformer volts/hertz exceeds the 24IP setting.

**Level 2 Inverse-Time Curve (24IC)**

**Range:** 0.5, 1.0, 2.0

The 24IC setting defines the element operating time curve shape.

**Level 2 Inverse-Time Factor (24ITD)**

**Range:** 0.10–10.0 s

The 24ITD setting defines the inverse element operate time in seconds when the transformer volts/hertz equals 200 percent.

**Level 2 Pickup Two (24D2P2)**

**Range:** 101–200%

**Level 2 Time-Delay Two (24D2D2)**

**Range:** 0.04–400.00 s

The 24D2P2 and 24D2D2 settings define the pickup and definite operating time of the definite-time portion of the composite curve. The relay asserts the 24C2T Relay Word bit in time defined by the inverse curve when the measured apparatus volts/hertz is less than the 24D2P2 setting.

The relay asserts the 24C2T Relay Word bit in time defined by the 24D2D2 definite-time settings when the measured apparatus volts/hertz is greater than the 24D2P2 setting. The setting for 24IP must be less than the setting for 24D2P2.

## When 24CCS = I

The element operates with a simple inverse-time characteristic, depending on the 24IC setting.

The relay asserts the 24C2T Relay Word bit in time defined by the inverse curve when the measured apparatus volts/hertz exceeds the 24IP setting.

**Level 2 Inverse-Time Pickup (24IP)**

Range: 100–200%

The 24IP setting defines the pickup point of the inverse-time portion of the operating time curve. The SEL-387E asserts the 24C2 Relay Word bit without time delay when the measured apparatus volts/hertz exceeds the 24IP setting.

**Level 2 Inverse-Time Curve (24IC)**

**Range:** 0.5, 1.0, 2.0

The 24IC setting defines the curve shape.

**Level 2 Inverse-Time Factor (24ITD)**

**Range:** 0.10–10.0 s

The 24ITD setting defines the inverse element operate time in seconds when the transformer volts/hertz equals 200 percent.

## When 24CCS = U

The element operates with a user-defined inverse-time characteristic. The user curve should be set using SEL-5806 PC software. This program handles individual mapping of points to make a curve that matches any transformer characteristic. It also handles all relay communication by either uploading the current curve or programming a new curve.

**Level 2 Inverse-Time Pickup (24IP)**

**Range:** 100–200%

The 24IP setting defines the pickup point of the user-defined operating time curve. The SEL-387E asserts the 24C2 Relay Word bit without time delay when the transformer volts/hertz exceeds the 24IP setting. The relay asserts the 24C2T Relay Word bit in time defined by the user-defined curve when the measured apparatus volts/hertz exceeds the user-defined setting.

## When 24CCS = DD, ID, I, or U

**Level 2 Reset Time (24CR)**

**Range:** 0.04–400.00 s

The 24CR setting defines the composite element reset time. When the element times out to trip, it will fully reset 24CR seconds after the applied volts/hertz drops below the element pickup setting. The element reset characteristic is linear, so if the element times 60 percent toward a trip, it will fully reset (0.6 • 24CR) seconds after the applied volts/hertz drops below the element pickup setting. When the element is reset, the relay asserts the 24CR Relay Word bit.

**24 Element Torque Control (24TC)**

**Range:** SELOGIC control equation

Both volts/hertz elements are disabled when the 24TC SELOGIC control equation equals logical 0. The elements are allowed to operate when the 24TC SELOGIC control equation equals logical 1, the default setting. You can add other supervisory conditions if you need these for your application.

## Volts/Hertz Setting Reference Information

$$t_p = \frac{24ITD}{\left(\frac{\left(\frac{Vp-p \bullet PTR}{freq} \bullet \frac{NFREQ}{VNOM \bullet 10^3}\right)}{\frac{24IP}{100\%}} - 1\right)^{0.5}} \text{ seconds if } V/Hz <= 1.5 \bullet 24IP$$

tp = 1.414 • 24ITD if V/Hz > 1.5 • 24IP

**Figure 3.39 Volts/Hertz Inverse-Time Characteristic, 24IC = 0.5**

$$t_p = \frac{24ITD}{\left(\frac{\left(\frac{\sqrt{3} \bullet V_{sec} \bullet PTR}{freq} \bullet \frac{NFREQ}{VNOM \bullet 10^3}\right)}{\frac{24IP}{100\%}} - 1\right)^1} \text{ seconds if } V/Hz <= 1.5 \bullet 24IP$$

$$tp = 2.00 \bullet 24ITD \text{ if } V/Hz > 1.5 \bullet 24IP$$

**Figure 3.40 Volts/Hertz Inverse-Time Characteristic, 24IC = 1**

$$t_p = \frac{24ITD}{\left(\frac{\left(\frac{\sqrt{3} \bullet V_{sec} \bullet PTR}{freq} \bullet \frac{NFREQ}{VNOM \bullet 10^3}\right)}{\frac{24IP}{100\%}} - 1\right)^2} \text{ seconds if } V/Hz <= 1.5 \bullet 24IP$$

$$tp = 4.00 \bullet 24ITD \text{ if } V/Hz > 1.5 \bullet 24IP$$

**Figure 3.41 Volts/Hertz Inverse-Time Characteristics, 24IC = 2**

# Section 4

# Control Logic

## Overview

This section explains the settings and operation of:

- Optoisolated inputs (IN101–IN106, IN201–IN208)
- Output contacts (OUT101–OUT107, ALARM, OUT201–OUT212)
- Remote control switches (Remote Bits RB1–RB16)
- Multiple setting groups (Group switching settings SS1–SS6)
- SELOGIC® control equation sets (1 through 3) variables (Timed variables and latch bits)
- LED targeting logic
- Trip and Close logic
- SELOGIC control equations (General discussion)
- Relay Word bits

The above items constitute the principal logic functions of the relay. While the protective elements (overcurrent elements and differential elements) have fixed internal logic, the availability of Relay Word bits and the use of SELOGIC control equations for many of the relay settings permit the user to customize how the protection functions interface with the user's control schemes and overall philosophy of operation.

Relay Word bits and SELOGIC control equation settings examples are used throughout this section. A complete listing of the Relay Word and explanation of the bit names are included at the end of this section, along with a discussion of SELOGIC control equations in general.

## Optoisolated Inputs

Relay Word bits IN101–IN106 and IN201–IN208 (interface board) follow the states of the optoisolated level-sensitive inputs having the same names. To assert an input, apply rated control voltage to the appropriate terminal pair. As noted in *Section 1: Introduction and Specifications* and *Section 2: Installation*, these inputs have a specific voltage range for operation, and a dropout voltage value below which the input will deassert. The inputs are not polarity sensitive; either terminal can be positive, the other negative.

### Input Functions

There are *no* optoisolated input settings such as:

IN101 =

IN102 =

Optoisolated inputs receive their function by how their corresponding Relay Word bits are used in SELOGIC control equations. Remember that any input Relay Word bit name will always appear on the right side of any SELOGIC control equation, as shown below.

### Factory Settings Examples

Relay Word bit IN101 is used in the factory settings for the SELOGIC control equation circuit breaker status setting:

52A1 = IN101

Connect input IN101 to a 52a circuit breaker auxiliary contact for the Winding 1 breaker to provide the relay information on the position of the breaker's contacts.

If a 52b circuit breaker auxiliary contact were connected to input IN101, the setting could be changed to:

52A1 = !IN101 [!IN101 = NOT(IN101)]

Input IN101 may also be used in other SELOGIC control equations. Any equation which requires information on the open or closed status of Breaker 1 would use the IN101 Relay Word bit as this indication.

# Local Control Switches

The local control switch feature of this relay replaces traditional panel-mounted control switches. Operate the 16 local control switches using the front-panel keyboard/display (see *Section 8: Front-Panel Operation*).

# Remote Control Switches

Remote control switches are operated via the serial communications port only (see *Section 7: Communications*).

The switch representation in this figure is derived from the standard:

Graphics Symbols for Electrical and Electronics Diagrams
IEEE Std 315-1975, CSA Z99-1975, ANSI Y32.2-1975,
4.11 Combination Locking and Nonlocking Switch, Item 4.11.1

**Figure 4.1 Remote Control Switches Drive Remote Bits RB1 Through RB16**

The outputs of the remote control switches in *Figure 4.1* are Relay Word bits RB*n* (*n* = 1 to 16), called remote bits. Use these remote bits in SELOGIC control equations.

Any given remote control switch can be put in one of the following three positions via the serial port commands shown. Begin with the **CON *n*** (Control Remote Bit *n*) command, then specify:

**SRB *n*** (Set Remote Bit *n*) ON (logical 1)

**CRB *n*** (Clear Remote Bit *n*) OFF (logical 0)

**PRB *n*** (Pulse Remote Bit *n*) MOMENTARY (logical 1 for one-eighth cycle)

## Remote Bit Application

With SELOGIC control equations, the remote bits can be used in applications where you want certain logic to be remotely enabled or disabled, depending on operating conditions of the system. Also, remote bits can be used in operating Latch Bit control switches in the additional SELOGIC control equation Sets 1 through 3. Pulse (momentarily operate) the remote bits for this application. Latch Bits are discussed later in this section.

## Remote Bit States Not Retained When Power Is Lost

The states of the remote bits (Relay Word bits RB1 through RB16) are not retained if power to the relay is lost and then restored. The remote control switches always come back in the OFF position (corresponding remote bit is deasserted to logical 0) when power is restored to the relay.

## Remote Bit States Retained When Settings Changed or Active Setting Group Changed

The state of each remote bit (Relay Word bits RB1 through RB16) is retained if relay settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed. If a remote control switch is in the ON position (corresponding remote bit is asserted to logical 1) before a setting change or an active setting group change, it comes back in the ON position (corresponding remote bit is still asserted to logical 1) after the change.

If settings are changed for a setting group other than the active setting group, there is no interruption of the remote bits (the relay is not momentarily disabled).

# Multiple Setting Groups

The relay has six (6) independent setting groups. Each group contains Configuration Settings, General Data, Differential Elements, Overcurrent Elements, Voltage Elements, Volts-per-Hertz Elements, Frequency Elements, Miscellaneous Timers, SELOGIC control equation Sets 1 through 3, Trip Logic, Close Logic, Event Report Triggering, and Output Contact Logic. These settings can be viewed or changed via the **SHO *n*** and **SET *n*** commands. The settings for selecting which of the six groups is to be active is contained in the Global settings area (**SHO G/SET G** commands).

## 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:

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.

## Selecting the Active Setting Group

The active setting group is selected with:

- SELOGIC control equation settings SS1 through SS6,
- the serial port **GRO n** command (see *Section 7: Communications*), or
- the front-panel GROUP pushbutton (see *Section 8: Front-Panel Operation*).

SELOGIC control equation settings SS1 through SS6 have priority over the serial port **GRO *n*** command and the front-panel GROUP pushbutton in selecting the active setting group. Within the SS1 through SS6 settings the currently active group setting SS*n* has priority over the other group SS*n* variables.

## Operation of SELOGIC Control Equation Settings SS1 through SS6

The Global settings contain the set of SELOGIC control equation settings SS1 through SS6. If the SELOGIC control equation for setting SS*n* (*n* = 1 to 6) is TRUE (logical state 1), the relay is instructed to go to, or remain in, Setting Group *n*.

**Table 4.1 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 Setting Group 5 as the active setting group, after waiting for qualifying time setting TGR to expire:

TGR Group Change Delay Setting (settable from 0 to 900 seconds)

In this example TGR qualifies the assertion of setting SS5 before it can change the active setting group.

## Operation of Serial Port GROUP Command and Front-Panel GROUP Pushbutton

SELOGIC control equation settings SS1 through SS6 have priority over the serial port **GRO *n*** command and the front-panel GROUP pushbutton in selecting the active setting group. If any *one* of SS1 through SS6 asserts to logical 1, neither the serial port **GRO *n*** command nor the front-panel GROUP pushbutton can be used to switch the active setting group. But if SS1 through SS6 *all* deassert to logical 0, the serial port **GRO *n*** command or the front-panel GROUP pushbutton can be used to switch the active setting group.

See *Section 7: Communications* for more information on the serial port **GRO *n*** command. See *Section 8: Front-Panel Operation* for more information on the front-panel GROUP pushbutton.

## Relay Disabled Momentarily During Active Setting Group Change

The relay is disabled for a *few power system cycles* while the relay is in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in specific logic description.

## Active Setting Group Switching Example

Previous SEL relays (e.g., SEL-321 Relay and SEL-251 Relay) have had multiple settings groups controlled by the assertion of three optoisolated inputs (e.g., IN101, IN102, and IN103) in different combinations as shown in *Table 4.2*.

**Table 4.2 Active Setting Group Switching Input Logic** (Sheet 1 of 2)

| Input States | | | Active Setting Group |
|---|---|---|---|
| IN103 | IN102 | IN101 | |
| 0 | 0 | 0 | Remote |
| 0 | 0 | 1 | Group 1 |
| 0 | 1 | 0 | Group 2 |
| 0 | 1 | 1 | Group 3 |
| 1 | 0 | 0 | Group 4 |

**Table 4.2 Active Setting Group Switching Input Logic** (Sheet 2 of 2)

| Input States | | | Active Setting Group |
|---|---|---|---|
| IN103 | IN102 | IN101 | |
| 1 | 0 | 1 | Group 5 |
| 1 | 1 | 0 | Group 6 |

The SEL-387E Relay can be programmed to operate similarly. Use three optoisolated inputs to switch between the six setting groups in the SEL-387E. In this example, optoisolated inputs IN101, IN102, and IN103 on the relay are connected to a rotating selector switch in *Figure 4.2*.

**Figure 4.2 Rotating Selector Switch for Active Setting Group Selection**

The selector switch has multiple internal contacts arranged to assert inputs IN101, IN102, and IN103, dependent on the switch position. As shown in *Table 4.3*, as the selector switch is moved from one position to another, a different setting group is activated. The logic in *Table 4.2* is implemented in the SELOGIC control equation settings in *Table 4.3*.

**Table 4.3 SELOGIC Control Equation Settings for Rotating Selector Switch**

| | |
|---|---|
| SS1 = !IN103 * !IN102 * IN101 | = NOT(IN103) * NOT(IN102) * IN101 |
| SS2 = !IN103 * IN102 * !IN101 | = NOT(IN103) * IN102 * NOT(IN101) |
| SS3 = !IN103 * IN102 * IN101 | = NOT(IN103) * IN102 * IN101 |
| SS4 = IN103 * !IN102 * !IN101 | = IN103 * NOT(IN102) * NOT(IN101) |
| SS5 = IN103 * !IN102 * IN101 | = IN103 * NOT(IN102) * IN101 |
| SS6 = IN103 * IN102 * !IN101 | = IN103 * IN102 * NOT(IN101) |

The REMOTE switch position de-energizes all relay inputs, thus placing all of the SS*n* variables in state 0. With none of the SS*n* variables asserted, the **GRO *n*** command, or the **GROUP** pushbutton on the front panel, can be used to change the setting group. With the switch in any other position, 1 through 6, the **GRO *n*** and GROUP functions will not effect a group change.

The setting TGR, the group change delay setting, should be set long enough so that the switch, as it is rotated from one position to another, will not remain at any intermediate position long enough to make any setting group change. For example, in rotating from position 1 to position 5, the switch must pass through positions 2, 3, and 4. It should not remain in 2, 3, or 4 for longer than TGR during this process, or it may produce multiple group changes before it finally gets to position 5.

The settings in *Table 4.3* are made in the Global settings area.

## CHSG Relay Word Bit Asserts During Setting Group Changes

The Relay Word bit CHSG is asserted whenever a setting group change is in process. It is defined in *Table 4.9* and *Table 4.10* as "Timing to change setting groups." When group changes are initiated through one of the SS*n* SELOGIC control equation settings, CHSG is asserted as soon as the new SS*n* bit is asserted and the relay has made the decision to change groups. It deasserts when the SG*n* bit for the new group agrees with the SS*n* bit, indicating that the relay has changed to the newly requested group number. For example, assume the relay is in Group 1. The active group bit SG1 equals one, while other SG*n* bits are zero. All of the SS*n* bits are also zero. SS4 is asserted, requesting a change to Group 4. Because SS1 (same group as the active group) is not asserted, the group change process is initiated, and CHSG is asserted at the same time as SS4. After the group change is made, SG1 will deassert and SG4 will assert, indicating the relay is now in Group 4. When this agreement of SS4 and SG4 occurs, CHSG will deassert to indicate the relay is no longer in the process of changing groups.

When the active group bit SG*n* and its associated SS*n* bit are both asserted, for example SG1 and SS1, the relay does not respond to the assertion of a new SS*n* bit, such as SS3, and no group change will occur. Similarly, the CHSG bit will not assert along with SS3, because the SG1 and SS1 bits are in agreement. This agreement acts like a continuous "reset" applied to the CHSG bit.

In applications where a system-related condition requires that a change of setting groups must be done quickly and automatically, this would likely be accomplished via a contact input to the relay, which would assert an SS*n* bit. In such cases, you may want to immediately block some relay elements as soon as the change is needed to prevent misoperation. This could easily be done via the CHSG bit. CHSG could be used, for example, to supervise the tripping variable for differential trips. The default TR4 setting is TR4 = 87R + 87U; this could be changed to TR4 = 87R*!CHSG + 87U*!CHSG. CHSG optimizes (in this case minimizes) the amount of time to block TR4, because CHSG asserts exactly when the change of groups is needed, and deasserts exactly when the change has taken place.

For setting group changes that do not make use of the SS*n* bits, namely those using the **GRO *n*** serial port command or the `GROUP` front-panel pushbutton, CHSG asserts about two cycles after the change command is received and deasserts shortly after the group change is made. For these cases, CHSG does not overlap the desired time period quite as precisely as when the SS*n* bits are used, but group changes initiated manually through the serial port or front panel are inherently not as time critical, so a few cycles difference is not likely to matter as much, if at all.

## Active Setting Group Retained for Power Loss, Settings Change

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, it comes back with the same setting group active when power is restored.

If settings are changed (for the active setting group or one of the other setting groups), the active setting group is retained.

If settings are changed for a setting group other than the active setting group, no interruption of the active setting group occurs (the relay is not momentarily disabled).

If the 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.

### Note: Make Active Setting Group Switching Settings With Care

The active setting group is stored in nonvolatile memory so it can be retained during power loss or settings change. The nonvolatile memory is rated for a finite number of "writes" for all setting group changes. Exceeding the limit can result in an EEPROM self-test failure. *An average of one setting group change per day can be made for a 25-year relay service life.*

*This requires that SELOGIC control equation settings SS1 through SS6 be set with some care.* Settings SS1 through SS6 cannot result in continuous cyclical changing of the active setting group. Time setting TGR qualifies settings SS1 through SS6 before changing the active setting group.

# SELOGIC Control Equation Sets (1 Through 3) Variables

Each Setting Group (1 through 6) has three sets of SELOGIC control equation variables for use in constructing control equations. In the SEL-387E, these variables are of two types: timed variables and latch bits. The variables are processed in the order in which they appear in the Settings Sheets. If variables that appear earlier are used as inputs to later variables, the processing of both will occur within the same processing interval. If a later variable is an input to an earlier variable, the scheme output will be delayed one processing interval.

The SELOGIC control equation sets must be enabled by Group settings ESLS1, ESLS2, and/or ESLS3, in the configuration settings.

There are a total of 16 timed variables and 16 latch bits available to the user. The three SELOGIC control equation sets have different mixes of variable types, as shown below in *Table 4.4*.

**Table 4.4 SELOGIC Control Equation Variable Mix by Set**

| SELOGIC Control Equation Set | Timed Variables | Latch Bits |
|---|---|---|
| 1 | 4 | 4 |
| 2 | 4 | 4 |
| 3 | 8 | 8 |

The format of the setting names for these variables is as follows:

| | | |
|---|---|---|
| Timed Variable Name: | S*n*V*m* | (*n* = Set Number; *m* = Variable Number) |
| Timer Pickup Delay: | S*n*V*m*PU | (cycles) |
| Timer Dropout Delay: | S*n*V*m*DO | (cycles) |
| Set Latch Bit: | S*n*SLT*m* | |
| Reset Latch Bit: | S*n*RLT*m* | (Reset takes precedence over Set) |

Timers S*n*V*m*PU and S*n*V*m*DO have a setting range of about 4.63 hours:

0.000 through 999,999.000 cycles in 0.125-cycle increments

The two types of variables are discussed in the following paragraphs.

## Variables/Timers

*Figure 4.3* shows the logic for the timed variables. A SELOGIC control equation defines the variable S*n*V*m*. When this equation is true, the Relay Word bit S*n*V*m* is asserted. If S*n*V*m* remains true for the length of the S*n*V*m*PU setting, in cycles, the timer output asserts the Relay Word bit S*n*V*m*T (variable timed out). If S*n*V*m* deasserts, S*n*V*m*T will deassert S*n*V*m*DO cycles later.

**Figure 4.3 Timed Variables in SELOGIC Control Equation Sets**

There are 16 variables of this type spread through the three SELOGIC control equation sets.

### Timers Reset When Power Is Lost, Settings Are Changed, or Active Setting Group Is Changed

If power is lost to the relay, settings are changed (for the active setting group), or the active setting group is changed, the SELOGIC control equation variables/timers are reset. Relay Word bits S*n*V*m* and S*n*V*m*T are reset to logical 0 and corresponding timer settings S*n*V*m*PU and S*n*V*m*DO load up again after power restoration, settings change, or active setting group switch.

## Latch Control Switches

The SELOGIC control equations latch bit feature of this relay replaces latching relays. Traditional latching relays maintain their output contact state-they are not dependent on dc voltage to maintain their output contact state. For example, if a latching relay output contact is closed and then dc voltage is lost to the panel, the latching relay output contact remains closed.

The state of a traditional latching relay output contact is changed by pulsing the latching relay inputs (see *Figure 4.4*). Pulse the set input to close ("set") the latching relay output contact. Pulse the reset input to open ("reset") the latching relay output contact. Often the external contacts wired to the latching relay inputs are from remote control equipment (e.g., SCADA, RTU, etc.).

**Figure 4.4 Traditional Latching Relay**

The latch bits in the SEL-387E provide latching relay type functions (*Figure 4.5*).

**Figure 4.5 Latch Bits in SELOGIC Control Equation Sets**

The output of the latch bit logic is a Relay Word bit S*n*LT*m*. The bit is set by application of S*n*SLT*m* (Set LaTch bit), and reset by the application of S*n*RLT*m* (Reset LaTch bit). The Set/Reset values come from the logical state of the SELOGIC control equations stored for these two settings. These latch bits may be used in SELOGIC control equations, wherever a latching function is required.

If setting S*n*SLT*m* (Set) asserts to logical 1, latch bit S*n*LT*m* asserts to logical 1 and seals itself via the OR and AND gates. If setting S*n*RLT*m* (Reset) asserts to logical 1, the seal-in is broken and latch bit S*n*LT*m* deasserts to logical 0. If both settings S*n*SLT*m* and S*n*RLT*m* assert to logical 1, setting S*n*RLT*m* (Reset) takes precedence, and latch bit S*n*LT*m* deasserts to logical 0.

## Latch Bit Behavior for Power Loss, Settings Change, Active Group Change

If power to the relay is lost and then restored, the states of the latch bits remain unchanged. This is done by retaining the latest states of the latch bits in EEPROM, where they can be recovered when the relay turns on.

If settings are changed in one of the nonactive setting groups, the states of the latch bits remain the same.

If settings are changed in the active setting group, or if a new setting group is selected to be the active group, the states of the latch bits may change. When the active group changes are enabled in the relay, the latch bits will respond to the states of the S*n*SLT*m* (Set) and S*n*RLT*m* (Reset) equations, in the manner discussed above for *Figure 4.5*. The new latch bit states thus depend on the original state of the latch bit and on the effects of the user changes upon the set and reset equations.

The net effect is that the latch bits in the SEL-387E behave exactly like traditional latching relays.

### Note: Make Latch Bit Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss, settings change, or active setting group change. The nonvolatile memory is rated for a finite number of "writes" for all cumulative latch bit state changes. Exceeding the limit can result in an EEPROM self-test failure. *An average of 70 latch bit changes per day can be made for a 25-year relay service life.*

# Output Contacts

SELOGIC control equation settings control Relay Word bits having the same names. These Relay Word bits in turn control the output contacts (interface board). Alarm logic/circuitry controls the ALARM output contact.

## Factory Settings Example

In the factory SELOGIC control equation settings, all seven standard main board output contacts are used:

| | |
|---|---|
| OUT101 = TRIP1 | Used to trip Breaker 1 |
| OUT102 = TRIP2 | Used to trip Breaker 2 |
| OUT103 = TRIP3 | Used to trip Breaker 3 |
| OUT104 = TRIP4 | Used to energize 86 device for tripping Breakers 1 through 3 |
| OUT105 = CLS1 | Used to close Breaker 1 |
| OUT106 = CLS2 | Used to close Breaker 2 |
| OUT107 = CLS3 | Used to close Breaker 3 |

## Operation of Output Contacts for Different Output Contact Types

### Output Contacts OUT101 through OUT107

The execution of the serial port command **PULSE *xxx*** (*xxx* = OUT101–OUT107, OUT201–OUT212), asserts the corresponding Relay Word bit (e.g., OUT104) to logical 1, for one or more seconds as defined by the user. The assertion of SELOGIC control equation setting OUT*m* (*m* = 101–107, 201–212) to logical 1 also asserts the corresponding Relay Word bit OUT*m* to logical 1.

The assertion of Relay Word bit OUT*m* to logical 1 causes the energization of the corresponding output contact OUT*m* coil. Depending on the contact type (a or b), the output contact closes or opens. An “a” type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A “b” type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized. Solder jumpers **JMP22** through **JMP29** (main board) and **JMP17** through **JMP28** (interface board) permit the user to configure any OUT*m* contact to either an “a” or “b” type. OUT101 through OUT107 are factory configured as type “a,” as are OUT201 through OUT212 if the additional interface board is ordered.

The state of OUT*m* remains the same while a setting change is in progress. However, once the new settings are enabled, the SELOGIC control equation setting for OUT*m* will determine the new state of OUT*m*.

OUT107 coil operation may be set to follow that of the ALARM contact by setting jumper **JMP23** in the left position on the main board. OUT107 then will not respond to Relay Word bit OUT107. The OUT107 contact configuration can be set as “a” or “b,” as noted above. See *Section 2: Installation* for more information.

### ALARM Output Contact

When the relay is functioning properly, the alarm logic/circuitry keeps the ALARM output contact coil energized. The type “b” ALARM output contact is normally held open. Solder jumper **JMP21** may also be configured by the user for a type “a” contact, if desired.

To verify ALARM output contact functionality, execute the serial port command **PULSE NOTALM**. Execution of this command momentarily de-energizes the ALARM output contact coil.

The Relay Word bit NOTALM (not ALARM) is asserted to logical 1, and the ALARM output contact coil is energized, when the SEL-387E is operating correctly. When the serial port command **PULSE NOTALM** (or front-panel CNTRL ALARM) is executed, the NOTALM Relay Word bit momentarily deasserts to logical 0. Also, when the relay enters Access Level 2 or Access Level B, or a settings change is made, the NOTALM Relay Word bit momentarily deasserts to logical 0. When NOTALM is zero, the ALARM output contact coil is de-energized momentarily and the “b” contact closes. The ALARM contact also closes when a loss of power occurs.

## Rotating Default Display

The rotating default display on the relay front panel replaces indicating panel lights. Traditional indicating panel lights are turned on and off by circuit breaker auxiliary contacts, front-panel switches, SCADA contacts, etc. See *Section 8: Front-Panel Operation* for details.

# LED Targeting Logic

The SEL-387E has 16 LEDs on the front panel. One (**EN**) is dedicated to indication of the relay's operational condition. Twelve are dedicated to specific targeting functions. Three (**LEDA**, **LEDB**, and **LEDC**) have default targeting logic, but are fully programmable by the user.

The states of the 12 dedicated LEDs (all but **EN**, **A**, **B**, and **C**) are stored in nonvolatile memory. If power is lost to the relay, these 12 targets will be restored to their last state when the relay power is restored. **EN** responds only to internal self-test routines, while **A**, **B**, and **C** respond to the present state of their respective Global SELOGIC control equation settings.

The array of LEDs is shown below in *Figure 4.6*.

**Figure 4.6 SEL-387E Relay Front-Panel LEDs**

*Table 4.5* describes the basic targeting functions associated with each of the 16 LEDs.

**Table 4.5 LED Assignments**

| LED | Legend | Description |
|---|---|---|
| 1 | EN | Relay enabled |
| 2 | TRIP[a] | Relay trip |
| 3 | INST[a] | Instantaneous trip |
| 4 | 87-1[a] | Differential element 1 asserted at, or 1 cycle after, rising edge of trip |
| 5 | 87-2[a] | Differential element 2 asserted at, or 1 cycle after, rising edge of trip |
| 6 | 87-3[a] | Differential element 3 asserted at, or 1 cycle after, rising edge of trip |
| 7 | 81[a] | O/U frequency element asserted at, or 1 cycle after, rising edge of trip |
| 8 | 24[a] | Volts/hertz element asserted at, or 1 cycle after, rising edge of trip |
| 9 | A | A-phase involved in the fault (Programmable LEDA) |
| 10 | B | B-phase involved in the fault (Programmable LEDB) |
| 11 | C | C-phase involved in the fault (Programmable LEDC) |
| 12 | N[a] | Residual element asserted at, or 1 cycle after, rising edge of trip |
| 13 | W1[a] | Winding 1 overcurrent asserted at, or 1 cycle after, rising edge of trip |
| 14 | W2[a] | Winding 2 overcurrent asserted at, or 1 cycle after, rising edge of trip |
| 15 | W3[a] | Winding 3 overcurrent asserted at, or 1 cycle after, rising edge of trip |
| 16 | 50[a]/51[a] | O/C element asserted at, or 1 cycle after, rising edge of trip |

[a] Indicates nonvolatile targets.

The operation of each LED will be discussed in the following paragraphs.

## LED 1: EN—Relay Enabled

LED 1 illuminates only when the relay is fully enabled and ready for service. It will turn off if the relay should become disabled by certain critical failure or alarm conditions. LED 1 is the only green LED of the 16; the remaining LEDs are red.

## LED 2: TRIP—Relay Trip

LED 2 illuminates at the rising edge of any of the four trip elements, TRIP1 through TRIP4. It remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

## LED 3: INST—Instantaneous Trip

This LED will illuminate if any instantaneous element present in the TR1 through TR4 settings is asserted at the rising edge of the trip or one cycle later. Instantaneous elements include any of the overcurrent elements indicated as "50***", the volts/hertz elements 24D1 and 24C2, and the frequency elements 81D*n* ($1 \leq n \leq 6$), as well as the 87R and 87U differential elements. LED 3 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

## LED 4: 87-1—Differential Element 1

This LED will illuminate if the differential elements 87R or 87U are present in the TR1 through TR4 settings, and Relay Word bits 87R1 and 87R, or 87U1, are found to be asserted at the rising edge of any trip or one cycle later. If so, the 87E1 bit is also set. LED 4 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

## LED 5: 87-2—Differential Element 2

This LED will illuminate if the differential elements 87R or 87U are present in the TR1 through TR4 settings, and Relay Word bits 87R2 and 87R, or 87U2, are found to be asserted at the rising edge of any trip or one cycle later. If so, the 87E2 bit is also set. LED 5 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

## LED 6: 87-3—Differential Element 3

This LED will illuminate if the differential elements 87R or 87U are present in the TR1 through TR4 settings, and Relay Word bits 87R3 and 87R, or 87U3, are found to be asserted at the rising edge of any trip or one cycle later. If so, the 87E3 bit is also set. LED 6 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

## LED 7: 81—Over-/Underfrequency Element Trip

This LED will illuminate if any over-/underfrequency element present in the TR1 through TR4 settings is asserted at the rising edge of any trip or one cycle later. Over-/underfrequency elements include 81D*n* and 81D*n*T ($1 \leq n \leq 6$). LED 8 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

## LED 8: 24—Volts-per-Hertz Element

This LED will illuminate if any volts/hertz element present in the TR1 through TR4 settings is asserted at the rising edge of any trip or one cycle later. Volts/hertz elements include 24D1, 24D1T, 24C2, and 24C2T. LED 7 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

## LED 9: A—A-Phase Involved in the Fault (Programmable LEDA)

**LED 9** is programmable via the LEDA SELOGIC control equations Global setting. It is updated each processing interval. If LEDA is true, **LED 9** is illuminated. Otherwise, it is reset. The factory default setting is LEDA = OCA + 87E1.

Relay Word bit OCA indicates A-phase overcurrent during the fault. It is derived by first checking which winding "W*n*" LED is lit, then asserting if the associated 50A*n*4 overcurrent element bit is asserted, or if the magnitude of the IAW*n* phase current is greater than or equal to the magnitudes of IBW*n* and ICW*n*.

Relay Word bit 87E1 indicates differential element 87-1 operation, and follows **LED 4** operation (see *LED 4: 87-1—Differential Element 1 on page 4.14*).

## LED 10: B—B-Phase Involved in the Fault (Programmable LEDB)

**LED 10** is programmable via the LEDB SELOGIC control equation Global setting. It is updated each processing interval. If LEDB is true, **LED 10** is illuminated. Otherwise, it is reset. The factory default setting is LEDB = OCB + 87E2.

Relay Word bit OCB indicates B-phase overcurrent during the fault. It is derived by first checking which winding "W*n*" LED is lit, then asserting if the associated 50B*n*4 overcurrent element bit is asserted, or if the magnitude of the IBW*n* phase current is greater than or equal to the magnitudes of IAW*n* and ICW*n*.

Relay Word bit 87E2 indicates differential element 87-2 operation and follows **LED 5** operation (see *LED 5: 87-2—Differential Element 2 on page 4.14*).

## LED 11: C—C-Phase Involved in the Fault (Programmable LEDC)

**LED 11** is programmable via the LEDC SELOGIC control equations Global setting. It is updated each processing interval. If LEDC is true, **LED 11** is illuminated. Otherwise, it is reset. The factory default setting is LEDC = OCC + 87E3.

Relay Word bit OCC indicates C-phase overcurrent during the fault. It is derived by first checking which winding "W*n*" LED is lit, then asserting if the associated 50C*n*4 overcurrent element bit is asserted or if the magnitude of the ICW*n* phase current is greater than or equal to the magnitudes of IAW*n* and IBW*n*.

Relay Word bit 87E3 indicates differential element 87-3 operation and follows **LED 6** operation (see *LED 6: 87-3—Differential Element 3 on page 4.14*).

## LED 12: N—Residual Overcurrent Element Trip

This LED will illuminate if any residual overcurrent element present in the TR1 through TR4 settings is asserted at the rising edge of the trip or one cycle later. Applicable elements include any of the winding overcurrent elements indicated by Relay Word bits "50N**," "50N**T," or "51N*T." The combined overcurrent element indicated by Relay Word bit 51NC1T is also included. **LED 12** remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the **TARGET RESET** pushbutton on the front panel or via the serial port command **TAR R**.

## LED 13: W1—Winding 1 Overcurrent Element Operation

This LED will illuminate if any Winding 1 overcurrent element present in the TR1 through TR4 settings is asserted at the rising edge of the trip or one cycle later. Applicable elements include any of the 23 Relay Word bits associated with Winding 1 overcurrent elements. **LED 13** remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the **TARGET RESET** pushbutton on the front panel or via the serial port command **TAR R**.

### LED 14: W2—Winding 2 Overcurrent Element Operation

This LED will illuminate if any Winding 2 overcurrent element present in the TR1 through TR4 settings is asserted at the rising edge of the trip or one cycle later. Applicable elements include any of the 23 Relay Word bits associated with Winding 2 overcurrent elements. LED 14 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

### LED 15: W3—Winding 3 Overcurrent Element Operation

This LED will illuminate if any Winding 3 overcurrent element present in the TR1 through TR4 settings is asserted at the rising edge of the trip or one cycle later. Applicable elements include any of the 23 Relay Word bits associated with Winding 3 overcurrent elements. LED 15 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

### LED 16: 50/51—Overcurrent Trip

This LED will illuminate if any overcurrent element present in the TR1 through TR4 settings is asserted at the rising edge of the trip or one cycle later. Applicable elements include any of the overcurrent elements indicated by Relay Word bits “50***”, “50***T”, or “51**(*)T. LED 16 remains lit until reset by the TRGTR element. TRGTR is asserted for one cycle either via the TARGET RESET pushbutton on the front panel or via the serial port command **TAR R**.

# Trip and Close Logic

The trip logic and close logic for the SEL-387E operate in a similar manner. Each has a SELOGIC control equation setting to set or latch the logic and another SELOGIC control equation setting to reset or unlatch the logic. Each also has other elements or functions that will unlatch the logic. The output of each logic is a Relay Word bit that can be assigned to operate output contacts, or in any other manner for which a Relay Word bit can be used. The specifics of each type of logic are discussed below.

## Trip Logic

There are four specific sets of trip logic within the SEL-387E. They are designed to operate when SELOGIC control equation trip variable setting TR*m* is asserted (*m* = 1, 2, 3, 4), and to unlatch when SELOGIC control equation setting ULTR*m* is asserted. The output of the logic is Relay Word bit TRIP*m*. The logic operates much like the Latch Bit function in SELOGIC control equation Sets 1 through 3, with additional characteristics. In the trip logic the set or latch function has priority over the reset or unlatch function.

*Figure 4.7* shows the logic diagram for the TRIP1 logic. The remaining logic for TRIP2 through TRIP4 is identical, using variables TR2 through TR4 and ULTR2 through ULTR4, respectively.

**Figure 4.7 SEL-387E Relay Trip Logic (TRIP1)**

The logic begins with the assertion of SELOGIC control equation TR1, one of the Group variables. In our example application Relay Word bits representing three Winding 1 overcurrent elements and the **OPE 1** command are used to assert TR1. TR1 directly asserts TRIP1 via the three-input OR gate at the right.

However, TR1 may assert more briefly than is needed. There are two means to ensure a longer TRIP1 assertion. At the top of the diagram is an Edge Trigger Timer. It detects the rising edge of TR1 and issues a second output to the OR gate. This second output will last the duration of Group setting TDURD (minimum trip duration timer). Once the rising edge has been detected and the timing started, the ongoing state of the TR1 input to the timer is ignored. Thus, TRIP1 will be asserted for a minimum of TDURD cycles, even if TR1 is asserted for as little as one processing interval, or if the unlatch portion of the logic is asserted before TDURD expires. The default setting of TDURD is nine cycles.

TRIP1 also seals-in itself via the AND gate at the bottom. This AND gate receives the negated inputs from the unlatching functions. As long as no unlatch function is asserted, the seal of TRIP1 remains intact. TRIP1 is used to drive an output contact to initiate tripping of the breaker or breakers. In our example, OUT101 = TRIP1.

There are three means of unlatching the trip logic. The first is the assertion of the SELOGIC control equation setting ULTR1. In our example ULTR1 = !50P13 = NOT 50P13. This current element is set to pick up at 0.5 A. Thus, ULTR1 asserts when the currents in all three phases drop below 0.5 A, indicating successful three-pole opening of the breaker.

The other unlatching mechanism is manual, via pushing of the **TARGET RESET** pushbutton on the front panel or sending the **TAR R** serial port command to the relay. Either of these asserts the Relay Word bit TRGTR, which is also used to reset the LED targets on the front panel. In the trip logic assertion of ULTR1 or TRGTR places a zero input on the AND gate and thereby breaks the TRIP1 seal-in loop.

With the deassertion of TRIP1, OUT101 opens, de-energizing the trip circuit. Presumably, the trip circuit current has already been interrupted by a breaker 52a contact in series with the trip coil. Should a failure to trip occur, followed by backup tripping of other breakers, the TR1 setting may deassert and the ULTR1 setting may assert, while the contact continues to carry dc trip circuit

current. This could damage the contact as it tries to interrupt this current. The emergency nature of the situation might warrant this minor risk, but another choice might be to program into the ULTR1 setting not only removal of current, but also indication that the breaker has opened.

Note that TRIP1 will always be asserted as long as TR1 is asserted, regardless of the action of ULTR1 or the **TARGET RESET** commands, and that TRIP1 will be asserted for an absolute minimum of TDURD cycles, no matter how short a time TR1 has been asserted. This is the essence of the trip logic.

At the bottom of *Figure 4.7* is an additional OR gate. The four TRIP*m* Relay Word bits are all inputs to this gate, and the output is another Relay Word bit TRIPL. TRIPL asserts for any trip output. It may be useful for other applications of SELOGIC control equations in the SEL-387E.

The *Settings Sheets* contain two specific areas highlighting the assignment of variables for the Trip Logic and Close Logic. These functions, along with those in the Output Contact Logic area, must be programmed in order for the relay to take action. Settings in all three areas are SELOGIC control equations.

There are four trip variables, TR1 to TR4, to define conditions under which a trip will be issued. This will cover trip conditions for three separate breakers, plus one extra for a general trip of all breakers. The settings for the example transformer application illustrate this.

In the example, TR1 through TR3 are set to respond to overcurrent elements specific to the winding associated with breakers one to three. For example, TR1 = 50P11T + 51P1T + 51Q1T. Complete operation of the phase definite-time or inverse-time elements, or the negative-sequence inverse-time element, will set the appropriate Relay Word bits 5*xxxx*T to one, and TR1 will respond to any of them. TR1 initiates the Trip Logic, producing output of the logic and setting of Relay Word bit TRIP1 to one. For tripping Breaker 2, TR2 = 51P2T + 51Q2T. For tripping Breaker 3, TR3 = 50P31 + 51P3T. Technically, 50P31T should have been used, because this would indicate that the definite-time element has timed out. However, because 50P31 is set for zero delay, or is instantaneous, there is no reason to wait. For group tripping of all three breakers, TR4 = 87R + 87U. This results in a tripping output to an external 86 lockout device, which then trips the three breakers with separate contacts. This takes place only if a differential operation, either restrained or unrestrained, is detected.

In general, definition of the TR1 and TR4 variables should include only Relay Word bits that remain firmly asserted during a fault, but otherwise are not asserted. For this reason, rising-edge detection (/), falling-edge detection (\), and the NOT operator (!) should be avoided for the Relay Word bits used in these four settings. Exceptions might be bits used for opening the breaker by command during nonfault conditions, such as the OC*n* bits or the remote bits, RB*n*.

When the trip logic is activated, and one or more Relay Word bits TRIP1 to TRIP4 are set to logical 1, a trip can take place. However, in order for this to happen an output contact must be assigned for each trip. These assignments are made on the Output Contact Logic setting sheet area. In this case OUT101 = TRIP1, OUT102 = TRIP2, OUT103 = TRIP3, and OUT104 = TRIP4. OUT101 to OUT103 go directly to the three breaker trip coils, and OUT104 goes to the 86 operate coil. These connections are shown in *Figure 2.20*.

Four unlatch variables, ULTR1 to ULTR4, correspond to the four trip variables in the Trip Logic setting area. ULTR1 to ULTR4 define the conditions to unlatch the seal-in of trip logic that takes place when TR*n* goes

to logical 1. They sense when it is appropriate to de-energize the trip circuit. In this case the instantaneous overcurrent elements 50P*n*3 were set very low, and unlatch is defined as when the phase currents in all three phases drop below the setting. This is done with the NOT operator. That is, ULTR1 = !50P13, ULTR2 = !50P23, and ULTR3 = !50P33. ULTR4 = !(50P13 + 50P23 + 50P33) and unlatches TRIP4 when all phase currents on all windings drop below the 0.5 A setting.

TDURD, or minimum trip duration time, is an additional miscellaneous timer setting for trip logic. TDURD defines the minimum length of time the trip signal will be issued, regardless of other inputs to the trip logic. The default setting is 9 cycles.

## Close Logic

There are three specific sets of close logic within the SEL-387E. They are designed to operate when SELOGIC control equation close variable setting CL*m* is asserted (*m* = 1, 2, 3) and to unlatch when SELOGIC control equation setting ULCL*m* is asserted. The output of the logic is Relay Word bit CLS*m*. The logic operates much like the Latch Bit function in SELOGIC control equation Sets 1 through 3, with additional characteristics. In the close logic the reset or unlatch function has priority over the set or latch function.

*Figure 4.8* shows the logic diagram for the CLS1 logic. The remaining logic for CLS2 through CLS3 is identical, using variables CL2 through CL3 and ULCL2 through ULCL3, respectively.

**Figure 4.8 SEL-387E Relay Close Logic (CLS1)**

The logic begins with the assertion of SELOGIC control equation CL1, one of the Group variables. In our example application CL1 = CC1 + /IN104. Thus, CL1 will assert either if (1) a **CLO 1** command has been sent to the relay via a serial port, or if (2) input IN104 has been energized via an external SCADA, recloser or control switch contact, for example. CL1 does not directly assert CLS1 but acts as one input to the AND gate at the center. The other input to the AND gate is a negated OR gate output which asserts whenever any of the unlatching functions is in effect. Thus, unlatch elements take precedence over the close command elements.

Assuming no unlatch elements are asserted, assertion of CL1 produces assertion of the output Relay Word bit CLS1. CLS1 seals itself in via the OR gate at the top and begins to drive the output contact OUT105 (= CLS1), leading to the Breaker 1 closing circuit. CLS1 can also be used in other SELOGIC control equations. CLS1 will remain asserted, and OUT105 will

remain closed, until the close logic is unlatched by one of three means: assertion of the ULCL1 setting, closure of the breaker 52a auxiliary contact, or a Close Failure Detection. These three functions are inputs to the OR gate at the mid-left.

The ULCL1 SELOGIC control equation setting defines conditions for unlatching the close logic. If CL1 is not asserted when ULCL1 asserts, ULCL1 effectively "blocks" the close logic. If CL1 should assert after ULCL1 has been asserted, the logic will effectively ignore CL1 and CLS1 will not assert. If CL1 has asserted before ULCL1 and the closing process has begun, assertion of ULCL1 will unseal CLS1 and interrupt the process. In our example, ULCL1 = TRIP1 + TRIP4. That is, if a Winding 1 overcurrent trip or a high-speed differential trip has been initiated, ULCL1 will prevent the close process from starting or will prevent the close process from going to completion if it has already begun.

Under normal circumstances, the second means of unlatching, closure of the Breaker 1 52a contact, occurs. The close logic setting 52A1 = IN101. When CLS1 asserts, OUT105 closes and the breaker begins to close. When the breaker closing is complete, the 52a contact closes, duplicating the operation of the breaker contacts themselves and effectively indicating that the breaker is closed. The 52a contact is wired to IN101. When IN101 asserts, the equation 52A1 asserts and unlatches the close logic, deasserting CLS1 and opening OUT105. The close process is now complete. (Presumably, interruption of the current in the closing circuit has been accomplished via a breaker 52b contact and not by OUT105.)

The third means of unlatching is a Close Failure Detection. This function can be set to OFF but is useful in the event the breaker does not close in response to energization of the closing circuit. This might be due to electrical problems or mechanical binding or breakage. With the breaker not moving, CLS1 will remain asserted and OUT105 will stay closed for an extended period, possibly resulting in an electrical fire, system damage, or injury to personnel. Within the logic, when CLS1 asserts, an input is also sent to the AND gate at the bottom. The second AND input is 1 if the Close Failure detection timer (CFD) is set to some value and 0 if CFD is set to OFF. In our example we have selected CFD = 60 cycles (one second). With CFD set to some value, a timer is started. At the expiration of CFD, an output is asserted, as Relay Word bit CF1T. This bit is pulsed for one processing interval and sent to the OR gate for the unlatch functions, where it interrupts the closing process. This interruption prevents the closing circuit from being energized too long but also creates the possibility that the OUT105 contact may be damaged by interrupting the closing circuit current flow. However, the emergency nature of the situation generally warrants the risk. The CFT1 bit might also be used to set a SELOGIC control equation Latch Bit to close a contact, informing a SCADA system of the aborted closure attempt.

In the Close Logic setting area, inputs are defined to represent the 52a auxiliary contacts from the individual breakers. Defined as well are the three Close and three Unlatch Close variables, if the closing function is to be used.

In our example, inputs IN101 to IN103 are assigned to represent the 52a contacts. That is, 52A1 = IN101, 52A2 = IN102, and 52A3 = IN103. (Note again that inputs appear in the right side of an equation, outputs on the left side.) The connections for the 52a inputs are shown in *Figure 2.20*.

The three Close variables, CL1 through CL3, are set up to define the conditions under which a closing can take place. In our example these are set up to respond to a **CLOSE *n*** command from a communications port or an external contact input from a SCADA RTU or other switch.

Specifically, CL1 = CC1+ /IN104, CL2 = CC2 + /IN105, and CL3 = CC3 + /IN106, where "/" denotes detection of a "rising edge" for the input shown. Within these SELogic control equations, inputs IN104 to IN106 have been defined as being related to the close initiation function for the specific breakers. The CL*n* variable initiates the close logic, resulting in Relay Word bit CLS*n* being set to logical 1, unless the logic is disabled by an unlatch condition, discussed below. Note that connections for the closing function are not shown in *Figure 2.20*.

Closing can now take place, but only if an output contact has been assigned to this function. Returning to the Output Contact Logic setting area for our example, we set OUT105 = CLS1, OUT106 = CLS2, and OUT107 = CLS3. These contacts must be wired to the closing circuits of the individual breakers.

In the Close Logic setting area three variables remain. ULCL1 to ULCL3 define the conditions for unlatching the close logic. These are set in our example to be the presence of any trip logic output. That is, ULCL1 = TRIP1 + TRIP4, ULCL2 = TRIP2 + TRIP4, and ULCL3 = TRIP3 + TRIP4. ULCL*n* will remove the seal-in of the close logic, and return Relay Word bit CLS*n* to zero. A closed 52a contact or a Close Failure Detection will also unlatch the Close logic. The output contact that follows the CLS*n* bit will open in response.

CFD, or Close Failure Detection time delay, is an additional miscellaneous timer setting for close logic. CFD is an overriding timer to unlatch the close logic if the breaker has not yet closed. The default setting is 60 cycles.

# SELogic Control Equations

This manual refers throughout to settings or variables that take the form of SELogic control equations. These equations are convenient for customizing control logic to the relay and enhancing relay performance for specific customer needs and practices.

While most users of SEL relays are familiar with SELogic control equations, the capabilities of this logic, types of operators, number of variables, and equation syntax have varied from one relay product to another. We intend in this manual to explain how SELogic control equations work in general and how we implement these equations in the SEL-387E.

## SELogic Control Equations Fundamental Description

Relay Word bits are the basic building blocks of SELogic control equations. The end of this section of the manual contains a complete list of these bits. The Relay Word bits are simple digital quantities having a logical value of either 0 or 1. The terms "assert" or "asserted" refer to a Relay Word bit that has a value of 1 or is changing from 0 to 1. The terms "deassert" or "deasserted" refer to a Relay Word bit that has a value of 0 or is changing from 1 to 0. Various relay elements cause assertion or deassertion of Relay Word bits, which the fixed internal logic of the relay uses to make decisions, to interpret inputs, or to drive outputs. You have access to these bits and can use them to exercise flexibility in defining inputs or outputs, specifying control variables for internal logic, or for creating special customized logic through the use of SELogic control equations.

SELogic control equations use logic similar to Boolean algebra logic. A SELogic control equation consists of some combination of Relay Word bits and logical operators that define how the Relay Word bits are to be evaluated

as a group or individually. The Relay Word bits take on their values of 0 or 1, the operators perform logical operations on these values, and the result is a logical value of 0 or 1 for the SELOGIC control equation itself. Thus, expressions of assertion or deassertion apply to the SELOGIC control equations as a whole, as well as to the individual components of the equation. In the end, the SELOGIC control equation itself is a simple digital variable having a value of 0 or 1.

## SELOGIC Control Equation Logical Operators

In the SEL-387E, there are six logical operators that can be used in SELOGIC control equations. These operators exist in a hierarchy, from the highest level operator to be processed to the lowest level operator. *Table 4.6* lists these operators in their order of processing.

**Table 4.6 SELOGIC Control Equation Operators**

| Operator | Logic Function |
|---|---|
| ( ) | parentheses |
| ! | NOT (negation) |
| / | rising edge detect |
| \ | falling edge detect |
| * | AND |
| + | OR |

### Parentheses Operator, ( )

More than one set of parentheses can be used in a SELOGIC control equation. However, parentheses cannot be “nested”; you cannot have parentheses within parentheses. The following is an example:

S1V1 = (IN105 + RB3) * (87R + 87U)

The expressions within the parentheses are evaluated first. The logic determines whether IN105 OR RB3 is asserted and then whether 87R OR 87U is asserted. Assuming that at least one bit asserts for each pair of parentheses, the equation can now be evaluated: S1V1 = 1*1 = 1. The equation for S1V1 is thus asserted.

### NOT Operator, !

The ! operator performs a simple negation or inversion. On logic diagrams, a small circle on an input or output line represents this inversion. Whatever the state of the logical quantity to which it is applied, it simply reverses that state. For example, if 87R is a logical 1, then !87R is a logical 0. The ! operator can be applied to parentheses containing several elements. The expression within the parentheses is evaluated first, then the result is negated.

### Rising-Edge and Falling-Edge Operators, / and \

These operators can be applied to individual Relay Word bits only; they cannot be used on groups in parentheses or on negated elements. Instead of detecting the present value of Relay Word bits, as do most operators, these operators are only intended to detect a *change* of value. The rising-edge operator, “/ ”, detects a change from a 0 state to a 1 state. The falling-edge operator, “ \”, detects a change from a 1 state to a 0 state. Typical applications

might include triggering an event report or unlatching internal logic. These two operators assert a 1 for a single processing interval when they sense the change of state.

### AND and OR Operators, * and +

These operators produce an output state that combines the states of two or more inputs. The AND operator requires that every one of the inputs is a logical 1 before it issues a logical 1 output. For example, in the equation S1V1 = 87R * IN103, S1V1 will only assert if 87R = 1 and IN103 = 1.

The OR operator only requires that one of the several inputs be a logical 1 in order to assert an output state of 1. For example, in this relay there is a Relay Word bit TRIPL = TRIP1 + TRIP2 + TRIP3 + TRIP4. All TRIPL needs to assert is a 1 from any of the four ORed inputs. Thus, it is useful for indicating that "any trip" has occurred.

## Ways of Setting SELogic Control Equation Relay Settings

Many of the Group and Global settings are defined as being SELOGIC control equations. A typical example would be the torque-control variables for the various overcurrent elements. For example, let us look at the setting 51P1TC, for torque controlling the Winding 1 phase inverse-time overcurrent element.

We could set 51P1TC to a single Relay Word bit. For example, 51P1TC = IN105. This might be used for torque controlling by a contact input from some external device like a directional relay.

We could set 51P1TC to some combination of Relay Word bits. For example, 51P1TC = IN105*!IN106. Here, we might wish to supervise the element as before, from an external directional relay, but only if there is no input to IN106. IN106 could be a contact input from SCADA or a manual control switch, to disable the operation of the Winding 1 inverse-time element. So long as voltage is applied to IN106, the 51P1 element will not operate, even if the directional relay gives permission.

We could set 51P1TC directly to 1. If 51P1TC = 1, the 51P1 element is always ready to operate on current alone.

We could set 51P1TC directly to 0. If 51P1TC = 0, the 51P1 element will never operate. This is one way, for example, to temporarily disable the 51P1 for some operational reason. It could be done using the **SET** command via a serial port from a remote location.

## Limitations of SELogic Control Equations

Any single SELOGIC control equation setting is limited to 17 Relay Word bits that can be combined together with the SELOGIC control equation operators listed in *Table 4.6*. If this limit must be exceeded, use a SELOGIC control equation variable (S*n*V*m*) as an intermediate setting step.

For example, assume that a trip equation (SELOGIC control equation trip setting, TR*n*) needs more than 17 Relay Word bits in its equation setting. Instead of placing all Relay Word bits into TR*n*, program some of them into the SELOGIC control equation setting, S*n*V*m*. Next use the resultant SELOGIC control equation variable output (Relay Word bit S*n*V*m*) in the SELOGIC control equation trip setting, TR*n*.

The SELOGIC control equation settings in the Group settings are limited to no more than 402 elements and 67 rising-edge or falling-edge operators. In the Global settings, they are limited to no more than 81 elements and 14 rising-edge or falling-edge operators. *Table 4.7* summarizes this information.

An attempt to set the relay with more than 17 operands will result in the message "Maximum of 17 elements allowed in a SELOGIC equation." The relay will then prompt the user to reenter the equation. An attempt to save Group settings with more than 402 Relay Word bits or Global settings with more than 81 Relay Word bits will result in the message "Overall SELOGIC setting size too large. Try simplifying equations." The relay will then return to the first nonhidden SELOGIC control equation for editing.

SELOGIC control equation settings that are set directly to 1 (logical 1) or 0 (logical 0) also have to be included in these limitations-each such setting counts as one element.

After SELOGIC control equation settings have been made and the settings are saved, the SEL-387E responds with the following message:

```
SCEUSE     xx.x
GRnCHK     yyyy
```

This message indicates that xx.x% of the maximum number of Relay Word bits are being used (SCEUSE = SELOGIC control equation use) and that the Global or Group *n* checksum (GBLCHK or GR*n*CHK) is yyyy. The relay provides use and checksum results for the GLOBAL and GROUP *n* settings.

**Table 4.7 Maximums for SELOGIC Control Equations**

| | Group Setting Class | Global Setting Class |
|---|---|---|
| Relay Word bits per Equation | 17 | 17 |
| Relay Word bits per Setting Class | 402 | 81 |
| Equations per Setting Class (with two 16-output interface boards) | 134 | 29 |
| Rising- or Falling-Edge Operators per Setting Class | 67 | 14 |

# Relay Word Bits

The Relay Word bits available for use in SELOGIC control equations (except Row 0 or Row 1 target elements) are listed below in *Table 4.8* through *Table 4.10*. *Table 4.8* shows the names and locations in each row. The row number or bit name can be used when using the **TAR** command. *Table 4.9* lists the Relay Word bit definitions, in their row order. *Table 4.10* lists the Relay Word bits alphabetically, to provide an easier method for looking for a specific bit.

**Table 4.8 SEL-387E Relay Word Bits and Locations** (Sheet 1 of 3)

| Row | SEL 387E Relay Word Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | EN | TRIP | INST | 87-1 | 87-2 | 87-3 | 81 | 24 |
| 1 | A | B | C | N | W1 | W2 | W3 | 50/51 |
| 2 | 50P11 | 50P11T | 50P12 | 51P1 | 51P1T | 51P1R | PDEM1 | OCA |
| 3 | 50A13 | 50B13 | 50C13 | 50P13 | 50A14 | 50B14 | 50C14 | 50P14 |
| 4 | 50N11 | 50N11T | 50N12 | 51N1 | 51N1T | 51N1R | NDEM1 | OC1 |
| 5 | 50Q11 | 50Q11T | 50Q12 | 51Q1 | 51Q1T | 51Q1R | QDEM1 | CC1 |
| 6 | 50P21 | 50P21T | 50P22 | 51P2 | 51P2T | 51P2R | PDEM2 | OCB |

**Table 4.8 SEL-387E Relay Word Bits and Locations** (Sheet 2 of 3)

| Row | SEL 387E Relay Word Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7 | 50A23 | 50B23 | 50C23 | 50P23 | 50A24 | 50B24 | 50C24 | 50P24 |
| 8 | 50N21 | 50N21T | 50N22 | 51N2 | 51N2T | 51N2R | NDEM2 | OC2 |
| 9 | 50Q21 | 50Q21T | 50Q22 | 51Q2 | 51Q2T | 51Q2R | QDEM2 | CC2 |
| 10 | 50P31 | 50P31T | 50P32 | 51P3 | 51P3T | 51P3R | PDEM3 | OCC |
| 11 | 50A33 | 50B33 | 50C33 | 50P33 | 50A34 | 50B34 | 50C34 | 50P34 |
| 12 | 50N31 | 50N31T | 50N32 | 51N3 | 51N3T | 51N3R | NDEM3 | OC3 |
| 13 | 50Q31 | 50Q31T | 50Q32 | 51Q3 | 51Q3T | 51Q3R | QDEM3 | CC3 |
| 14 | *[a] | 27V1 | 27PP2 | 27PP1 | 27P2 | 27P1 | *[a] | CTS |
| 15 | 59Q | 59G2 | 59G1 | 59V1 | 59PP2 | 59PP1 | 59P2 | 59P1 |
| 16 | 81D1 | 81D2 | 81D3 | 81D4 | 81D5 | 81D6 | ISQTAL | 27B81 |
| 17 | 81D1T | 81D2T | 81D3T | 81D4T | 81D5T | 81D6T | *[a] | *[a] |
| 18 | 87U1 | 87U2 | 87U3 | 87U | 87R1 | 87R2 | 87R3 | 87R |
| 19 | 2HB1 | 2HB2 | 2HB3 | 5HB1 | 5HB2 | 5HB3 | TH5 | TH5T |
| 20 | 87BL1 | 87BL2 | 87BL3 | 87BL | 87E1 | 87E2 | 87E3 | 32IE |
| 21 | 87O1 | 87O2 | 87O3 | 24D1 | 24D1T | 24C2 | 24C2T | 24CR |
| 22 | 51PC1 | 51PC1T | 51PC1R | 51NC1 | 51NC1T | 51NC1R | DC1 | DC2 |
| 23 | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] | DC3 | DC4 |
| 24 | RB1 | RB2 | RB3 | RB4 | RB5 | RB6 | RB7 | RB8 |
| 25 | RB9 | RB10 | RB11 | RB12 | RB13 | RB14 | RB15 | RB16 |
| 26 | SG1 | SG2 | SG3 | SG4 | SG5 | SG6 | CHSG | *[a] |
| 27 | 4HBL | DCBL | IN106 | IN105 | IN104 | IN103 | IN102 | IN101 |
| 28[b] | IN208 | IN207 | IN206 | IN205 | IN204 | IN203 | IN202 | IN201 |
| 29[b] | IN216 | IN215 | IN214 | IN213 | IN212 | IN211 | IN210 | IN209 |
| 30 | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] |
| 31 | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] |
| 32 | S1V1 | S1V2 | S1V3 | S1V4 | S1V1T | S1V2T | S1V3T | S1V4T |
| 33 | S2V1 | S2V2 | S2V3 | S2V4 | S2V1T | S2V2T | S2V3T | S2V4T |
| 34 | S3V1 | S3V2 | S3V3 | S3V4 | S3V5 | S3V6 | S3V7 | S3V8 |
| 35 | S3V1T | S3V2T | S3V3T | S3V4T | S3V5T | S3V6T | S3V7T | S3V8T |
| 36 | S1LT1 | S1LT2 | S1LT3 | S1LT4 | S2LT1 | S2LT2 | S2LT3 | S2LT4 |
| 37 | S3LT1 | S3LT2 | S3LT3 | S3LT4 | S3LT5 | S3LT6 | S3LT7 | S3LT8 |
| 38 | *[a] | *[a] | *[a] | 50GC | 50G3 | 32IR | 32IF | REFP |
| 39 | BCWA1 | BCWB1 | BCWC1 | BCW1 | BCWA2 | BCWB2 | BCWC2 | BCW2 |
| 40 | BCWA3 | BCWB3 | BCWC3 | BCW3 | *[a] | P5SEL | P6SEL | LNKFAIL |
| 41 | TRIP1 | TRIP2 | TRIP3 | TRIP4 | *[a] | TRIPL | *[a] | TRGTR |
| 42 | CLS1 | CLS2 | CLS3 | *[a] | CF1T | CF2T | CF3T | *[a] |
| 43 | NOTALM | OUT107 | OUT106 | OUT105 | OUT104 | OUT103 | OUT102 | OUT101 |
| 44[b] | OUT201 | OUT202 | OUT203 | OUT204 | OUT205 | OUT206 | OUT207 | OUT208 |
| 45[b] | OUT209 | OUT210 | OUT211 | OUT212 | OUT213 | OUT214 | OUT215 | OUT216 |
| 46[b] | OUT301 | OUT302 | OUT303 | OUT304 | OUT305 | OUT306 | OUT307 | OUT308 |

**Table 4.8 SEL-387E Relay Word Bits and Locations** (Sheet 3 of 3)

| Row | SEL 387E Relay Word Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **47[b]** | OUT309 | OUT310 | OUT311 | OUT312 | OUT313 | OUT314 | OUT315 | OUT316 |
| **48** | LB1 | LB2 | LB3 | LB4 | LB5 | LB6 | LB7 | LB8 |
| **49** | LB9 | LB10 | LB11 | LB12 | LB13 | LB14 | LB15 | LB16 |

[a] Reserved for future use.
[b] These rows will show asterisks in response to the TAR command if the optional interface board is not installed.

**Table 4.9 Relay Word Bit Definitions** (Sheet 1 of 11)

| Row | Bit | Definition |
|---|---|---|
| 0 | All | LED targets—not usable in SELOGIC control equations |
| 1 | All | LED targets—not usable in SELOGIC control equations |
| 2 | 50P11 | Winding 1 phase definite-time O/C Level 1 element picked up |
| | 50P11T | Winding 1 phase definite-time O/C Level 1 element timed out |
| | 50P12 | Winding 1 phase instantaneous O/C Level 2 element picked up |
| | 51P1 | Winding 1 phase inverse-time O/C element picked up |
| | 51P1T | Winding 1 phase inverse-time O/C element timed out |
| | 51P1R | Winding 1 phase inverse-time O/C 51P1 element is reset |
| | PDEM1 | Winding 1 phase demand current threshold exceeded |
| | OCA | O/C element A-phase selection |
| 3 | 50A13 | Winding 1 A-phase instantaneous O/C Level 3 element picked up |
| | 50B13 | Winding 1 B-phase instantaneous O/C Level 3 element picked up |
| | 50C13 | Winding 1 C-phase instantaneous O/C Level 3 element picked up |
| | 50P13 | 50A13 + 50B13 + 50C13 |
| | 50A14 | Winding 1 A-phase instantaneous O/C Level 4 element picked up |
| | 50B14 | Winding 1 B-phase instantaneous O/C Level 4 element picked up |
| | 50C14 | Winding 1 C-phase instantaneous O/C Level 4 element picked up |
| | 50P14 | 50A14 + 50B14 + 50C14 |
| 4 | 50N11 | Winding 1 residual definite-time O/C Level 1 element picked up |
| | 50N11T | Winding 1 residual definite-time O/C Level 1 element timed out |
| | 50N12 | Winding 1 residual instantaneous O/C Level 2 element picked up |
| | 51N1 | Winding 1 residual inverse-time O/C element picked up |
| | 51N1T | Winding 1 residual inverse-time O/C element timed out |
| | 51N1R | Winding 1 residual inverse-time O/C 51N1 element is reset |
| | NDEM1 | Winding 1 residual demand current threshold exceeded |
| | OC1 | Breaker 1 **OPEN** command execution |
| 5 | 50Q11 | Winding 1 neg.-seq. definite-time O/C Level 1 element picked up |
| | 50Q11T | Winding 1 neg.-seq. definite-time O/C element timed out |
| | 50Q12 | Winding 1 neg.-seq. instantaneous O/C Level 2 element picked up |
| | 51Q1 | Winding 1 neg.-seq. inverse-time O/C element picked up |
| | 51Q1T | Winding 1 neg.-seq. inverse-time O/C element timed out |
| | 51Q1R | Winding 1 neg.-seq. inverse-time O/C 51Q1 element is reset |
| | QDEM1 | Winding 1 neg.-seq. demand current threshold exceeded |
| | CC1 | Breaker 1 **CLOSE** command execution |

**Table 4.9 Relay Word Bit Definitions** (Sheet 2 of 11)

| Row | Bit | Definition |
|---|---|---|
| 6 | 50P21 | Winding 2 phase definite-time O/C Level 1 element picked up |
| | 50P21T | Winding 2 phase definite-time O/C Level 1 element timed out |
| | 50P22 | Winding 2 phase instantaneous O/C Level 2 element picked up |
| | 51P2 | Winding 2 phase inverse-time O/C element picked up |
| | 51P2T | Winding 2 phase inverse-time O/C element timed out |
| | 51P2R | Winding 2 phase inverse-time O/C 51P2 element is reset |
| | PDEM2 | Winding 2 phase demand current threshold exceeded |
| | OCB | O/C element B-phase selection |
| 7 | 50A23 | Winding 2 A-phase instantaneous O/C Level 3 element picked up |
| | 50B23 | Winding 2 B-phase instantaneous O/C Level 3 element picked up |
| | 50C23 | Winding 2 C-phase instantaneous O/C Level 3 element picked up |
| | 50P23 | 50A23 + 50B23 + 50C23 |
| | 50A24 | Winding 2 A-phase instantaneous O/C Level 4 element picked up |
| | 50B24 | Winding 2 B-phase instantaneous O/C Level 4 element picked up |
| | 50C24 | Winding 2 C-phase instantaneous O/C Level 4 element picked up |
| | 50P24 | 50A24 + 50B24 + 50C24 |
| 8 | 50N21 | Winding 2 residual definite-time O/C Level 1 element picked up |
| | 50N21T | Winding 2 residual definite-time O/C Level 1 element timed out |
| | 50N22 | Winding 2 residual instantaneous O/C Level 2 element picked up |
| | 51N2 | Winding 2 residual inverse-time O/C element picked up |
| | 51N2T | Winding 2 residual inverse-time O/C element timed out |
| | 51N2R | Winding 2 residual inverse-time O/C 51N2 element is reset |
| | NDEM2 | Winding 2 residual demand current threshold exceeded |
| | OC2 | Breaker 2 **OPEN** command execution |
| 9 | 50Q21 | Winding 2 neg.-seq. definite-time O/C Level 1 element picked up |
| | 50Q21T | Winding 2 neg.-seq. definite-time O/C Level 1 element timed out |
| | 50Q22 | Winding 2 neg.-seq. instantaneous O/C Level 2 element picked up |
| | 51Q2 | Winding 2 neg.-seq. inverse-time O/C element picked up |
| | 51Q2T | Winding 2 neg.-seq. inverse-time O/C element timed out |
| | 51Q2R | Winding 2 neg.-seq. inverse-time O/C 51Q2 element is reset |
| | QDEM2 | Winding 2 neg.-seq. demand current threshold exceeded |
| | CC2 | Breaker 2 **CLOSE** command execution |
| 10 | 50P31 | Winding 3 phase definite-time O/C Level 1 element picked up |
| | 50P31T | Winding 3 phase definite-time O/C Level 1 element timed out |
| | 50P32 | Winding 3 phase instantaneous O/C Level 2 element picked up |
| | 51P3 | Winding 3 phase inverse-time O/C element picked up |
| | 51P3T | Winding 3 phase inverse-time O/C element timed out |
| | 51P3R | Winding 3 phase inverse-time O/C 51P3 element is reset |
| | PDEM3 | Winding 3 phase demand current threshold exceeded |
| | OCC | O/C element C-phase selection |

**Table 4.9 Relay Word Bit Definitions** (Sheet 3 of 11)

| Row | Bit | Definition |
|---|---|---|
| 11 | 50A33 | Winding 3 A-phase instantaneous O/C Level 3 element picked up |
| | 50B33 | Winding 3 B-phase instantaneous O/C Level 3 element picked up |
| | 50C33 | Winding 3 C-phase instantaneous O/C Level 3 element picked up |
| | 50P33 | 50A33 + 50B33 + 50C33 |
| | 50A34 | Winding 3 A-phase instantaneous O/C Level 4 element picked up |
| | 50B34 | Winding 3 B-phase instantaneous O/C Level 4 element picked up |
| | 50C34 | Winding 3 C-phase instantaneous O/C Level 4 element picked up |
| | 50P34 | 50A34 + 50B34 + 50C34 |
| 12 | 50N31 | Winding 3 residual definite-time O/C Level 1 element picked up |
| | 50N31T | Winding 3 residual definite-time O/C level 1 element timed out |
| | 50N32 | Winding 3 residual instantaneous O/C Level 2 element picked up |
| | 51N3 | Winding 3 residual inverse-time O/C element picked up |
| | 51N3T | Winding 3 residual inverse-time O/C element timed out |
| | 51N3R | Winding 3 residual inverse-time O/C 51N3 element is reset |
| | NDEM3 | Winding 3 residual demand current threshold exceeded |
| | OC3 | Breaker 3 **OPEN** command execution |
| 13 | 50Q31 | Winding 3 neg.-seq. definite-time O/C Level 1 element picked up |
| | 50Q31T | Winding 3 neg.-seq. definite-time O/C Level 1 element timed out |
| | 50Q32 | Winding 3 neg.-seq. instantaneous O/C Level 2 element picked up |
| | 51Q3 | Winding 3 neg.-seq. inverse-time O/C element picked up |
| | 51Q3T | Winding 3 neg.-seq. inverse-time O/C element timed out |
| | 51Q3R | Winding 3 neg.-seq. inverse-time O/C 51Q3 element is reset |
| | QDEM3 | Winding 3 neg.-seq. demand current threshold exceeded |
| | CC3 | Breaker 3 **CLOSE** command execution |
| 14 | * | Reserved for future use |
| | 27V1 | Positive-sequence undervoltage picked up |
| | 27PP2 | Level 2 phase-to-phase undervoltage picked up |
| | 27PP1 | Level 1 phase-to-phase undervoltage picked up |
| | 27P2 | Level 2 phase undervoltage picked up |
| | 27P1 | Level 1 phase undervoltage picked up |
| | * | Reserved for future use |
| | CTS | Current transformer saturation |
| 15 | 59Q | Negative-sequence overvoltage picked up |
| | 59G2 | Level 2 residual overvoltage picked up |
| | 59G1 | Level 1 residual overvoltage picked up |
| | 59V1 | Positive-sequence overvoltage picked up |
| | 59PP2 | Level 2 phase-to-phase overvoltage picked up |
| | 59PP1 | Level 1 phase-to-phase overvoltage picked up |
| | 59P2 | Level 2 phase overvoltage picked up |
| | 59P1 | Level 1 phase overvoltage picked up |

**Table 4.9 Relay Word Bit Definitions** (Sheet 4 of 11)

| Row | Bit | Definition |
|---|---|---|
| 16 | 81D1 | Level 1 frequency element |
| | 81D2 | Level 2 frequency element |
| | 81D3 | Level 3 frequency element |
| | 81D4 | Level 4 frequency element |
| | 81D5 | Level 5 frequency element |
| | 81D6 | Level 6 frequency element |
| | ISQTAL | Cumulative through-fault $I^2t$ on a phase of a designated winding has exceeded the through-fault $I^2t$ threshold ISQT |
| | 27B81 | Undervoltage element for frequency blocking |
| 17 | 81D1T | Level 1 definite-time frequency element |
| | 81D2T | Level 2 definite-time frequency element |
| | 81D3T | Level 3 definite-time frequency element |
| | 81D4T | Level 4 definite-time frequency element |
| | 81D5T | Level 5 definite-time frequency element |
| | 81D6T | Level 6 definite-time frequency element |
| | * | Reserved for future use |
| | * | Reserved for future use |
| 18 | 87U1 | Unrestrained differential element 1 picked up |
| | 87U2 | Unrestrained differential element 2 picked up |
| | 87U3 | Unrestrained differential element 3 picked up |
| | 87U | Unrestrained differential element picked up |
| | 87R1 | Restrained differential element 1 picked up |
| | 87R2 | Restrained differential element 2 picked up |
| | 87R3 | Restrained differential element 3 picked up |
| | 87R | Restrained differential element picked up |
| 19 | 2HB1 | Second-harmonic block asserted for differential element 1 |
| | 2HB2 | Second-harmonic block asserted for differential element 2 |
| | 2HB3 | Second-harmonic block asserted for differential element 3 |
| | 5HB1 | Fifth-harmonic block asserted for differential element 1 |
| | 5HB2 | Fifth-harmonic block asserted for differential element 2 |
| | 5HB3 | Fifth-harmonic block asserted for differential element 3 |
| | TH5 | Fifth-harmonic alarm threshold exceeded |
| | TH5T | Fifth-harmonic alarm threshold exceeded for longer than TH5D |
| 20 | 87BL1 | Harmonic block asserted for differential element 1 |
| | 87BL2 | Harmonic block asserted for differential element 2 |
| | 87BL3 | Harmonic block asserted for differential element 3 |
| | 87BL | Harmonic block asserted for differential element |
| | 87E1 | Trip by differential element 1 |
| | 87E2 | Trip by differential element 2 |
| | 87E3 | Trip by differential element 3 |
| | 32IE | Internal enable for the 32I element |

**Table 4.9 Relay Word Bit Definitions** (Sheet 5 of 11)

| Row | Bit | Definition |
|---|---|---|
| 21 | 87O1 | Restrained differential element 1 operating current above O87P |
| | 87O2 | Restrained differential element 2 operating current above O87P |
| | 87O3 | Restrained differential element 3 operating current above O87P |
| | 24D1 | Level 1 volts/hertz instantaneous pickup |
| | 24D1T | Level 1 volts/hertz definite-time element timed out |
| | 24C2 | Level 2 volts/hertz composite element pickup |
| | 24C2T | Level 2 volts/hertz composite element timed out |
| | 24CR | Level 2 volts/hertz element fully reset |
| 22 | 51PC1 | Windings 1 and 2 phase inverse-time O/C element picked up |
| | 51PC1T | Windings 1 and 2 phase inverse-time O/C element timed out |
| | 51PC1R | Windings 1 and 2 phase inverse-time O/C element is reset |
| | 51NC1 | Windings 1 and 2 residual inverse-time O/C element picked up |
| | 51NC1T | Windings 1 and 2 residual inverse-time O/C element timed out |
| | 51NC1R | Windings 1 and 2 residual inverse-time O/C element is reset |
| | DC1 | DC battery voltage Level 1 exceeded |
| | DC2 | DC battery voltage Level 2 exceeded |
| 23 | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | DC3 | DC battery voltage Level 3 exceeded |
| | DC4 | DC battery voltage Level 4 exceeded |
| 24 | RB1 | Remote bit RB1 asserted |
| | RB2 | Remote bit RB2 asserted |
| | RB3 | Remote bit RB3 asserted |
| | RB4 | Remote bit RB4 asserted |
| | RB5 | Remote bit RB5 asserted |
| | RB6 | Remote bit RB6 asserted |
| | RB7 | Remote bit RB7 asserted |
| | RB8 | Remote bit RB8 asserted |
| 25 | RB9 | Remote bit RB9 asserted |
| | RB10 | Remote bit RB10 asserted |
| | RB11 | Remote bit RB11 asserted |
| | RB12 | Remote bit RB12 asserted |
| | RB13 | Remote bit RB13 asserted |
| | RB14 | Remote bit RB14 asserted |
| | RB15 | Remote bit RB15 asserted |
| | RB16 | Remote bit RB16 asserted |

**Table 4.9 Relay Word Bit Definitions** (Sheet 6 of 11)

| Row | Bit | Definition |
|---|---|---|
| 26 | SG1 | Setting Group 1 is the active setting group |
| | SG2 | Setting Group 2 is the active setting group |
| | SG3 | Setting Group 3 is the active setting group |
| | SG4 | Setting Group 4 is the active setting group |
| | SG5 | Setting Group 5 is the active setting group |
| | SG6 | Setting Group 6 is the active setting group |
| | CHSG | Timing to change setting groups |
| | * | Reserved for future use |
| 27 | 4HBL | Fourth-harmonic block asserted |
| | DCBL | DC block asserted |
| | IN106 | Input IN106 asserted |
| | IN105 | Input IN105 asserted |
| | IN104 | Input IN104 asserted |
| | IN103 | Input IN103 asserted |
| | IN102 | Input IN102 asserted |
| | IN101 | Input IN101 asserted |
| 28 | IN208 | Input IN208 asserted |
| | IN207 | Input IN207 asserted |
| | IN206 | Input IN206 asserted |
| | IN205 | Input IN205 asserted |
| | IN204 | Input IN204 asserted |
| | IN203 | Input IN203 asserted |
| | IN202 | Input IN202 asserted |
| | IN201 | Input IN201 asserted |
| 29 | IN216 | Input IN216 asserted |
| | IN215 | Input IN215 asserted |
| | IN214 | Input IN214 asserted |
| | IN213 | Input IN213 asserted |
| | IN212 | Input IN212 asserted |
| | IN211 | Input IN211 asserted |
| | IN210 | Input IN210 asserted |
| | IN209 | Input IN209 asserted |
| 30 | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |

**Table 4.9 Relay Word Bit Definitions** (Sheet 7 of 11)

| Row | Bit | Definition |
|---|---|---|
| 31 | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| 32 | S1V1 | Set 1 SELOGIC control equation variable S1V1 timer input asserted |
| | S1V2 | Set 1 SELOGIC control equation variable S1V2 timer input asserted |
| | S1V3 | Set 1 SELOGIC control equation variable S1V3 timer input asserted |
| | S1V4 | Set 1 SELOGIC control equation variable S1V4 timer input asserted |
| | S1V1T | Set 1 SELOGIC control equation variable S1V1 timer output asserted |
| | S1V2T | Set 1 SELOGIC control equation variable S1V2 timer output asserted |
| | S1V3T | Set 1 SELOGIC control equation variable S1V3 timer output asserted |
| | S1V4T | Set 1 SELOGIC control equation variable S1V4 timer output asserted |
| 33 | S2V1 | Set 2 SELOGIC control equation variable S2V1 timer input asserted |
| | S2V2 | Set 2 SELOGIC control equation variable S2V2 timer input asserted |
| | S2V3 | Set 2 SELOGIC control equation variable S2V3 timer input asserted |
| | S2V4 | Set 2 SELOGIC control equation variable S2V4 timer input asserted |
| | S2V1T | Set 2 SELOGIC control equation variable S2V1 timer output asserted |
| | S2V2T | Set 2 SELOGIC control equation variable S2V2 timer output asserted |
| | S2V3T | Set 2 SELOGIC control equation variable S2V3 timer output asserted |
| | S2V4T | Set 2 SELOGIC control equation variable S2V4 timer output asserted |

**Table 4.9 Relay Word Bit Definitions** (Sheet 8 of 11)

| Row | Bit | Definition |
|---|---|---|
| 34 | S3V1 | Set 3 SELOGIC control equation variable S3V1 timer input asserted |
| | S3V2 | Set 3 SELOGIC control equation variable S3V2 timer input asserted |
| | S3V3 | Set 3 SELOGIC control equation variable S3V3 timer input asserted |
| | S3V4 | Set 3 SELOGIC control equation variable S3V4 timer input asserted |
| | S3V5 | Set 3 SELOGIC control equation variable S3V5 timer input asserted |
| | S3V6 | Set 3 SELOGIC control equation variable S3V6 timer input asserted |
| | S3V7 | Set 3 SELOGIC control equation variable S3V7 timer input asserted |
| | S3V8 | Set 3 SELOGIC control equation variable S3V8 timer input asserted |
| 35 | S3V1T | Set 3 SELOGIC control equation variable S3V1 timer output asserted |
| | S3V2T | Set 3 SELOGIC control equation variable S3V2 timer output asserted |
| | S3V3T | Set 3 SELOGIC control equation variable S3V3 timer output asserted |
| | S3V4T | Set 3 SELOGIC control equation variable S3V4 timer output asserted |
| | S3V5T | Set 3 SELOGIC control equation variable S3V5 timer output asserted |
| | S3V6T | Set 3 SELOGIC control equation variable S3V6 timer output asserted |
| | S3V7T | Set 3 SELOGIC control equation variable S3V7 timer output asserted |
| | S3V8T | Set 3 SELOGIC control equation variable S3V8 timer output asserted |
| 36 | S1LT1 | Set 1 latch bit S1LT1 asserted |
| | S1LT2 | Set 1 latch bit S1LT2 asserted |
| | S1LT3 | Set 1 latch bit S1LT3 asserted |
| | S1LT4 | Set 1 latch bit S1LT4 asserted |
| | S2LT1 | Set 2 latch bit S2LT1 asserted |
| | S2LT2 | Set 2 latch bit S2LT2 asserted |
| | S2LT3 | Set 2 latch bit S2LT3 asserted |
| | S2LT4 | Set 2 latch bit S2LT4 asserted |

**Table 4.9 Relay Word Bit Definitions** (Sheet 9 of 11)

| Row | Bit | Definition |
|---|---|---|
| 37 | S3LT1 | Set 3 latch bit S3LT1 asserted |
| | S3LT2 | Set 3 latch bit S3LT2 asserted |
| | S3LT3 | Set 3 latch bit S3LT3 asserted |
| | S3LT4 | Set 3 latch bit S3LT4 asserted |
| | S3LT5 | Set 3 latch bit S3LT5 asserted |
| | S3LT6 | Set 3 latch bit S3LT6 asserted |
| | S3LT7 | Set 3 latch bit S3LT7 asserted |
| | S3LT8 | Set 3 latch bit S3LT8 asserted |
| 38 | * | Reserved for future use |
| | * | Reserved for future use |
| | * | Reserved for future use |
| | 50GC | Combined residual current sensitivity threshold exceeded |
| | 50G3 | W3 residual current sensitivity threshold exceeded |
| | 32IR | 32I element reverse (external) fault declaration |
| | 32IF | 32I element forward (internal) fault declaration |
| | REFP | Restricted earth fault inverse-time O/C element timed out |
| 39 | BCWA1 | A-phase Breaker 1 contact wear threshold exceeded |
| | BCWB1 | B-phase Breaker 1 contact wear threshold exceeded |
| | BCWC1 | C-phase Breaker 1 contact wear threshold exceeded |
| | BCW1 | BCWA1 + BCWB1 + BCWC1 |
| | BCWA2 | A-phase Breaker 2 contact wear threshold exceeded |
| | BCWB2 | B-phase Breaker 2 contact wear threshold exceeded |
| | BCWC2 | C-phase Breaker 2 contact wear threshold exceeded |
| | BCW2 | BCWA2 + BCWB2 + BCWC2 |
| 40 | BCWA3 | A-phase Breaker 3 contact wear threshold exceeded |
| | BCWB3 | B-phase Breaker 3 contact wear threshold exceeded |
| | BCWC3 | C-phase Breaker 3 contact wear threshold exceeded |
| | BCW3 | BCWA3 + BCWB3 + BCWC3 |
| | * | Reserved for future use |
| | P5SEL | Asserts when Port 5 is selected |
| | P6SEL | Asserts when Port 6 is selected |
| | LNKFAIL | Asserts when the active Ethernet port is down |
| 41 | TRIP1 | Trip 1 logic asserted |
| | TRIP2 | Trip 2 logic asserted |
| | TRIP3 | Trip 3 logic asserted |
| | TRIP4 | Trip 4 logic asserted |
| | * | Reserved for future use |
| | TRIPL | Any trip asserted |
| | * | Reserved for future use |
| | TRGTR | TARGET RESET pushbutton/**TAR R** command |

**Table 4.9 Relay Word Bit Definitions** (Sheet 10 of 11)

| Row | Bit | Definition |
|---|---|---|
| 42 | CLS1 | Breaker 1 CLOSE output asserted |
| | CLS2 | Breaker 2 CLOSE output asserted |
| | CLS3 | Breaker 3 CLOSE output asserted |
| | * | Reserved for future use |
| | CF1T | Breaker 1 close failure timer timed out |
| | CF2T | Breaker 2 close failure timer timed out |
| | CF3T | Breaker 3 close failure timer timed out |
| | * | Reserved for future use |
| 43 | NOTALM | ALARM output not asserted |
| | OUT107 | Output OUT107 asserted |
| | OUT106 | Output OUT106 asserted |
| | OUT105 | Output OUT105 asserted |
| | OUT104 | Output OUT104 asserted |
| | OUT103 | Output OUT103 asserted |
| | OUT102 | Output OUT102 asserted |
| | OUT101 | Output OUT101 asserted |
| 44 | OUT201 | Output OUT201 asserted |
| | OUT202 | Output OUT202 asserted |
| | OUT203 | Output OUT203 asserted |
| | OUT204 | Output OUT204 asserted |
| | OUT205 | Output OUT205 asserted |
| | OUT206 | Output OUT206 asserted |
| | OUT207 | Output OUT207 asserted |
| | OUT208 | Output OUT208 asserted |
| 45 | OUT209 | Output OUT209 asserted |
| | OUT210 | Output OUT210 asserted |
| | OUT211 | Output OUT211 asserted |
| | OUT212 | Output OUT212 asserted |
| | OUT213 | Output OUT213 asserted |
| | OUT214 | Output OUT214 asserted |
| | OUT215 | Output OUT215 asserted |
| | OUT216 | Output OUT216 asserted |
| 46 | OUT301 | Output OUT301 asserted |
| | OUT302 | Output OUT302 asserted |
| | OUT303 | Output OUT303 asserted |
| | OUT304 | Output OUT304 asserted |
| | OUT305 | Output OUT305 asserted |
| | OUT306 | Output OUT306 asserted |
| | OUT307 | Output OUT307 asserted |
| | OUT308 | Output OUT308 asserted |

**Table 4.9 Relay Word Bit Definitions** (Sheet 11 of 11)

| Row | Bit | Definition |
|---|---|---|
| 47 | OUT309 | Output OUT309 asserted |
| | OUT310 | Output OUT310 asserted |
| | OUT311 | Output OUT311 asserted |
| | OUT312 | Output OUT312 asserted |
| | OUT313 | Output OUT313 asserted |
| | OUT314 | Output OUT314 asserted |
| | OUT315 | Output OUT315 asserted |
| | OUT316 | Output OUT316 asserted |
| 48 | LB1 | Local Bit 1 asserted |
| | LB2 | Local Bit 2 asserted |
| | LB3 | Local Bit 3 asserted |
| | LB4 | Local Bit 4 asserted |
| | LB5 | Local Bit 5 asserted |
| | LB6 | Local Bit 6 asserted |
| | LB7 | Local Bit 7 asserted |
| | LB8 | Local Bit 8 asserted |
| 49 | LB9 | Local Bit 9 asserted |
| | LB10 | Local Bit 10 asserted |
| | LB11 | Local Bit 11 asserted |
| | LB12 | Local Bit 12 asserted |
| | LB13 | Local Bit 13 asserted |
| | LB14 | Local Bit 14 asserted |
| | LB15 | Local Bit 15 asserted |
| | LB16 | Local Bit 16 asserted |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 1 of 11)

| Bit | Definition | Row |
|---|---|---|
| All | LED targets—not usable in SELOGIC control equations | 0 |
| All | LED targets—not usable in SELOGIC control equations | 1 |
| 2HB1 | Second-harmonic block asserted for Differential Element 1 | 19 |
| 2HB2 | Second-harmonic block asserted for Differential Element 2 | 19 |
| 2HB3 | Second-harmonic block asserted for Differential Element 3 | 19 |
| 4HBL | Fourth-harmonic element asserted | 27 |
| 5HB1 | Fifth-harmonic block asserted for Differential Element 1 | 19 |
| 5HB2 | Fifth-harmonic block asserted for Differential Element 2 | 19 |
| 5HB3 | Fifth-harmonic block asserted for Differential Element 3 | 19 |
| 24C2 | Level 2 volts/hertz composite element pickup | 21 |
| 24C2T | Level 2 volts/hertz composite element timed out | 21 |
| 24CR | Level 2 volts/hertz element fully reset | 21 |
| 24D1 | Level 1 volts/hertz instantaneous pickup | 21 |
| 24D1T | Level 1 volts/hertz definite-time element timed out | 21 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 2 of 11)

| Bit | Definition | Row |
|---|---|---|
| 27B81 | Undervoltage element for frequency blocking | 16 |
| 27P1 | Level 1 phase undervoltage picked up | 14 |
| 27P2 | Level 2 phase undervoltage picked up | 14 |
| 27PP1 | Level 1 phase-to-phase undervoltage picked up | 14 |
| 27PP2 | Level 2 phase-to-phase undervoltage picked up | 14 |
| 27V1 | Positive-sequence undervoltage picked up | 14 |
| 32IE | Internal enable for the 32I element | 20 |
| 32IF | 32I element forward (internal) fault declaration | 38 |
| 32IR | 32I element reverse (external) fault declaration | 38 |
| 50A13 | Winding 1 A-phase instantaneous O/C Level 3 element picked up | 3 |
| 50A14 | Winding 1 A-phase instantaneous O/C Level 4 element picked up | 3 |
| 50A23 | Winding 2 A-phase instantaneous O/C Level 3 element picked up | 7 |
| 50A24 | Winding 2 A-phase instantaneous O/C Level 4 element picked up | 7 |
| 50A33 | Winding 3 A-phase instantaneous O/C Level 3 element picked up | 11 |
| 50A34 | Winding 3 A-phase instantaneous O/C Level 4 element picked up | 11 |
| 50B13 | Winding 1 B-phase instantaneous O/C Level 3 element picked up | 3 |
| 50B14 | Winding 1 B-phase instantaneous O/C Level 4 element picked up | 3 |
| 50B23 | Winding 2 B-phase instantaneous O/C Level 3 element picked up | 7 |
| 50B24 | Winding 2 B-phase instantaneous O/C Level 4 element picked up | 7 |
| 50B33 | Winding 3 B-phase instantaneous O/C Level 3 element picked up | 11 |
| 50B34 | Winding 3 B-phase instantaneous O/C Level 4 element picked up | 11 |
| 50C13 | Winding 1 C-phase instantaneous O/C Level 3 element picked up | 3 |
| 50C14 | Winding 1 C-phase instantaneous O/C Level 4 element picked up | 3 |
| 50C23 | Winding 2 C-phase instantaneous O/C Level 3 element picked up | 7 |
| 50C24 | Winding 2 C-phase instantaneous O/C Level 4 element picked up | 7 |
| 50C33 | Winding 3 C-phase instantaneous O/C Level 3 element picked up | 11 |
| 50C34 | Winding 3 C-phase instantaneous O/C Level 4 element picked up | 11 |
| 50G3 | W3 residual current sensitivity threshold exceeded | 38 |
| 50GC | Combined residual current sensitivity threshold exceeded | 38 |
| 50N11 | Winding 1 residual definite-time O/C Level 1 element picked up | 4 |
| 50N11T | Winding 1 residual definite-time O/C Level 1 element timed out | 4 |
| 50N12 | Winding 1 residual instantaneous O/C Level 2 element picked up | 4 |
| 50N21 | Winding 2 residual definite-time O/C Level 1 element picked up | 8 |
| 50N21T | Winding 2 residual definite-time O/C Level 1 element timed out | 8 |
| 50N22 | Winding 2 residual instantaneous O/C Level 2 element picked up | 8 |
| 50N31 | Winding 3 residual definite-time O/C Level 1 element picked up | 12 |
| 50N31T | Winding 3 residual definite-time O/C level 1 element timed out | 12 |
| 50N32 | Winding 3 residual instantaneous O/C Level 2 element picked up | 12 |
| 50P11 | Winding 1 phase definite-time O/C Level 1 element picked up | 2 |
| 50P11T | Winding 1 phase definite-time O/C Level 1 element timed out | 2 |
| 50P12 | Winding 1 phase instantaneous O/C Level 2 element picked up | 2 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 3 of 11)

| Bit | Definition | Row |
|---|---|---|
| 50P13 | 50A13 + 50B13 + 50C13 | 3 |
| 50P14 | 50A14 + 50B14 + 50C14 | 3 |
| 50P21 | Winding 2 phase definite-time O/C Level 1 element picked up | 6 |
| 50P21T | Winding 2 phase definite-time O/C Level 1 element timed out | 6 |
| 50P22 | Winding 2 phase instantaneous O/C Level 2 element picked up | 6 |
| 50P23 | 50A23 + 50B23 + 50C23 | 7 |
| 50P24 | 50A24 + 50B24 + 50C24 | 7 |
| 50P31 | Winding 3 phase definite-time O/C Level 1 element picked up | 10 |
| 50P31T | Winding 3 phase definite-time O/C Level 1 element timed out | 10 |
| 50P32 | Winding 3 phase instantaneous O/C Level 2 element picked up | 10 |
| 50P33 | 50A33 + 50B33 + 50C33 | 11 |
| 50P34 | 50A34 + 50B34 + 50C34 | 11 |
| 50Q11 | Winding 1 neg.-seq. definite-time O/C Level 1 element picked up | 5 |
| 50Q11T | Winding 1 neg.-seq. definite-time O/C element timed out | 5 |
| 50Q12 | Winding 1 neg.-seq. instantaneous O/C Level 2 element picked up | 5 |
| 50Q21 | Winding 2 neg.-seq. definite-time O/C Level 1 element picked up | 9 |
| 50Q21T | Winding 2 neg.-seq. definite-time O/C Level 1 element timed out | 9 |
| 50Q22 | Winding 2 neg.-seq. instantaneous O/C Level 2 element picked up | 9 |
| 50Q31 | Winding 3 neg.-seq. definite-time O/C Level 1 element picked up | 13 |
| 50Q31T | Winding 3 neg.-seq. definite-time O/C Level 1 element timed out | 13 |
| 50Q32 | Winding 3 neg.-seq. instantaneous O/C Level 2 element picked up | 13 |
| 51N1 | Winding 1 residual inverse-time O/C element picked up | 4 |
| 51N1R | Winding 1 residual inverse-time O/C 51N1 element is reset | 4 |
| 51N1T | Winding 1 residual inverse-time O/C element timed out | 4 |
| 51N2 | Winding 2 residual inverse-time O/C element picked up | 8 |
| 51N2R | Winding 2 residual inverse-time O/C 51N2 element is reset | 8 |
| 51N2T | Winding 2 residual inverse-time O/C element timed out | 8 |
| 51N3 | Winding 3 residual inverse-time O/C element picked up | 12 |
| 51N3R | Winding 3 residual inverse-time O/C 51N3 element is reset | 12 |
| 51N3T | Winding 3 residual inverse-time O/C element timed out | 12 |
| 51NC1 | Windings 1 and 2 residual inverse-time O/C element picked up | 22 |
| 51NC1R | Windings 1 and 2 residual inverse-time O/C element is reset | 22 |
| 51NC1T | Windings 1 and 2 residual inverse-time O/C element timed out | 22 |
| 51P1 | Winding 1 phase inverse-time O/C element picked up | 2 |
| 51P1R | Winding 1 phase inverse-time O/C 51P1 element is reset | 2 |
| 51P1T | Winding 1 phase inverse-time O/C element timed out | 2 |
| 51P2 | Winding 2 phase inverse-time O/C element picked up | 6 |
| 51P2R | Winding 2 phase inverse-time O/C 51P2 element is reset | 6 |
| 51P2T | Winding 2 phase inverse-time O/C element timed out | 6 |
| 51P3 | Winding 3 phase inverse-time O/C element picked up | 10 |
| 51P3R | Winding 3 phase inverse-time O/C 51P3 element is reset | 10 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 4 of 11)

| Bit | Definition | Row |
|---|---|---|
| 51P3T | Winding 3 phase inverse-time O/C element timed out | 10 |
| 51PC1 | Windings 1 and 2 phase inverse-time O/C element picked up | 22 |
| 51PC1R | Windings 1 and 2 phase inverse-time O/C element is reset | 22 |
| 51PC1T | Windings 1 and 2 phase inverse-time O/C element timed out | 22 |
| 51Q1 | Winding 1 neg.-seq. inverse-time O/C element picked up | 5 |
| 51Q1R | Winding 1 neg.-seq. inverse-time O/C 51Q1 element is reset | 5 |
| 51Q1T | Winding 1 neg.-seq. instantaneous O/C Level 1 element timed out | 5 |
| 51Q2 | Winding 2 neg.-seq. inverse-time O/C element picked up | 9 |
| 51Q2R | Winding 2 neg.-seq. inverse-time O/C 51Q2 element is reset | 9 |
| 51Q2T | Winding 2 neg.-seq. inverse-time O/C element timed out | 9 |
| 51Q3 | Winding 3 neg.-seq. inverse-time O/C element picked up | 13 |
| 51Q3R | Winding 3 neg.-seq. inverse-time O/C 51Q3 element is reset | 13 |
| 51Q3T | Winding 3 neg.-seq. inverse-time O/C element timed out | 13 |
| 59G1 | Level 1 residual overvoltage picked up | 15 |
| 59G2 | Level 2 residual overvoltage picked up | 15 |
| 59P1 | Level 1 phase overvoltage picked up | 15 |
| 59P2 | Level 2 phase overvoltage picked up | 15 |
| 59PP1 | Level 1 phase-to-phase overvoltage picked up | 15 |
| 59PP2 | Level 2 phase-to-phase overvoltage picked up | 15 |
| 59Q | Negative-sequence overvoltage picked up | 15 |
| 59V1 | Positive-sequence overvoltage picked up | 15 |
| 81D1 | Level 1 frequency element | 16 |
| 81D2 | Level 2 frequency element | 16 |
| 81D3 | Level 3 frequency element | 16 |
| 81D4 | Level 4 frequency element | 16 |
| 81D5 | Level 5 frequency element | 16 |
| 81D6 | Level 6 frequency element | 16 |
| 81D1T | Level 1 definite-time frequency element | 17 |
| 81D2T | Level 2 definite-time frequency element | 17 |
| 81D3T | Level 3 definite-time frequency element | 17 |
| 81D4T | Level 4 definite-time frequency element | 17 |
| 81D5T | Level 5 definite-time frequency element | 17 |
| 81D6T | Level 6 definite-time frequency element | 17 |
| 87BL | Harmonic block asserted for Differential Element | 20 |
| 87BL1 | Harmonic block asserted for Differential Element 1 | 20 |
| 87BL2 | Harmonic block asserted for Differential Element 2 | 20 |
| 87BL3 | Harmonic block asserted for Differential Element 3 | 20 |
| 87E1 | Trip by Differential Element 1 | 20 |
| 87E2 | Trip by Differential Element 2 | 20 |
| 87E3 | Trip by Differential Element 3 | 20 |
| 87O1 | Retrained Differential Element 1 operating current above O87P | 21 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 5 of 11)

| Bit | Definition | Row |
|---|---|---|
| 87O2 | Retrained Differential Element 2 operating current above O87P | 21 |
| 87O3 | Retrained Differential Element 3 operating current above O87P | 21 |
| 87R | Restrained Differential Element picked up | 18 |
| 87R1 | Restrained Differential Element 1 picked up | 18 |
| 87R2 | Restrained Differential Element 2 picked up | 18 |
| 87R3 | Restrained Differential Element 3 picked up | 18 |
| 87U | Unrestrained Differential Element picked up | 18 |
| 87U1 | Unrestrained Differential Element 1 picked up | 18 |
| 87U2 | Unrestrained Differential Element 2 picked up | 18 |
| 87U3 | Unrestrained Differential Element 3 picked up | 18 |
| BCW1 | BCWA1 + BCWB1 + BCWC1 | 39 |
| BCW2 | BCWA2 + BCWB2 + BCWC2 | 39 |
| BCW3 | BCWA3 + BCWB3 + BCWC3 | 40 |
| BCWA1 | A-phase Breaker 1 contact wear threshold exceeded | 39 |
| BCWA2 | A-phase Breaker 2 contact wear threshold exceeded | 39 |
| BCWA3 | A-phase Breaker 3 contact wear threshold exceeded | 40 |
| BCWB1 | B-phase Breaker 1 contact wear threshold exceeded | 39 |
| BCWB2 | B-phase Breaker 2 contact wear threshold exceeded | 39 |
| BCWB3 | B-phase Breaker 3 contact wear threshold exceeded | 40 |
| BCWC1 | C-phase Breaker 1 contact wear threshold exceeded | 39 |
| BCWC2 | C-phase Breaker 2 contact wear threshold exceeded | 39 |
| BCWC3 | C-phase Breaker 3 contact wear threshold exceeded | 40 |
| CC1 | Breaker 1 **CLOSE** command execution | 5 |
| CC2 | Breaker 2 **CLOSE** command execution | 9 |
| CC3 | Breaker 3 **CLOSE** command execution | 13 |
| CF1T | Breaker 1 close failure timer timed out | 42 |
| CF2T | Breaker 2 close failure timer timed out | 42 |
| CF3T | Breaker 3 close failure timer timed out | 42 |
| CHSG | Timing to change setting groups | 26 |
| CLS1 | Breaker 1 CLOSE output asserted | 42 |
| CLS2 | Breaker 2 CLOSE output asserted | 42 |
| CLS3 | Breaker 3 CLOSE output asserted | 42 |
| CTS | Current transformer saturation | 14 |
| DC1 | DC battery voltage Level 1 exceeded | 22 |
| DC2 | DC battery voltage Level 2 exceeded | 22 |
| DC3 | DC battery voltage Level 3 exceeded | 23 |
| DC4 | DC battery voltage Level 4 exceeded | 23 |
| DCBL | DC block asserted | 27 |
| IN101 | Input IN101 asserted | 27 |
| IN102 | Input IN102 asserted | 27 |
| IN103 | Input IN103 asserted | 27 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 6 of 11)

| Bit | Definition | Row |
|---|---|---|
| IN104 | Input IN104 asserted | 27 |
| IN105 | Input IN105 asserted | 27 |
| IN106 | Input IN106 asserted | 27 |
| IN201 | Input IN201 asserted | 28 |
| IN202 | Input IN202 asserted | 28 |
| IN203 | Input IN203 asserted | 28 |
| IN204 | Input IN204 asserted | 28 |
| IN205 | Input IN205 asserted | 28 |
| IN206 | Input IN206 asserted | 28 |
| IN207 | Input IN207 asserted | 28 |
| IN208 | Input IN208 asserted | 28 |
| IN209 | Input IN209 asserted | 29 |
| IN210 | Input IN210 asserted | 29 |
| IN211 | Input IN211 asserted | 29 |
| IN212 | Input IN212 asserted | 29 |
| IN213 | Input IN213 asserted | 29 |
| IN214 | Input IN214 asserted | 29 |
| IN215 | Input IN215 asserted | 29 |
| IN216 | Input IN216 asserted | 29 |
| IN301 | Input IN301 asserted | 30 |
| IN302 | Input IN302 asserted | 30 |
| IN303 | Input IN303 asserted | 30 |
| IN304 | Input IN304 asserted | 30 |
| IN305 | Input IN305 asserted | 30 |
| IN306 | Input IN306 asserted | 30 |
| IN307 | Input IN307 asserted | 30 |
| IN308 | Input IN308 asserted | 30 |
| IN309 | Input IN309 asserted | 31 |
| IN310 | Input IN310 asserted | 31 |
| IN311 | Input IN311 asserted | 31 |
| IN312 | Input IN312 asserted | 31 |
| IN313 | Input IN313 asserted | 31 |
| IN314 | Input IN314 asserted | 31 |
| IN315 | Input IN315 asserted | 31 |
| IN316 | Input IN316 asserted | 31 |
| ISQTAL | Cumulative through-fault $I^2t$ on a phase of a designated winding has exceeded the through-fault $I^2t$ threshold ISQT | 16 |
| LB1 | Local bit 1 asserted | 48 |
| LB10 | Local bit 10 asserted | 49 |
| LB11 | Local bit 11 asserted | 49 |
| LB12 | Local bit 12 asserted | 49 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 7 of 11)

| Bit | Definition | Row |
|---|---|---|
| LB13 | Local bit 13 asserted | 49 |
| LB14 | Local bit 14 asserted | 49 |
| LB15 | Local bit 15 asserted | 49 |
| LB16 | Local bit 16 asserted | 49 |
| LB2 | Local bit 2 asserted | 48 |
| LB3 | Local bit 3 asserted | 48 |
| LB4 | Local bit 4 asserted | 48 |
| LB5 | Local bit 5 asserted | 48 |
| LB6 | Local bit 6 asserted | 48 |
| LB7 | Local bit 7 asserted | 48 |
| LB8 | Local bit 8 asserted | 48 |
| LB9 | Local bit 9 asserted | 49 |
| LNKFAIL | Asserts when the active Ethernet port is down | 40 |
| NDEM1 | Winding 1 residual demand current threshold exceeded | 4 |
| NDEM2 | Winding 2 residual demand current threshold exceeded | 8 |
| NDEM3 | Winding 3 residual demand current threshold exceeded | 12 |
| NOTALM | ALARM output not asserted | 43 |
| OC1 | Breaker 1 **OPEN** command execution | 4 |
| OC2 | Breaker 2 **OPEN** command execution | 8 |
| OC3 | Breaker 3 **OPEN** command execution | 12 |
| OCA | O/C element A-phase selection | 2 |
| OCB | O/C element B-phase selection | 6 |
| OCC | O/C element C-phase selection | 10 |
| OUT101 | Output OUT101 asserted | 43 |
| OUT102 | Output OUT102 asserted | 43 |
| OUT103 | Output OUT103 asserted | 43 |
| OUT104 | Output OUT104 asserted | 43 |
| OUT105 | Output OUT105 asserted | 43 |
| OUT106 | Output OUT106 asserted | 43 |
| OUT107 | Output OUT107 asserted | 43 |
| OUT201 | Output OUT201 asserted | 44 |
| OUT202 | Output OUT202 asserted | 44 |
| OUT203 | Output OUT203 asserted | 44 |
| OUT204 | Output OUT204 asserted | 44 |
| OUT205 | Output OUT205 asserted | 44 |
| OUT206 | Output OUT206 asserted | 44 |
| OUT207 | Output OUT207 asserted | 44 |
| OUT208 | Output OUT208 asserted | 44 |
| OUT209 | Output OUT209 asserted | 45 |
| OUT210 | Output OUT210 asserted | 45 |
| OUT211 | Output OUT211 asserted | 45 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 8 of 11)

| Bit | Definition | Row |
|---|---|---|
| OUT212 | Output OUT212 asserted | 45 |
| OUT213 | Output OUT213 asserted | 45 |
| OUT214 | Output OUT214 asserted | 45 |
| OUT215 | Output OUT215 asserted | 45 |
| OUT216 | Output OUT216 asserted | 45 |
| OUT301 | Output OUT301 asserted | 46 |
| OUT302 | Output OUT302 asserted | 46 |
| OUT303 | Output OUT303 asserted | 46 |
| OUT304 | Output OUT304 asserted | 46 |
| OUT305 | Output OUT305 asserted | 46 |
| OUT306 | Output OUT306 asserted | 46 |
| OUT307 | Output OUT307 asserted | 46 |
| OUT308 | Output OUT308 asserted | 46 |
| OUT309 | Output OUT309 asserted | 47 |
| OUT310 | Output OUT310 asserted | 47 |
| OUT311 | Output OUT311 asserted | 47 |
| OUT312 | Output OUT312 asserted | 47 |
| OUT313 | Output OUT313 asserted | 47 |
| OUT314 | Output OUT314 asserted | 47 |
| OUT315 | Output OUT315 asserted | 47 |
| OUT316 | Output OUT216 asserted | 47 |
| P5SEL | Asserts when Port 5 is selected | 40 |
| P6SEL | Asserts when Port 6 is selected | 40 |
| PDEM1 | Winding 1 phase demand current threshold exceeded | 2 |
| PDEM2 | Winding 2 phase demand current threshold exceeded | 6 |
| PDEM3 | Winding 3 phase demand current threshold exceeded | 10 |
| QDEM1 | Winding 1 neg.-seq. demand current threshold exceeded | 5 |
| QDEM2 | Winding 2 neg.-seq. demand current threshold exceeded | 9 |
| QDEM3 | Winding 3 neg.-seq. demand current threshold exceeded | 13 |
| RB1 | Remote bit RB1 asserted | 24 |
| RB2 | Remote bit RB2 asserted | 24 |
| RB3 | Remote bit RB3 asserted | 24 |
| RB4 | Remote bit RB4 asserted | 24 |
| RB5 | Remote bit RB5 asserted | 24 |
| RB6 | Remote bit RB6 asserted | 24 |
| RB7 | Remote bit RB7 asserted | 24 |
| RB8 | Remote bit RB8 asserted | 24 |
| RB9 | Remote bit RB9 asserted | 25 |
| RB10 | Remote bit RB10 asserted | 25 |
| RB11 | Remote bit RB11 asserted | 25 |
| RB12 | Remote bit RB12 asserted | 25 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 9 of 11)

| Bit | Definition | Row |
|---|---|---|
| RB13 | Remote bit RB13 asserted | 25 |
| RB14 | Remote bit RB14 asserted | 25 |
| RB15 | Remote bit RB15 asserted | 25 |
| RB16 | Remote bit RB16 asserted | 25 |
| REFP | Restricted earth fault inverse-time O/C element timed out | 38 |
| S1LT1 | Set 1 latch bit S1LT1 asserted | 36 |
| S1LT2 | Set 1 latch bit S1LT2 asserted | 36 |
| S1LT3 | Set 1 latch bit S1LT3 asserted | 36 |
| S1LT4 | Set 1 latch bit S1LT4 asserted | 36 |
| S1V1 | Set 1 SELOGIC control equation variable S1V1 timer input asserted | 32 |
| S1V1T | Set 1 SELOGIC control equation variable S1V1 timer output asserted | 32 |
| S1V2 | Set 1 SELOGIC control equation variable S1V2 timer input asserted | 32 |
| S1V2T | Set 1 SELOGIC control equation variable S1V2 timer output asserted | 32 |
| S1V3 | Set 1 SELOGIC control equation variable S1V3 timer input asserted | 32 |
| S1V3T | Set 1 SELOGIC control equation variable S1V3 timer output asserted | 32 |
| S1V4 | Set 1 SELOGIC control equation variable S1V4 timer input asserted | 32 |
| S1V4T | Set 1 SELOGIC control equation variable S1V4 timer output asserted | 32 |
| S2LT1 | Set 2 latch bit S2LT1 asserted | 36 |
| S2LT2 | Set 2 latch bit S2LT2 asserted | 36 |
| S2LT3 | Set 2 latch bit S2LT3 asserted | 36 |
| S2LT4 | Set 2 latch bit S2LT4 asserted | 36 |
| S2V1 | Set 2 SELOGIC control equation variable S2V1 timer input asserted | 33 |
| S2V1T | Set 2 SELOGIC control equation variable S2V1 timer output asserted | 33 |
| S2V2 | Set 2 SELOGIC control equation variable S2V2 timer input asserted | 33 |
| S2V2T | Set 2 SELOGIC control equation variable S2V2 timer output asserted | 33 |
| S2V3 | Set 2 SELOGIC control equation variable S2V3 timer input asserted | 33 |
| S2V3T | Set 2 SELOGIC control equation variable S2V3 timer output asserted | 33 |
| S2V4 | Set 2 SELOGIC control equation variable S2V4 timer input asserted | 33 |
| S2V4T | Set 2 SELOGIC control equation variable S2V4 timer output asserted | 33 |
| S3LT1 | Set 3 latch bit S3LT1 asserted | 37 |
| S3LT2 | Set 3 latch bit S3LT2 asserted | 37 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 10 of 11)

| Bit | Definition | Row |
|---|---|---|
| S3LT3 | Set 3 latch bit S3LT3 asserted | 37 |
| S3LT4 | Set 3 latch bit S3LT4 asserted | 37 |
| S3LT5 | Set 3 latch bit S3LT5 asserted | 37 |
| S3LT6 | Set 3 latch bit S3LT6 asserted | 37 |
| S3LT7 | Set 3 latch bit S3LT7 asserted | 37 |
| S3LT8 | Set 3 latch bit S3LT8 asserted | 37 |
| S3V1 | Set 3 SELOGIC control equation variable S3V1 timer input asserted | 34 |
| S3V1T | Set 3 SELOGIC control equation variable S3V1 timer output asserted | 35 |
| S3V2 | Set 3 SELOGIC control equation variable S3V2 timer input asserted | 34 |
| S3V2T | Set 3 SELOGIC control equation variable S3V2 timer output asserted | 35 |
| S3V3 | Set 3 SELOGIC control equation variable S3V3 timer input asserted | 34 |
| S3V3T | Set 3 SELOGIC control equation variable S3V3 timer output asserted | 35 |
| S3V4 | Set 3 SELOGIC control equation variable S3V4 timer input asserted | 34 |
| S3V4T | Set 3 SELOGIC control equation variable S3V4 timer output asserted | 35 |
| S3V5 | Set 3 SELOGIC control equation variable S3V5 timer input asserted | 34 |
| S3V5T | Set 3 SELOGIC control equation variable S3V5 timer output asserted | 35 |
| S3V6 | Set 3 SELOGIC control equation variable S3V6 timer input asserted | 34 |
| S3V6T | Set 3 SELOGIC control equation variable S3V6 timer output asserted | 35 |
| S3V7 | Set 3 SELOGIC control equation variable S3V7 timer input asserted | 34 |
| S3V7T | Set 3 SELOGIC control equation variable S3V7 timer output asserted | 35 |
| S3V8 | Set 3 SELOGIC control equation variable S3V8 timer input asserted | 34 |
| S3V8T | Set 3 SELOGIC control equation variable S3V8 timer output asserted | 35 |
| SG1 | Setting Group 1 is the active setting group | 26 |
| SG2 | Setting Group 2 is the active setting group | 26 |
| SG3 | Setting Group 3 is the active setting group | 26 |
| SG4 | Setting Group 4 is the active setting group | 26 |
| SG5 | Setting Group 5 is the active setting group | 26 |
| SG6 | Setting Group 6 is the active setting group | 26 |
| TH5 | Fifth-harmonic alarm threshold exceeded | 19 |
| TH5T | Fifth-harmonic alarm threshold exceeded for longer than TH5D | 19 |
| TRGTR | TARGET RESET pushbutton/**TAR R** command | 41 |

**Table 4.10 Relay Word Bits Sorted Alphabetically** (Sheet 11 of 11)

| Bit | Definition | Row |
|---|---|---|
| TRIP1 | Trip 1 logic asserted | 41 |
| TRIP2 | Trip 2 logic asserted | 41 |
| TRIP3 | Trip 3 logic asserted | 41 |
| TRIP4 | Trip 4 logic asserted | 41 |
| TRIPL | Any trip asserted | 41 |

# Section 5

# Metering and Monitoring

## Introduction

The SEL-387E Relay provides metering information in several report formats, for each of the three 3-phase winding current inputs and three voltage inputs, and for the three differential elements. A dc battery monitor reports on the supply voltage to the relay and can be programmed to alarm for voltage excursions. There is also a breaker monitor function that keeps track of breaker trips, the cumulative current interrupted over time, and the amount of estimated contact wear. These functions and their associated reports are discussed in this section.

## Metering Functions

There are three types of fundamental frequency metering functions in the SEL-387E: instantaneous, demand (thermal), and peak demand. Quantities metered include one set of phase voltage and phase currents for each winding input; positive-, negative-, and zero-sequence (residual) voltages and currents for all current and voltage inputs, three-phase power (MW, MVAR), energy; and operate, restraint, second-harmonic, and fifth-harmonic currents for the three differential elements. There are several report formats, employing different groups of the above quantities, accessible by variants of the **METER** command through the relay serial port. This information is also available at the relay front panel via the LCD.

There is also a specialized metering function, harmonic metering. This function provides a snapshot of harmonic magnitudes of all analog inputs, fundamental through the 15th harmonic.

This section will discuss which quantities are used in each of the report formats and show the format for each of the **METER** command displays, as they appear on the screen. The relay front-panel LCD displays the same quantities but requires several stages of keystrokes to select the data of interest. These displays are covered in *Section 8: Front-Panel Operation*.

All METER displays herein show the default Analog Input Labels (IAW1, IBW1, etc.). Relay displays show the user setting values of the Analog Input Labels.

## Instantaneous Phase Meter Function (METER Command)

The **METER** (**MET**) command, with no additional parameters, displays instantaneous current, voltage, and power magnitudes, in primary quantities. Phase, positive-sequence, negative-sequence, and residual currents and voltages are displayed for each of the three winding and voltage inputs. Power is calculated from the supplied voltages and currents and displayed in real, reactive, and apparent power quantities. Frequency, percent volts-per-hertz, and the value of the station battery dc supply voltage at the relay are also included. The station battery voltage is obtained from the Battery Voltage Monitor. If the command is typed as **MET *m***, where m is any number from 1 to 32767, the report will be repeated m times in succession. In this mode, subsequent reports are not generated until the previous report has been completely sent.

**NOTE:** If current or voltage transformers are connected delta (DELTA_Y = D, WnCT = D) or only one voltage is connected (TPVI = N), only total power (MW, MVAR, MVA) will display in the METER report. This restricted calculation assumes balanced load conditions. Setting the current voltage winding setting (VIWDG) to 12 combines the current in Winding 1 and Winding 2 and displays their sum in the METER report.

The format for the METER report is as follows:

```
=>>METER <Enter>

XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

                    Phase Currents                      Sequence Currents
Wdg1             IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)         123       123       123            123       123       123
Wdg2             IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)         123       123       123            123       123       123
Wdg3             IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)         123       123       123            123       123       123
Wdg1&2          IAW12     IBW12     ICW12          IRW12
I (A,pri)         123       123       123            123
                    Phase Voltages                      Sequence Voltages
WdgX             VAWX      VBWX      VCWX          3V1WX     3V2WX      VRWX
V (KV,pri)       123.12    123.12    123.12        123.12    123.12     123.12
                    Power Quantities
                    MW        MWA       MWB       MWC
P (MW,pri)       123.12    123.12    123.12    123.12
                 MVAR      MVRA      MVRB      MVRC
Q (MVar,pri)     123.12    123.12    123.12    123.12
                  MVA      MVAA      MVAB      MVAC
S (MVa,pri)      123.12    123.12    123.12    123.12

FREQ (Hz)       12.12
V/Hz (percent)  12.12
VDC (V)         123.1
=>>
```

## Demand Meter Function (METER D Command)

The SEL-387E includes a thermal demand metering function for all three current windings and for three-phase real and reactive power using the windings selected with the VIWDG setting. In response to the **METER D** (**MET D**) command, the individual phase demand currents, as well as the negative-sequence and residual demand currents for each winding, are displayed in primary RMS amperes. If the command is typed as **MET D *m***, where *m* is any number from 1 to 32767, the report will be repeated m times in succession. In this mode subsequent reports are not generated until the previous report has been completely sent. The format for the METER D report is as follows:

```
=>>METER D <Enter>
XFMR 1                        Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

                      Phase Currents                  Sequence Currents

Wdg1                IAW1      IBW1      ICW1          3I2W1      IRW1
Dem I (A,pri)      12345     12345     12345          12345     12345

Wdg2                IAW2      IBW2      ICW2          3I2W2      IRW2
Dem I (A,pri)      12345     12345     12345          12345     12345

Wdg3                IAW3      IBW3      ICW3          3I2W3      IRW3
Dem I (A,pri)      12345     12345     12345          12345     12345

                      Power Quantities (Three-Phase)
                      MW
Dem P (MW,pri)  12345.67
                    MVAR
Dem Q (MVar,pri)12345.67

LAST DEMAND RESET FOR         Wdg1:    mm/dd/yy    hh:mm:ss.sss
                              Wdg2:    mm/dd/yy    hh:mm:ss.sss
                              Wdg3:    mm/dd/yy    hh:mm:ss.sss

=>>
```

The most recent demand resets for each winding are shown in the METER D report.

The demand meter function simulates the long-term heating effects of the measured quantity at a particular level by accumulating the demand current on an exponential basis, using a thermal time constant setting, DATC*n*, for each winding (*n* = 1, 2, 3). DATC*n* can be set over a range of 5 to 255 minutes (4 hours 15 minutes). The demand values in secondary amperes are compared to user-defined thresholds, PDEM*n*P, QDEM*n*P, and NDEM*n*P. PDEM*n*P is compared to the largest of the three individual phase current demands for Winding *n*, while QDEM*n*P is compared to the negative-sequence demand, and NDEM*n*P is compared to the residual demand. Relay Word bits PDEM*n*, QDEM*n*, or NDEM*n* are asserted if the appropriate demand exceeds the stated threshold. These bits can be used to initiate a display or to close an output contact for alarming or tripping purposes. Three-phase power demand quantities (MW and MVAR) are provided for metering purposes only and are not associated with any threshold alarms.

The demand meter output for a step change in current of S amperes is a smoothly rising exponential that produces a demand change of 0.9 times S at time DATC*n* after the step change occurred (see *Figure 5.1*). For example, if the demand current has stabilized at some value Id0 before time zero and at t = 0 the current suddenly jumps to a new value $I_{NEW}$, the demand current as a function of time will have the equation:

$$Id(t) = I_{NEW} + (Id_0 - I_{NEW}) \bullet e^{\frac{-[\ln(10) \bullet t]}{DATCn}}$$ **Equation 5.1**

The next function, the peak demand meter function, keeps track of the largest value of Id(t) since the last reset of the peak demand registers.

## Peak Demand Meter Function (METER P Command)

The peak demand meter function compares the value of the demand meter outputs for each current winding, i.e., the largest of the phase current demands, and three-phase real and reactive power demand, the negative-sequence demand, and the residual demand, against registers containing the largest demand value of each type since the last reset of the registers. This happens every two seconds. If the particular Id(t) exceeds the register value, it replaces the value in the register and becomes the new peak value. These peak values are time and date stamped.

In response to the **METER P** (**MET P**) command, the phase current peak demands, as well as the negative-sequence and residual current peak demands for each winding, are displayed in primary amperes. Three-phase peak power demands are displayed in megawatts and megavars. If the command is typed as **MET P *m***, where *m* is any number from 1 to 32767, the report will be repeated *m* times in succession. In this mode subsequent reports are not generated until the previous report has been completely sent. The format for the **METER P** report is as follows:

```
=>>METER P <Enter>
XFMR 1                            Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
                    Peak Dem I (A,pri)      Date:           Time:

             Wdg 1    IAW1    12345        MM/DD/YY        HH:MM:SS.SSS
                      IBW1    12345        MM/DD/YY        HH:MM:SS.SSS
                      ICW1    12345        MM/DD/YY        HH:MM:SS.SSS
                     3I2W1    12345        MM/DD/YY        HH:MM:SS.SSS
                      IRW1    12345        MM/DD/YY        HH:MM:SS.SSS

             Wdg 2    IAW2    12345        MM/DD/YY        HH:MM:SS.SSS
                      IBW2    12345        MM/DD/YY        HH:MM:SS.SSS
                      ICW2    12345        MM/DD/YY        HH:MM:SS.SSS
                     3I2W2    12345        MM/DD/YY        HH:MM:SS.SSS
                      IRW2    12345        MM/DD/YY        HH:MM:SS.SSS

             Wdg 3    IAW3    12345        MM/DD/YY        HH:MM:SS.SSS
                      IBW3    12345        MM/DD/YY        HH:MM:SS.SSS
                      ICW3    12345        MM/DD/YY        HH:MM:SS.SSS
                     3I2W3    12345        MM/DD/YY        HH:MM:SS.SSS
                      IRW3    12345        MM/DD/YY        HH:MM:SS.SSS
          Peak Dem Power       (MW,pri,Three-Phase)
                        MW 12345.67        MM/DD/YY        HH:MM:SS.SSS
          Peak Dem Power       (MVAR,pri,Three-Phase)
                      MVAR 12345.67        MM/DD/YY        HH:MM:SS.SSS

         LAST PEAK DEMAND RESET FOR Wdg1:  MM/DD/YY        HH:MM:SS.SSS
                                    Wdg2:  MM/DD/YY        HH:MM:SS.SSS
                                    Wdg3:  MM/DD/YY        HH:MM:SS.SSS
=>>
```

The report for **METER P** contains the last reset times for the peak demand registers for each winding.

## Differential Metering Function (METER DIF Command)

This metering function is performed on an element basis, not on a winding basis, because of the nature of the function. The relay has three differential elements, one per phase, denoted 87-1, 87-2, and 87-3. The “A-phase” currents for each winding are compensated for CT and transformer winding connections, divided by the tap value for each winding, and then entered into the calculations as dimensionless “multiples of tap.” These values are then summed in 87-1 on a phasor basis for determining operating current (IOP*k*) and on a scalar magnitude basis for the restraint current (IRT*k*) calculation ($k$ = 1, 2, 3). The B-phase and C-phase values find their ways to 87-2 and 87-3, respectively.

In response to the **METER DIF** (**MET DIF**) command, the fundamental frequency operate and restraint currents for each differential element are displayed in multiples of tap. The second- and fifth-harmonic currents in each element are also shown in multiples of tap. These are calculated in the same way as the operate currents, using the harmonic current from each winding in

a phasor addition. If the command is typed as **MET DIF *m***, where *m* is any number from 1 to 32767, the report will be repeated m times in succession. In this mode subsequent reports are not generated until the previous report has been completely sent. The format for the METER DIF report is as follows:

```
=>>METER DIF <Enter>
XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
                        Operate Currents            Restraint Currents
                    IOP1      IOP2      IOP3      IRT1      IRT2      IRT3
I (Mult. of Tap)    123.12    123.12    123.12    123.12    123.12    123.12
                    Second Harmonic Currents      Fifth Harmonic  Currents
                    I1F2      I2F2      I3F2      I1F5      I2F5      I3F5
I (Mult. of Tap)    123.12    123.12    123.12    123.12    123.12    123.12
=>>
```

The quantities I1F2/IOP1, I2F2/IOP2, I3F2/IOP3, and I1F5/IOP1, etc., form the basis for the harmonic blocking feature. To determine if blocking should take place, these ratios of harmonic-to-fundamental operating current (times 100 percent) are compared to the user-selected blocking threshold settings PCT2 and PCT5.

## Phasor Metering Function (METER SEC Command)

The phasor metering function is a useful tool for verifying proper phase rotation of input currents, for checking CT connections and polarities, and for checking that “in” currents are about 180° out-of-phase with “out” currents. With normal load currents on the transformer, the correctness (or lack thereof) of all the input connections becomes apparent.

In response to the **METER SEC** (**MET SEC**) command, the separate phase currents, as well as the positive-sequence, negative-sequence, and residual currents for each winding are shown in secondary amperes and at a calculated phase angle. The relay uses the sample data to calculate the RMS phasor magnitudes and instantaneous phase angles as a kind of “snapshot” of all the phasor currents at an instant in time. If the command is typed as **MET SEC *m***, where *m* is any number from 1 to 32767, the report will be repeated m times in succession. In this mode subsequent reports are not generated until the previous report has been completely sent. The format for the METER SEC report is as follows:

```
=>>METER SEC <Enter>
XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
                  Phase Currents                    Sequence Currents
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,sec)       123.12    123.12    123.12        123.12    123.12     123.12
Angle (deg)     123.12    123.12    123.12        123.12    123.12     123.12
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,sec)       123.12    123.12    123.12        123.12    123.12     123.12
Angle (deg)     123.12    123.12    123.12        123.12    123.12     123.12
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,sec)       123.12    123.12    123.12        123.12    123.12     123.12
Angle (deg)     123.12    123.12    123.12        123.12    123.12     123.12
                  Phase Voltages                    Sequence Voltages
WdgX            VAWX      VBWX      VCWX          3V1WX     3V2WX      VRWX
V (V,sec)       123.12    123.12    123.12        123.12    123.12     123.12
Angle (deg)     123.12    123.12    123.12        123.12    123.12     123.12
=>>
```

The phase angles given are all referenced to voltage VAWX. That is, the full set of 24 calculated phasors is rotated in a manner that brings VAWX to an angle of zero degrees. However, if the magnitude of VAWX is less than $0.0975 \cdot V_{nom}$ (13 V for a 120 V relay), the angles are listed according to the phasor calculation, without further adjustment.

## Demand Reset Functions (METER RD and METER RP Commands)

The demand meter function performs an integration of a selected quantity over time and contains a "history" of these quantities dating back minutes or hours from the present time. The peak demand function maintains registers with the highest recorded demands of each type over a period of time since the last reset of the registers. For both of these functions, you may want to erase this "history."

The **METER RD** (**MET RD**) ***n*** (Reset Demand) command returns the demand values to zero. This is useful during testing, for example, so that previous test quantities do not appear as part of the metered values, or to check the shape of the rising exponential for a fixed current over a period of time.

The **METER RP** (**MET RP**) ***n*** (Reset Peak Demand) command stores the present values of the demands, along with their associated date/time stamps, in the registers used to store the values of the peaks. These become the new peaks of record until higher values occur. This function might typically be performed on a daily, weekly, or monthly basis, to determine a peak demand profile of the equipment over time.

Both of the reset commands must be followed by a value for "*n*." A value of 1, 2, or 3 will reset all demand or peak demand values for Winding *n*. For reset of three-phase power values, the selected value of *n* must correspond to the current winding used in the VIWDG setting. For example, if VIWDG = 1, then using *n* = 1 will reset the power demand quantities. If two windings are selected for VIWDG (i.e., 1, 2), use *n* = 1 to reset the power demand values. If the letter A is entered, reset will be done on all of the windings. Failure to enter a value will produce an `Invalid parameter` response from the relay. For valid *n* values, the relay will ask for a Yes/No verification of your request to reset. No reports are issued for either command.

*Figure 5.1* is an overall diagram representative of the five demand meters for each Winding *n*, and the relationship of the four related commands (**MET D**, **MET P**, **MET RD**, **MET RP**). The currents are indicated generically as IX, the demand of each as XD(t), the peak demand of each XD(t) as PXD, the three demand alarm thresholds as XDEM*n*P, and the associated Relay Word bit as XDEM*n*. The greatest of the XD(t) demands for IAW*n*, IBW*n*, and ICW*n* is compared to the phase threshold PDEM*n*P; if the threshold is exceeded, Relay Word bit PDEM*n* is set. Negative-sequence current demand is compared to QDEM*n*P, and Relay Word bit QDEM*n* is set if the threshold is exceeded. Residual current demand is compared to NDEM*n*P, and Relay Word bit NDEM*n* is set if the threshold is exceeded.

**Figure 5.1 SEL-387E Relay Demand Meter Functions and Commands**

## Harmonic Metering Function (METER H Command)

The harmonic metering function, in response to the **METER H** (**MET H**) command, retrieves one full cycle of unfiltered sample data (64 samples) from each of the 12 analog inputs. Harmonic magnitudes are obtained using a Fast Fourier Transform method, which calculates a Discrete Fourier Transform, given by the following equation, for each harmonic from fundamental to 15th.

$$H_n = \sum_{k=0}^{N-1} h_k \bullet e^{j \bullet \frac{2\pi k n}{N}}$$

**Equation 5.2**

where

| | |
|---|---|
| N = | samples per cycle = 64 |
| n = | order of the harmonic = 1, 2, …, 15 |
| $h_k$ = | sampled data for one full cycle at system frequency |
| k = | summation index = 0, 1, …, 63 |
| $H_n$ = | result of the Discrete Fourier Transform calculation for the *n*th harmonic |

After all harmonics are calculated, they are adjusted to compensate for filter gain and the resulting magnitudes are listed in secondary quantities:

```
=>>METER H <Enter>
processing harmonic spectrum ............


XFMR 1            Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

      Magnitudes of Harmonic Currents (Amps Sec, Volts Sec)
H   IAW1   IBW1   ICW1    IAW2    IBW2    ICW2    IAW3    IBW3    ICW3    VAWX    VBWX    VCWX

1   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
2   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
3   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
4   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
5   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
6   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
7   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
8   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
9   123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
10  123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
11  123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
12  123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
13  123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
14  123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12
15  123.12 123.12 123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12  123.12

=>>
```

The Analog Input Labels, IAW1, etc., will be listed as they are set in the Global Settings section of the relay.

## Energy Metering Function (METER E Command)

The energy metering function, in response to the **METER E** (**MET E**) command, provides energy quantities as follows:

```
=>MET E <Enter>

XFMR 1                                    Date: 10/30/01    Time: 11:09:48.362
STATION A
                MWh3P            MWhA            MWhB            MWhC
IN   123456789012.1 123456789012.1 123456789012.1 123456789012.1
OUT  123456789012.1 123456789012.1 123456789012.1 123456789012.1

              MVARh3P          MVARhA          MVARhB          MVARhC
IN   123456789012.1 123456789012.1 123456789012.1 123456789012.1
OUT  123456789012.1 123456789012.1 123456789012.1 123456789012.1

LAST ENERGY RESET          11/25/00          10:15:17.235

=>
```

The element runs every second, using the average value of the last 16 cycles of the previous second to calculate the energy quantities. The element calculates the real (cosine of the angle between current and voltage) and reactive powers (sine of the angle between current and voltage), as well as the direction of the flow, as referenced below:

**Table 5.1 Energy Metering Data[a]**

| Sign of Cosine | Sign of Sine | Direction |
|---|---|---|
| Positive | Positive | A-phase, B-phase, and C-phase outgoing real power<br>Three-phase outgoing real power<br>A-phase, B-phase, and C-phase outgoing reactive power<br>Three-phase outgoing reactive power |
| Positive | Negative | A-phase, B-phase, and C-phase outgoing real power<br>Three-phase outgoing real power<br>A-phase, B-phase, and C-phase incoming reactive power<br>Three-phase incoming reactive power |
| Negative | Positive | A-phase, B-phase, and C-phase incoming real power<br>Three-phase incoming real power<br>A-phase, B-phase, and C-phase outgoing reactive power<br>Three-phase outgoing reactive power |
| Negative | Negative | A-phase, B-phase, and C-phase incoming real power<br>Three-phase incoming real power<br>A-phase, B-phase, and C-phase incoming reactive power<br>Three-phase incoming reactive power |

[a] Energy metering requires absolute secondary magnitudes that are at least 2 percent of nominal current and more than 0.1 V secondary voltage. If current or voltage fall below these thresholds, energy is calculated as zero.

Use the **METER RE** (**MET RE**) to reset the energy data. In response to the **METER RE** command, the relay displays the following message:

```
Reset Energies (Y/N)?
```

If the prompt is confirmed, the relay resets all energy values and records the date, otherwise the relay responds with the command aborted message.

# Station DC Battery Monitor

Use the station dc battery monitor in the SEL-387E to alarm for undervoltage and overvoltage dc battery conditions and to view how station dc battery voltage fluctuates during tripping, closing, and other dc control functions. The monitor measures station dc battery voltage applied to the rear-panel terminals labeled Z25 (+) and Z26 (−). Access the station dc battery monitor settings (DC1P, DC2P, DC3P, and DC4P) with the **SET G** command.

## Instantaneous Battery Voltage Values

The **MET** serial port command provides instantaneous values of the station dc battery voltage (Vdc). To obtain these values from the relay front panel, press the METER pushbutton, use the arrow pushbuttons to highlight VDC, and then press the SELECT pushbutton.

## Undervoltage and Overvoltage Alarms

The flexibility of SELOGIC® control equations lets you create battery warning and failure alarms that trigger when the station dc battery voltage falls below or exceeds voltage thresholds. *Figure 5.2* shows the alarm logic and how Relay Word bits DC1 to DC4 can be used with DC1P, DC2P, DC3P, and DC4P threshold settings to create the alarms. *Figure 5.3* shows the warning and alarm regions.

**Figure 5.2 Station DC Battery Monitor Alarm Logic**

**Figure 5.3 Undervoltage and Overvoltage Warning and Alarm Regions**

From *Figure 5.2* and *Figure 5.3*, you can see that no warning or alarm triggers so long as the battery dc voltage neither exceeds DC3P nor falls below DC2P. The relay triggers a warning for voltages exceeding DC3P or falling below DC2P. The relay triggers a failure alarm for voltages exceeding DC4P or falling below DC1P. For example, if the battery voltage exceeds the DC3P threshold, but falls below the DC4P threshold, the Relay Word bit DC3 asserts and the relay triggers a warning.

## Detection of Voltage Dips in Event Reports

You can also use the battery monitor voltage threshold settings to detect momentary supply voltage fluctuations during periods of high demand on the station battery and charger system. The digital event report lists assertion of Relay Word bits DC1 through DC4. View this listing with the **EVE D** serial port command. To trigger an event report, include these bits in the SELOGIC control equation ER (event report trigger setting). Use the **CEV** command to retrieve a compressed event report containing the value of the station dc battery voltage during the event.

# Breaker Monitor

The SEL-387E breaker monitoring function captures information on the number of operations and total interrupted current for as many as three breakers. These data are used to estimate the amount of contact wear per pole, based on wear curve information the user derives from breaker manufacturer maintenance curves and enters into the relay. Separate settings for each breaker determine under what conditions the monitoring function initiates for that breaker. The breaker monitoring function is capable of differentiating between an internal trip, generated by units associated with the winding where the breaker is applied, and an external trip, initiated by another winding's units, another relay, or control contact. This information will assist the user in determining when to schedule maintenance of the breakers.

## Breaker Monitor Description and Initiation Setting

The breaker monitor function has one initiation setting for each breaker. The BKMON1 through BKMON3 settings, in the Global/Relay Settings area, are SELOGIC control equations, using Relay Word bits to initiate the monitor. The BKMON*n* settings look for rising edges (transition from logical 0 to logical 1) as an indication to read in current values. Currents are read 1.5 cycles after initiation, as symmetrical RMS current, and sent to the monitor IA, IB, and IC current accumulators. The trip counter is also advanced by one count. There are separate current accumulators and trip counters for internal and external trips.

An internal trip is defined as one initiated by the trip equation (TR*n*), which is associated with the particular Breaker *n* that BKMON*n* is monitoring. The monitor logic examines, for example, the status of the TRIP1 variable at the time the BKMON1 setting equation is asserted. If the TRIP1 variable is asserted when BKMON1 asserts, the trip count and the currents measured are recorded as internal. If TRIP1 is not asserted when BKMON1 asserts, the trip and currents are recorded as external. A trip initiated by any other winding elements (Windings 2 or 3) or the differential element is regarded as external, even though it originates within the same relay.

In our example transformer application, we want Breaker 1 to trip for its own overcurrent elements (OUT101 = TRIP1; TR1 = 50P11T+51P1T+51Q1T) or for a differential trip (86T device trip via OUT104 = TRIP4; TR4 = 87R+87U). In this case we set BKMON1 = TRIP1 + TRIP4. Winding 1 overcurrent trips (TRIP1) will be credited to the internal trip counter and current accumulators, and differential trips (TRIP4) will appear as external trips.

To capture trip information for other Breaker 1 trips initiated by devices other than the SEL-387E, BKMON*n* must be set to sense these trips. This can be done, for example, by using an input to monitor the trip bus for the given breaker. This is illustrated in *Figure 5.4*, where IN106 is connected to the Breaker 1 trip bus and asserts for any trip from any source. Setting BKMON1 = IN106 ensures that the monitor will initiate for any Breaker 1 trip. The monitor then compares IN106 with TRIP1 to sort internal and external trips.

**Figure 5.4 Trip Bus Sensing With Relay Input**

## Breaker Wear Curve Description and Settings

Based on maintenance curves supplied by manufacturers of the breakers, a contact wear curve for each breaker is constructed (*Figure 5.5*).

**Figure 5.5 Breaker Contact Wear Curve**

The curve is a plot of close/open operations versus interrupted current in kiloamperes (kA). The scales are logarithmic on both axes. For each Breaker *n*, three points are input in the Global setting area as relay settings. The points are defined by pairs of coordinates of current and operations. For Breaker *n*, these are the points (B*n*KAP1, B*n*COP1), (B*n*KAP2, B*n*COP2), and (B*n*KAP3, B*n*COP3). As shown in *Figure 5.5*, the point (B*n*KAP1, B*n*COP1)

must represent the lowest current value, point (B*n*KAP2, B*n*COP2) an intermediate current value, and point (B*n*KAP3, B*n*COP3) the maximum current value. The relay will not accept the settings unless B*n*KAP1 < B*n*KAP2 < B*n*KAP3.

For values of current in kA (I) below B*n*KAP1, the number of operations is assumed to be the same as for B*n*KAP1. In this part of the curve, the number of operations may be governed more by the cumulative mechanical wear and tear on the breaker operating mechanism, rather than actual contact degradation. For values of current in kA above B*n*KAP3, there is assumed to be no breaker capability to interrupt, and 100 percent contact wear is assumed. B*n*KAP3, then, is typically set at the maximum rated interrupting current for the particular breaker. B*n*KAP1 is set at a value approximating the continuous load current rating of the breaker. B*n*KAP2 is set at some intermediate value of current, chosen to provide the closest visual "fit" to the manufacturer's curve.

The two straight line segments of the curve between the three defined points define the number of operations as a function of current in kiloamperes by an equation of the form:

$$O(I) = K \bullet I^{\alpha}$$ **Equation 5.3**

To determine the constants K and α for a given segment, any two current-operations pairs in that segment must be known. For any given pairs (I1, O1) and (I2, O2), the alpha constant is determined by the equation:

$$\alpha = \frac{\log_{10}\left(\frac{O1}{O2}\right)}{\log_{10}\left(\frac{I1}{I2}\right)}$$ **Equation 5.4**

The K constant can be found by back substitution:

$$K = \frac{O1}{I1^{\alpha}}$$ **Equation 5.5**

or

$$K = \frac{O1}{I1^{\alpha}}$$ **Equation 5.6**

Here, we can use the endpoint pairs (B*n*KAP1, B*n*COP1) and (B*n*KAP2, B*n*COP2) to determine the equation that applies between these two input points and pairs (B*n*KAP2, B*n*COP2) and (B*n*KAP3, B*n*COP3) for the equation between the latter two points.

In *Figure 5.5*, for example, the two segments have the following equations:

$$O(I) = 14972 \bullet I^{-2.214}$$ **Equation 5.7**

and

$$O(I) = 46284 \bullet I^{-2.756}$$ **Equation 5.8**

For a particular value of I in kA, the calculated value O(I) represents 100 percent wear of the breaker contacts. Thus, the incremental percent wear for one trip operation at the defined current level is 100 / O(I) percent.

For I < B*n*KAP1, O(I) = B*n*COP1. For B*n*KAP1 < I < B*n*KAP2, O(I) is calculated by the first equation. For B*n*KAP2 < I < B*n*KAP3, O(I) is calculated by the second equation. For I > B*n*KAP3, O(I) = 0 and contact wear = 100 percent.

Because the breaker monitor calculates and accumulates current by phase, the wear for each pole of the breaker is calculated separately, using the same wear curve as a basis. Thus, over time, the cumulative percent wear for each of the three poles will be different. If a breaker already has some estimated wear when the relay is first applied, the user can preload a separate amount of wear for each pole of the breaker using the serial port command **BRE W *n*** (or **BRE *n* W**). Integer values of percent wear up to 100 percent are accepted by the relay. The incremental wear for the next interruption, and all subsequent interruptions, is added to the prestored value for a total wear value.

When the cumulative wear on any breaker pole reaches 100 percent, Relay Word bits are set to logical 1 for the particular pole, as well as for the breaker containing that pole. For example, for Breaker *n*, the Relay Word bits for the three poles are designated BCWA*n*, BCWB*n*, and BCWC*n*; for the breaker itself, Relay Word bit BCW*n* is set to logical 1 if any of the individual pole bits is set to logical 1. These bits may be used for alarm or display purposes, to alert the user that breaker inspection and maintenance may be required.

After breaker maintenance is performed or a new breaker installed, the breaker monitor operation counters, cumulative interrupted currents by pole, and percent wear by pole should be reset to zero. This can be done via the **BRE R *n*** (or **BRE *n* R**) serial port command or from the front panel via the OTHER pushbutton menu.

Both the **BRE W *n*** and **BRE R *n*** commands can be executed from Access Level B or 2.

## Breaker Wear Example

A breaker having the wear curve of *Figure 5.5* experiences a fault current interruption of 17000 A. Previous accumulated wear is 44 percent.

The fault current falls between B*n*KAP2 (8 kA) and B*n*KAP3 (20 kA). The second equation is used to calculate O(I).

$O(I) = 46284 \bullet 17^{-2.756} = 46284 \bullet 0.00041 = 18.81$

Incremental Percent Wear = 100/18.81 = 5.32%

Cumulative Percent Wear = 44 + 5.32 = 49.32% (which appears as 49% in BRE listing)

## Breaker Monitor Reporting

The accumulators for each breaker can be reviewed either by a serial port command **BRE** or via the front-panel display, using the OTHER button menu.

The report lists all breakers, giving the number of internal and external trips for each breaker, the total accumulated RMS current by phase, and the percent wear by pole. The operation accumulators for each trip type have a maximum value of 65000 trips. The current accumulators for each trip type have a maximum value of 99999.00 kA RMS. Percent wear never exceeds 100 percent. The accumulators can be reset by the serial port command **BRE *n* R** or via the OTHER front-panel pushbutton menu. The serial port report format is shown below.

```
=>>BREAKER <Enter>

XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

BREAKER 1
Int Trips=     12345   IAW1=     12345  IBW1=    12345  ICW1=    12345 kA(pri)
Ext Trips=     12345   IAW1=     12345  IBW1=    12345  ICW1=    12345 kA(pri)
Percent Wear:          POLE1=      123  POLE2=     123  POLE3=     123

BREAKER 2
Int Trips=     12345   IAW2=     12345  IBW2=    12345  ICW2=    12345 kA(pri)
Ext Trips=     12345   IAW2=     12345  IBW2=    12345  ICW2=    12345 kA(pri)
Percent Wear:         POLE1=      123  POLE2=     123  POLE3=     123

BREAKER 3
Int Trips=     12345   IAW3=     12345  IBW1=     12345  ICW3=     12345 kA(pri)
Ext Trips=     12345   IAW3=     12345  IBW1=     12345  ICW3=     12345 kA(pri)
Percent Wear:          POLE1=      123  POLE2=      123  POLE3=      123

LAST BREAKER MONITOR RESET FOR     Bkr1:  MM/DD/YY      HH:MM:SS.SSS
                                   Bkr2:  MM/DD/YY      HH:MM:SS.SSS
                                   Bkr3:  MM/DD/YY      HH:MM:SS.SSS

=>>
```

# Through-Fault Event Monitor

*Figure 5.6* shows a distribution feeder fault beyond the protection zone of the SEL-387E. Nevertheless, the fault current passes through the transformer bank, subjecting the windings to mechanical stress and the winding insulation to thermal stress. The more feeders on a distribution bus, the more the transformer bank is exposed to these through faults.

**Figure 5.6 Distribution Feeder Faults Expose Transformer Bank to Through Faults**

Monitor and document this through-fault activity with the through-fault event monitor in the SEL-387E. The through-fault event monitor captures maximum current levels, duration, and date/time for each transformer through fault. The monitor also performs a simple $I^2t$ calculation (analogous to the energy expended during the through fault) and cumulatively stores calculation results for each monitored phase.

## Through-Fault Event Monitor Settings

Activate and adjust the through-fault event monitor with the settings in *Table 5.2*.

**Table 5.2 Through-Fault Event Monitor Settings**

| Setting | Definition | Range |
|---|---|---|
| ETHRU | Enable Through-Fault Event Winding | N, 1, 2, 3 |
| THRU | Through-Fault Event Trigger (SELOGIC control equation | Relay Word bits (*Table 4.8*) |
| ISQT | Through-Fault $I^2t$ Alarm Threshold | OFF, 0–4294967 (kA)2 seconds |

Setting ETHRU = N turns off the through-fault event monitor. Any other setting selection for ETHRU designates the winding to monitor for through-fault events. For example, ETHRU = 2 designates Winding 2 as the winding to monitor for through-fault events. Specifically, Winding 2 current inputs IAW2, IBW2, and ICW2 (A-phase, B-phase, and C-phase, respectively) are monitored for maximum currents for through-fault events. Changing setting ETHRU resets/clears through-fault event information (see *Through-Fault Event (TFE) Serial Port Command on page 5.17*).

Setting THRU triggers the through-fault event—the through-fault event monitor starts acquiring maximum current and duration information, along with a date/time tag. Typically, the THRU setting is set with an overcurrent element. For example, set THRU to trigger a through-fault event on the pickup of a phase instantaneous overcurrent element on Winding 2:

THRU = 50P23

To block triggering of through-fault events resulting from transformer inrush, consider settings such as

THRU = 50P23 * !87BL

**NOTE:** The above examples show the designated current inputs (ETHRU = 2) and triggering element (THRU = 50P23) both from Winding 2. While this is a common setting approach, triggering elements can be from any winding or be of any element available in Table 4.8 (e.g., THRU = IN101; set to trigger a through-fault event on the assertion of input IN101).

*Figure 5.7* shows the time progression of a through fault, such as that in *Figure 5.6*. Typically, SELOGIC setting THRU would be set to some instantaneous overcurrent element (e.g., THRU = 50P23). When THRU asserts at the outset of the through fault, event duration timing begins. When THRU de-asserts (e.g., the distribution feeder breaker interrupts the fault), through-fault event duration timing ends and the duration time is recorded for that event.

If SELOGIC setting THRU is asserted (by whatever means), then maximum currents are recorded for the monitored current inputs. *Figure 5.7* shows the current jumping up to a short-term maximum before being interrupted (perhaps the feeder fault “burned through” and became more “bolted”). This short-term maximum current, which occurred within the duration timing, is what gets recorded for the particular monitored phase.

**Figure 5.7 Through-Fault Triggering, Duration, and Maximum Currents**

## Through-Fault Calculation

The through-fault event monitor uses the recorded duration time value and maximum currents to perform simple $I^2t$ calculations and cumulatively stores results of these calculations for each monitored phase. For example, if a through fault is 6000 A primary (maximum) and lasts 0.067 sec., the monitor would calculate $I^2t$ for that individual event as follows:

$$(6\ \text{kA})^2 \bullet 0.067\ \text{seconds} = 2.412\ (\text{kA})^2\ \text{seconds}$$

If the above calculation were for the example in *Figure 5.7*, it would be a conservative calculation (i.e., the calculation would indicate more $I^2t$ stress/wear than actually occurred). This is because the current peaked momentarily.

## Through-Fault Alarm

*Figure 5.8* shows an $I^2t$ alarm, with Through-Fault $I^2t$ Alarm Threshold setting ISQT. When the cumulative $I^2t$ for any monitored phase exceeds setting threshold ISQT, Relay Word bit ISQTAL (I-squared-t alarm) asserts. Setting threshold ISQT would usually be set to alarm for excessive, cumulative transformer bank stress, as such stress corresponds to a certain level of cumulative $I^2t$. Output Relay Word bit ISQTAL can be assigned to an output for annunciation or perhaps also be used to modify distribution feeder autoreclosing (e.g., reduce the number of reclosures from 3 to 2).

**Figure 5.8 Cumulative $I^2t$ Alarm (Relay Word bit ISQTAL)**

## Through-Fault Event (TFE) Serial Port Command

The **TFE** command displays the following discussed data for each individually recorded through-fault event:

- Date and time of the through fault
- Duration (seconds) of the through fault
- Maximum current (amperes primary) for each monitored current input

The following cumulative values (updated for each new through-fault event) are also displayed:

- Through-fault count
- Simple $I^2t$ calculation for each monitored current input

Relay response to the **TFE** command is:

```
=>TFE <Enter>

XFMR 1                                    Date: 06/17/06    Time: 18:59:49.130
STATION A

FID=SEL-387E-R700-V0-Z101003-D20060616
Number of Through Faults:     2    Last Reset: 02/10/04 19:56:22
Winding 1 Total I-squared-t (kA^2 seconds, primary):
          A-phase      B-phase      C-phase
            1.783       88.270        6.610

#      Date       Time      Duration       IA     IB     IC
                            (seconds)      (A, primary max)
   1 02/14/04 18:59:22.244     5.002      241   4158    260
   2 02/11/04 11:37:55.495    30.834      220    241    451
```

In the above response, only two through-fault events have been recorded since the monitor was last reset (most recent event listed first, labeled #1). Notice also that Winding 1 is the winding whose current inputs are being monitored.

The **TFE** command just by itself (no parameters, as in the above example) can list as many as 20 through-fault events. To list all the stored through-fault events since the monitor was last reset, execute the **TFE A** command. To list a particular number of through-fault events, execute the **TFE *n*** command ($n$ = 1 to 1200; 1200 is the maximum number of through-fault events that can be stored before overwriting begins).

To reset the cumulative through-fault count, reset cumulative $I^2t$, and clear out the stored through-fault events, execute the **TFE C** (clear) or **TFE R** (reset) command. The relay responds:

```
=>TFE R <Enter>
Clear Through Fault Event Buffer
Are you sure (Y/N) ? Y <Enter>
Clearing Complete
=>
```

Changing Global setting ETHRU also has the same effect as executing the **TFE C** or **TFE R** command.

Preload the following cumulative through-fault count and $I^2t$ values:

- 10 through-fault counts
- 147.8 $(kA)^2$ seconds on A-phase
- 303.5 $(kA)^2$ seconds on B-phase
- 237.9 $(kA)^2$ seconds on C-phase

Execute the **TFE P** command to preload these values. The relay responds:

```
=>TFE P <Enter>
Number of Through Faults Preload =     2? 10 <Enter>

Winding 1 Total I-squared-t Preload (kA^2 seconds, primary):
A-phase =       1.783? 147.8 <Enter>
B-phase =      88.270? 303.5 <Enter>
C-phase =       6.610? 237.9 <Enter>
Are you sure (Y/N) ? Y <Enter>
```

If the **TFE** command is then executed, the response shows the new preloaded values (the through-fault events at bottom are not disturbed):

```
=>TFE <Enter>

XFMR 1                                    Date: 06/17/06    Time: 18:59:49.130
STATION A

FID=SEL-387E-R700-V0-Z101003-D20060616
Number of Through Faults:    10    Last Reset: 02/10/04 19:56:22
Winding 1 Total I-squared-t (kA^2 seconds, primary):
          A-phase      B-phase      C-phase
          147.800      303.500      237.900

#      Date       Time      Duration       IA     IB     IC
                            (seconds)      (A, primary max)
   1 02/14/04 18:59:22.244     5.002      241   4158    260
   2 02/11/04 11:37:55.495    30.834      220    241    451
```

## Deriving Cumulative $I^2t$ Values for Preloading

If cumulative $I^2t$ values need to be derived for preloading, refer first to the preceding subsection Through-Fault Calculation to see how individual $I^2t$ calculations are made (even though this referenced subsection refers to how the relay does the calculation automatically, the same approach is still valid for “hand” calculations). In the referenced subsection, notice how the example 6000 A (6 kA) fault value is handled in the calculation, so that the resultant comes out in units of (kA)2 seconds. All the individual $I^2t$ calculations, for the corresponding faults on a specific phase, are then summed together to create a cumulative $I^2t$ value that can then be preloaded for that phase. Use the previously discussed **TFE P** command to preload the cumulative $I^2t$ values for each phase.

## Magnitude Limits on Through-Fault Event Data

In the above **TFE** command responses, there are limits, besides the aforementioned 1200 event limit on stored through-fault events, to data accumulation. These limits are:

- “Number of Through-Faults” counts: 65,535 counts
- “Total I-squared-t” (per phase): 4,294,967.295 $(kA)^2$ seconds
- “Duration” for through-fault event: 8191 cycles, converted to seconds
- “IA, IB, IC” for through-fault event: 65,535 A, primary

If any of these values exceed their limits, a plus sign (+) is appended to the above maximum limit number in the display. If “Duration” or “IA, IB, IC” values are at their maximums or beyond, then the monitor uses the above maximum values in performing subsequent simple $I^2t$ calculations and cumulatively storing calculation results for each monitored phase.

All these through-fault event data are stored in nonvolatile memory.

# Status Monitor

The status monitor of the SEL-387E is designed to provide information on the internal health of the major components of the relay. The relay continuously runs a variety of self-tests. Some tests have warning and failure states; others only have failure states.

## Status Monitor Report Function (STATUS Command)

The **STATUS** (**STA**) command displays a report of the self-test diagnostics. The relay automatically executes the **STA** command whenever the self-test software enters a warning or failure state.

If a warning or failure state occurs, the warning state is reported the next time the STA command is issued. If a warning or failure occurs, it will not be cleared until relay power is cycled and the problem is fixed. Saving relay settings performs a warm boot of relay logic. This may clear some warnings. If warnings persist, contact the factory.

Below is the STATUS report format. All warnings, represented by a W in the status report, generate an automatic serial port message and pulse the ALARM output contact for five seconds. All failures, represented by an F in the status report, generate an automatic serial port message, display the failure on the front-panel display, and latch the ALARM output contact.

```
=>>STATUS <Enter>

XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
FID=SEL-387E-R700-V0-Z101003-D20060616
SELF TESTS
W=Warn    F=Fail

       IAW1     IBW1     ICW1     IAW2     IBW2     ICW2
OS     1234     1234     1234     1234     1234     1234

       IAW3     IBW3     ICW3     VAWX  VBWX  VCWX
OS     1234     1234     1234     1234     1234     1234

       +5V_PS   +5V_REG  -5V_REG  +12V_PS  -12V_PS  +15V_PS  -15V_PS
PS      1.12     1.12     -1.12     12.12   -12.12  12.12   -12.12

       TEMP     RAM      ROM      A/D      CR_RAM   EEPROM   IO_BRD
 MB    123.1    OK       OK       OK       OK       OK       OK

       RAM      ROM      PORT 5   PORT 6   FPGA     BOARD    DPRAM     PS
 CC    OK       OK       NOLINK   LINK     OK       OK       OK        OK

Relay Enabled
=>>
```

To reset the self-test status, use the **STA C** command from Access Level 2.

The relay responds:

```
Reboot the relay and clear status
Are you sure (Y/N) ?
```

If you type **N** or **n**, the relay displays:

```
Canceled
```

and aborts the command.

If you type **Y** or **y**, the relay displays:

```
Rebooting the relay
```

The relay then restarts (just like powering down and then powering up the relay), and all diagnostics are rerun before the relay is enabled.

The quantities shown in the STATUS report are discussed below. The applicable limits for warning or failure of each self-test are summarized in *Table 5.3*.

When the optional Ethernet card is not installed, all Ethernet port self-check statuses indicate N/A, except BOARD, which indicates ABSENT.

The **STATUS** button on the front-panel interface can also be used to access the information in the report. See *Section 8: Front-Panel Operation*.

*Table 5.3* summarizes the limits for issuing warning or failure alarms during self-testing. The power supply and temperature alarms list the values below or above which the stated alarm is issued.

**Table 5.3 Self-Test Alarm Limits** (Sheet 1 of 2)

| Self-Test | Condition | Limit | Protection Disabled | ALARM Output | Description |
|---|---|---|---|---|---|
| IAW1, IBW1, ICW1, IAW2, IBW2, ICW2, IAW3, IBW3, ICW3, VAWX, VBWX, VCWX, Offset | Warning | 30 mV | No | Pulsed | Periodically measures the dc offset at each of the input channels. |
| +5 V PS | Warning | +4.80 V<br>+5.20 V | No | Pulsed | Periodically measures the +5 V power supply |
| | Failure | +4.65 V<br>+5.40 V | Yes | Latched | |
| 5 V REG | Warning | +4.80 V<br>+5.20 V<br>–4.80 V<br>–5.20 V | No | Pulsed | Periodically measures the regulated ±5 V power supply. |
| | Failure | +4.65 V<br>+5.40 V<br>–4.65 V<br>–5.40 V | Yes | Latched | |
| 12 V PS | Warning | +11.50 V<br>+12.50 V<br>–11.50 V<br>–12.50 V | No | Pulsed | Periodically measures the ±12 V power supply. |
| | Failure | +11.20 V<br>+14.00 V<br>–11.20<br>–14.00 V | Yes | Latched | |
| 15 V PS | Warning | +14.40 V<br>+15.60 V<br>–14.40 V<br>–15.60 V | No | Pulsed | Periodically measures the ±15 V power supply. |
| | Failure | +14.00 V<br>+16.00 V<br>–14.00 V<br>–16.00 V | Yes | Latched | |

**Table 5.3 Self-Test Alarm Limits** (Sheet 2 of 2)

| Self-Test | Condition | Limit | Protection Disabled | ALARM Output | Description |
|---|---|---|---|---|---|
| TEMP | Warning | –40°C<br>+85°C | No | | Periodically measures the main board temperature. |
| RAM | Failure | | Yes | Latched | Periodically performs a read/write test at each RAM location. |
| ROM | Failure | checksum | Yes | Latched | Periodically performs a checksum test on the relay program memory. |
| A/D | Failure | | Yes | Latched | Validates proper number of conversions each processing interval. |
| CR_RAM | Failure | checksum | Yes | Latched | Periodically performs a checksum test on the active copy of the relay settings. |
| EEPROM | Failure | checksum | Yes | Latched | Periodically performs checksum test on the nonvolatile copy of the relay settings. |
| I/O Board | Failure | | No | | Verifies correct I/O board is installed. Identifies when a board is changed or disconnected. |
| CC RAM | Failure | | No | Pulsed | Periodically performs a read/write test at each RAM location. |
| CC ROM | Failure | | No | Pulsed | Periodically performs a program comparison with RAM. |
| PORT 5 | Link | | | | Link established on Ethernet port. |
| | No Link | | | | No link established on Ethernet port. |
| PORT 6 | Link | | | | Link established on Ethernet port. |
| | No Link | | | | No link established on Ethernet port. |
| FPGA | Failure | | No | Pulsed | Ensures FPGA configures properly. |
| BOARD | Failure | | No | Pulsed | Checks to ensure Ethernet port hardware responds and watchdog timer has not expired. |
| DRAM | Failure | | No | Pulsed | Ensures dual port RAM configured properly. |
| PS | Failure | | No | Pulsed | Continually measures the input voltage supplied from the relay. |

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# Section 6

# Settings

## Introduction

Change or view settings with the **SET** and **SHOWSET** serial port commands and the front-panel SET pushbutton. *Table 6.1* lists the serial port **SET** commands.

**Table 6.1 Serial Port SET Commands**

| Command | Settings Type | Description |
|---|---|---|
| **SET *n*** | Relay | Overcurrent elements for Settings Group *n* (*n* = 1, 2, 3, 4, 5, 6). |
| **SET G** | Global | Battery and breaker monitor, analog input label, setting group control, programmable LED, display point, and local control switch settings. |
| **SET R** | SER | Sequential Events Recorder trigger condition settings. |
| **SET P *n*** | Port | Serial port settings for Serial Port *n* (*n* = 1, 2, 3, or 4). The Ethernet port, if available, is designated as Port 5 or Port 6. |

View settings with the respective serial port **SHOWSET** commands (**SHO**, **SHO G**, **SHO R**, **SHO P**). See discussion of **SHO** commands in *Section 7: Communications*. Settings Sheets are located at the end of this section.

## Settings Changes via the Front Panel

The relay front-panel **SET** pushbutton provides access to the Relay, Global, and Port settings only. Thus, the corresponding Relay, Global, and Port settings sheets that follow in this section can also be used when making these settings via the front panel. Refer to *Figure 8.9* for information on front-panel settings.

## Settings Changes via the Serial Port

NOTE: In this manual commands you type appear in bold/uppercase: **SHOWSET**. You need to type only the first three letters of a command, for example, **SHO**. Computer keys you press appear in bold/brackets: **<Enter>**.

See *Section 7: Communications* for information on serial port communications and relay access levels. The **SET** commands in *Table 6.1* operate at Access Level 2 (screen prompt: =>>). To change a specific setting, enter the command:

**SET *n m s* TERSE**

where

| | |
|---|---|
| ***n*** = | G, R, or P (parameter *n* is not entered for the Relay settings). |
| ***m*** = | group (1…6) or port (1…6). The relay selects the active group or port if *m* is not specified. |
| ***s*** = | the name of the specific setting you wish to jump to and begin setting. If *s* is not entered, the relay starts at the first setting. |
| **TERSE** = | instructs the relay to skip the SHOWSET display after the last setting. Use this parameter to speed up the **SET** command. If you wish to review the settings before saving, do not use the TERSE option. |

When you issue the **SET** command, the relay presents a list of settings, one at a time. Enter a new setting or press **<Enter>** to accept the existing setting. Editing keystrokes are shown in *Table 6.2*.

**Table 6.2 SET Command Editing Keystrokes**

| Press Key(s) | Results |
|---|---|
| **<Enter>** | Retains setting and moves to the next setting. |
| **^ <Enter>** | Returns to previous setting. |
| **< <Enter>** | Returns to previous setting. |
| **> <Enter>** | Moves to next setting. |
| **END <Enter>** | Exits editing session then prompts you to save the settings. |
| **<Ctrl + X>** | Aborts editing session without saving changes. |

The relay checks each entry to ensure that it is within the setting range. If it is not, an `Out of Range` message is generated, and the relay prompts for the setting again.

When all the settings are entered, the relay displays the new settings and prompts for approval to enable them. Answer **Y <Enter>** to enable the new settings. If changes are made to Global, SER, or Port settings (see *Table 6.1*), the relay is disabled while it saves the new settings. If changes are made to the Relay or Logic settings for the active setting group (see *Table 6.1*), the relay is disabled while it saves the new settings. The ALARM contact closes momentarily (for a “b” contact, opens for an “a”) and the **EN** LED extinguishes while the relay is disabled. The relay is disabled for about one second. If Logic settings are changed for the active group, the relay can be disabled for as long as 15 seconds.

If changes are made to the Relay or Logic settings for a setting group other than the active setting group (see *Table 6.1*), the relay is not disabled while it saves the new settings. The ALARM contact closes momentarily (for a “b” contact, opens for an “a”) but the **EN** LED remains on while the new settings are saved.

# Additional Relay Settings

The following explanations are for settings that are not discussed in earlier sections.

## Relay (RID) and Terminal (TID) Identification

The Relay Identifier (RID) and Terminal Identifier (TID) settings are typically used to identify the equipment protected by the relay or the circuit breaker(s) controlled by the relay. The relay tags event reports with the Relay and Terminal Identifier strings. This allows you to distinguish the event report as one generated for a specific breaker and substation. The RID setting is limited to 39 characters and the TID setting to 59 characters. For our example, we have selected RID = XFMR1 and TID = STATION A.

## Potential Transformer Ratio (PTR)

The relay uses the potential transformer ratio (PTR) to convert measured secondary phase-to-neutral voltages into primary phase-to-phase voltages for display in the meter report. For example, a 230 kV phase-to-phase line has a primary phase-to-neutral voltage of 230 kV/$\sqrt{3}$ = 132.8 kV. Because the secondary phase-to-neutral voltage is 67 V, the PTR = 132.8 kV/67 V ≈ 2000.

## Compensation Angle (COMPANG)

### Overview

The SEL-387E Relay uses three-phase currents for transformer differential protection, and either single- or three-phase voltages to calculate apparent, real, and reactive power. This document describes how PT configurations influence the phase angle between relay currents and voltages in various transformer applications, how these phase angles affect power measurements, and how to use the COMPANG setting in the SEL-387E Relay to offset these effects.

### Setting Description

The COMPANG setting provides a means for rotating the phase angle of the voltage vector from zero to 360 degrees. This allows adjustment of the various power quantities that use this phase angle as part of the real (kW) and reactive (kVAR) power calculations.

The SEL-387E uses the phase potential connection setting in the GLOBAL settings to determine whether the voltage inputs are read as line-to-line (L-L), or line-to-neutral (L-N). If the DELTA_Y setting is set for delta, the measured phase voltages are divided by the √3 (1.732) for use in the power equations. Note that when set to delta, phase quantities are assumed to be balanced, and only a total power readout is displayed. If set to Y, the incoming L-N voltages are used directly, and individual phase power information is displayed. It is important to note that the DELTA_Y setting does not affect the phase angle relationship as measured by the relay. The COMPANG setting is used to provide this function.

Current magnitudes for CT connections of delta or wye configuration are compensated for in the relay by means of the W*n*CT (*n* = 1, 2, 3) settings. For differential protection, use the W*n*CTC settings to compensate for phase shifts resulting from the transformer vector group. For power measurement, use

W*n*CT to compensate for current magnitude and the COMPANG setting to compensate for phase angle differences between the currents and voltages resulting from the PT configuration.

## Using COMPANG

First, take note that the only settings affected by the COMPANG setting are the real and reactive power. The COMPANG has no effect on any voltage or current magnitudes, nor on any current phase angle settings. To adjust current phase angle settings, see *Setting Calculation on page 3.26*.

The best case scenario for calculating power, and which requires zero degrees of voltage vector compensation is the application where the voltage inputs to the relay are either single-phase L-N or three-phase wye-type connection, with corresponding wye-connected CTs on the same winding. In this configuration, the voltages and currents are in phase with respect to each other coming into the relay and no voltage angle compensation is required.

The diagram below shows this type of connection, and the related voltage and current vectors for a three-phase connection.

**Figure 6.1 Voltages and Currents In Phase, COMPANG = 0**

The next case represents a common connection found in many applications. This connection uses wye-connected CTs on a winding with an open-delta PT configuration on the same winding. The open-delta PT configuration causes a 30-degree phase shift in the voltage vector, as well as a voltage magnitude shift (1.732 • Voltage L-N) that must be corrected. The magnitude correction is done automatically by setting the DELTA_Y setting to D (for delta). To compensate for the 30-degree phase angle shift, use the COMPANG setting. To do this, set the COMPANG setting to 30 degrees. With these settings the voltages measured by the relay will correspond to the proper L-N voltages,

and the calculated power quantities will be correct for the 30-degree phase shift between the current and voltage waveforms. *Figure 6.2* shows the current and voltage vectors for this connection.

**Figure 6.2 Wye-Connected CTs With Open-Delta PTs, COMPANG Setting = 30 Degrees**

It is highly recommended to keep the current and phase voltage measurements on the same winding of the transformer to eliminate any need for external (outside of the relay) scaling factors on the power measurement values. This is easy to do with the SEL-387E by using the VIWDG setting to identify the desired current inputs with the same winding that the voltage sensing is on.

The final common connection seen in transformers is the delta-connected CTs with wye-connected PTs. In this case, the current will either lead or lag the voltage by 30 degrees depending on the connection of the CTs (DAB or DAC). DAB connection will cause the current to lead the voltage by 30 degrees, requiring a COMPANG setting of 330 degrees to compensate. A DAC CT connection will cause current to lag the voltage by 30 degrees, requiring a 30-degree COMPANG setting to compensate. *Figure 6.3* shows a DAB CT connection, and the resulting need to rotate the voltage vector 330 degrees using the COMPANG setting.

**Figure 6.3 DAB Connected CTs With Wye-Connected PTs, COMPANG = 330 Degrees**

## Voltage-Current Winding (VIWDG)

Use this setting to tell the relay which winding current to use when calculating power for the meter report. The configuration for a breaker-and-a-half application has typically two sets of current transformers, the sum of whose currents supply the power transformer. For power calculations requiring the sum through two sets of current transformers, select the WDG12 option. With this selection, the relay vectorially adds the currents from Windings 1 and 2 and uses the resultant for further calculations.

## Three-Phase Voltage Input (TPVI)

**NOTE:** When TPVI = N, the relay assumes the voltage applied to the A-phase terminal is a line-to-neutral voltage. Therefore, if a phase-to-phase voltage is applied to the A-phase terminal, the volts/hertz element calculation does not result in the expected value.

Set TPVI = Y if you have a three-phase set of PTs or open-delta connected PTs. Set TPVI = N if you have only one PT. With TPVI = Y, the relay uses the highest of the three voltages in the V/Hz calculation; when TPVI = N, the relay uses the A-phase voltage. A setting of TPVI = Y enables the phase-to-phase, residual (ground), negative-sequence, and positive-sequence voltage elements; enables display of three-phase and single-phase power measurements in the meter report; and enables three-phase undervoltage blocking (Relay Word bit 27B81) of the frequency elements. The relay uses VAB, VBC, and VCA in place of VA, VB, and VC respectively for the 27B81 logic when the PT connections are connected open-delta and DELTA_Y = D. A setting of TPVI = N disables and hides all voltage elements but the phase-ground elements, removes single-phase power measurements from the meter report, and modifies the undervoltage blocking of the frequency elements so that it only uses VA. The three-phase power calculation assumes a balanced three-phase system when TPVI = N. The TPVI = N selection supports the V/Hz element when only a single PT is available, connected to the A-phase.

## Demand Meter (DATC, PDEM, QDEM, NDEM)

The relay provides demand meters for Windings 1 through 3, for phase, negative-sequence, and residual currents. Demand metering for three-phase real and reactive power is also provided. The relay saves time- and date-stamped peak demand readings for each of the quantities. View this information using the relay front panel or serial port **METER** commands.

The demand meters behave much like low-pass filters, responding to gradual trends in the current or power magnitude. The relay uses the demand meter time constant setting, DATC*n*, for all demand meter calculations for Winding *n*. It also applies this time constant to the power quantities associated with the windings identified in the VIWDG setting. The time constant is settable from 5 to 255 minutes. The demand meters operate such that if the respective demand quantity is reset and a constant input is applied, the demand output will be 90 percent of the constant input value DATC*n* minutes later.

Settable demand meter thresholds are available for all five demand meters in units of amperes secondary. The thresholds are PDEM*n*P, QDEM*n*P, and NDEM*n*P for the phase (A, B, and C), negative-sequence, and residual demand meters for Winding n. If demand currents exceed the set threshold, the respective Relay Word bit PDEM*n*, QDEM*n*, or NDEM*n* asserts. You can use these Relay Word bits to alarm for phase overload and negative-sequence or residual current unbalance for Winding *n*. See *Section 5: Metering and Monitoring* for more information. Demand thresholds are not provided for three-phase power demand values. These values are provided for metering purposes only.

For our example, the demand meter function is enabled only for Winding 1, the 230 kV primary winding, with the following settings: DATC1 = 15 minutes, PDEM1P = 7 A, QDEM1P = 1 A, and NDEM1P = 1 A.

The demand meter settings can be different in the six settings groups.

Instantaneous metering functions have no settings. Access is by the front panel or one of the communications ports.

## Assignment of Optoisolated Inputs and Output Contacts

Optoisolated inputs (IN101 through IN106) and output contacts (OUT101 through OUT107) are fully programmable, with no numbered input or output specifically dedicated to a function. The one exception is the ALARM contact, factory set as a “b” contact (normally closed), and dedicated to the alarm function. OUT107 can be made into an additional alarm contact that follows the normal ALARM contact via JMP23 on the main board (see *Section 2: Installation*). Standard SELOGIC® control equations can be written to drive the output contacts. The inputs appear as elements of SELOGIC control equations. Examples of this are illustrated in the next discussion on Trip and Close Logic. These settings can be different in the six settings groups.

## Event Report Triggering (ER) and Length Selection (LER, PRE)

There are three settings for Event Reports: (1) ER, (2) LER, and (3) PRE.

The first, ER, defines in a SELOGIC control equation the conditions under which a report will be generated. In our example, ER = /50P11 + /51P1 + /51Q1 + /51P2 + /51Q2 + /51P3. Events will be generated from the pickup of the various overcurrent elements, regardless of whether they fully time out. This will yield reports for some external faults that do not result in tripping of the transformer breakers, but for which information might be useful. Winding 3 element pickup is used to detect external tertiary circuit faults that may be too weak to be detected by the Winding 1 elements. Also, because tertiary circuits normally are short, probably only including the substation buses and auxiliary equipment, reports on faults of any kind would be of great interest.

The LER setting defines how long the overall report should be: 15, 29, or 60 cycles. The related setting PRE defines how much of that length should be "pre-trigger," and can be set from one cycle to LER-1 cycles. We have selected the standard SEL report length of 15 for LER, with PRE set at 4, giving 15 - 4 = 11 cycles of fault data. This is probably long enough to capture the entire event, for trips by high-speed elements (87R, 87U, 50P*xx*), but may not be long enough for inverse-time trips. Because any trip will generate an Event Report, inverse-time trips may be captured on two reports, one generated by element pickup and the other by the eventual trip.

Event Report settings are Global settings, accessible with a **SET G** command from a communications port.

## System Frequency (NFREQ) and Phase Rotation (PHROT)

The relay settings NFREQ and PHROT establish your basic system parameters for the SEL-387E.

1. Set NFREQ equal to the nominal power system operating frequency, either 50 Hz or 60 Hz.
2. Set PHROT to the power system phase rotation, either ABC or ACB.

These are Global settings, set after issuing a **SET G** command from a communications port.

## Phase Potential Connection (DELTA_Y)

Select D if your potential transformers (PTs) are connected in open-delta. A setting of Y enables the phase-ground voltage elements and enables display of three-phase and single-phase power measurements in the meter report. A setting of D removes the $\sqrt{3}$ multiplication from the V/Hz calculation that normally accounts for the difference between phase-to-neutral and phase-to-phase voltages, disables and hides the phase-ground voltage elements, and removes single-phase power measurements from the meter report.

Measured phase-to-phase voltages (VAB, VCB) from open-delta PTs are converted to calculated phase-to-phase voltages (VAB, VBC, VCA) when DELTA_Y=D. These voltages are used for various elements. The meter report converts the calculated phase-to-phase voltages (VAB, VBC, VCA) into phase-to-neutral voltages (VA, VB, VC) by dividing the phase-to-phase voltages by $\sqrt{3}$. Phase-to-phase voltages can only be converted to phase-to-neutral voltages using the 3 factor when the system is balanced. Relabel VA, VB, and VC to VAB, VBC, and VCA, respectively, using the **SET G** command and increase your PTR setting by a factor of $\sqrt{3}$ using the **SET** command to display phase-to-phase voltages rather than phase-to-neutral voltages. However, increasing the PTR by $\sqrt{3}$ also increases the V/Hz measurement by $\sqrt{3}$. To adjust for this V/Hz increase, multiply the VNOM setting by $\sqrt{3}$. For example, consider the following default settings:

VNOM = 230

PTR = 2000

To display phase-to-phase voltages and adjust the V/Hz calculation, apply the following settings:

VNOM = 230 • $\sqrt{3}$ = 398.4

PTR = 2000 • $\sqrt{3}$ = 3464

The values of the final affected measurements, 3V1 and 3V2, cannot be adjusted but remain increased by $\sqrt{3}$. You do not need to change the VNOM and PTR settings if the display of phase voltages is acceptable.

## Miscellaneous (DATE_F, SCROLD, FP_TO, TGR)

There are four miscellaneous settings to complete the setting process. These are the Date Format, Front-Panel Time-Out, Scroll Data, and Group Change Delay settings. These settings are Global settings, accessible with the **SET G** command from a communications port or the front panel.

The DATE_F setting permits the user to define either a Month-Day-Year (MDY) format or a Year-Month-Day (YMD) format for all relay date reporting. Default is MDY.

Use the display update rate (SCROLD or scroll data) setting to control how long each pair of display text messages is displayed on the front panel. Setting range is 1 to 60 seconds with a default of 2 seconds.

The front-panel time-out setting, FP_TO, defines the length of time before the panel returns to normal default scrolling displays and LED targeting. This feature is useful for preventing the panel from being accidentally left in a display state that was being used during testing or to confirm Relay Word bit status. It is settable from 0 to 30 minutes; default is 16 minutes.

The Group Change Delay timer setting, TGR, defines the amount of time that must pass before a new group of settings takes effect. It requires the conditions to change to a new group to persist for time TGR before the relay enacts the new settings. The setting range is 0 through 900 seconds. The factory default value is 3 seconds. 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.

## DC Battery Monitor (DC1P–DC4P)

The dc battery monitor function is described in *Section 5: Metering and Monitoring*. Four settable dc voltage thresholds, DC1P through DC4P, assert Relay Word bits DC1 to DC4 when supply voltage to the relay exceeds the specific threshold. This allows the user to readily determine if the voltage is within certain limits and to alarm if the voltage goes too high or low. The four threshold settings are found in the Global setting area.

## Breaker Monitor

The Breaker Monitor function is described fully in *Section 5: Metering and Monitoring*. There is one setting for each of three breakers, BKMON1 through BKMON3. This setting accepts a SELOGIC control equation using Relay Word elements to describe the triggering conditions for that particular monitor. When triggered, the monitor measures the three-phase currents 1.5 cycles after triggering, adds them to the total accumulated current for that breaker, and adds one to the external or internal trip counter, depending on whether the associated TRIP variable was asserted at time of triggering.

In addition, for each breaker there is a contact wear curve, defined by entering three operations versus current coordinate pairs. This curve is applied by pole to track and alarm when excessive contact wear is encountered. This helps the user to schedule breaker maintenance intervals.

## Analog Input Labels

In the Global setting area, the user is permitted to rename the 12 analog current inputs to suit local preferences. The present names, IAW1 through VWCX, can be replaced with other designations of not more than four characters. This function recognizes the desire of users to replace SEL designations with more familiar phase identifiers, such as “R, S, T.”

The new labels will appear wherever the currents were identified by the existing labels, including the displays for serial port commands **STATUS** (**STA**), **BREAKER** (**BRE**), **EVENT** (**EVE**), and **METER** (**MET**), including the variants of each command. The new labels will also appear in the front-panel LCDs for the STATUS and METER pushbutton menus.

## Front-Panel Displays

Fault type targets A, B, and C can be redefined using SELOGIC control equations LEDA, LEDB, and LEDC, respectively.

There are 16 programmable Display Points, for creating customized messages on the LCD. They appear in pairs and stay on screen for two seconds before scrolling to the next display. The variables DP1 through DP16 are defined by a SELOGIC control equation that at any time will have a logical value of 0 or 1. For each DP*m* there are two settings showing the display content. These are DP*m*_1 and DP*m*_0. The relay displays any nonblank DP*m*_1 or _0 values if the current logical value of DP*m* corresponds. The LED and Display Point settings are Global settings, accessible with the **SET G** command from a communications port.

For more information on the LEDs and Display Points, see *Section 8: Front-Panel Operation*.

## Sequential Events Reporting

The SER, or Sequential Events Recorder, lists as many as 512 events. This listing may help the user determine within a short time interval the correct order of operation during a complicated event with multiple device operations. The settings for the SER are the trigger conditions and the Relay Word bit ALIAS names. As many as 96 total Relay Word bit names may be selected and entered into settings SER1, SER2, SER3, and SER4 in any order, with a maximum of 24 bits in any SER*n*. As many as 20 Relay Word bits may be given ALIAS names, to make the SER report more user-friendly. For example, a given input may be given an ALIAS that designates a 52a input for a specific named breaker.

The SER settings are made after issuing the **SET R** command from a communications port. The SER operation and settings are described fully in *Section 9: Analyzing Events*.

## Communications Ports

There are four communications ports and two optional Ethernet ports on the SEL-387E. Port 1 is an EIA-485 port on the rear panel. Ports 2 and 3, also on the rear panel, are EIA-232. Port 4 is an EIA-232 port on the front panel. Ports 5 and 6 are the Ethernet ports on the rear panel. These ports are set via the **SET P** command. To identify the port by which one is presently communicating with the relay, issue the **SHO P** command, which will also list that port's settings.

Initial connection to the relay can be made with standard SEL protocol, at 2400 baud, 8 data bits, no parity, 1 stop bit, and VT100 emulation, using any standard communications program such as Microsoft Windows 95 HyperTerminal®.

Complete information on the communications ports and necessary settings can be found in *Section 7: Communications*.

# Default Settings

## SEL-387E Relay SHO G (Show Global Settings)

```
=>>SHO G <Enter>
LER     = 15        PRE     = 4         NFREQ   = 60        PHROT   = ABC
DELTA_Y = Y
DATE_F  = MDY       SCROLD  = 2         FP_TO   = 16        TGR     = 3
DC1P    = OFF       DC2P    = OFF       DC3P    = OFF       DC4P    = OFF

BKMON1  =TRIP1 + TRIP4
B1COP1  = 10000     B1KAP1  = 1.2
B1COP2  = 160       B1KAP2  = 8.0
B1COP3  = 12        B1KAP3  = 20.0

BKMON2  =TRIP2 + TRIP4
B2COP1  = 10000     B2KAP1  = 1.2
B2COP2  = 160       B2KAP2  = 8.0
B2COP3  = 12        B2KAP3  = 20.0

BKMON3  =TRIP3 + TRIP4
B3COP1  = 10000     B3KAP1  = 1.2
B3COP2  = 160       B3KAP2  = 8.0
B3COP3  = 12        B3KAP3  = 20.0

ETHRU   =N

IAW1    =IAW1
IBW1    =IBW1
ICW1    =ICW1
IAW2    =IAW2
IBW2    =IBW2
ICW2    =ICW2
IAW3    =IAW3
IBW3    =IBW3
ICW3    =ICW3
VAWX    =VAWX
VBWX    =VBWX
VCWX    =VCWX

SS1     =0
SS2     =0
SS3     =0
SS4     =0
SS5     =0
SS6     =0
LEDA    =OCA + 87E1
LEDB    =OCB + 87E2
LEDC    =OCC + 87E3

DP1     =IN101
DP1_1   =BREAKER 1 CLOSED DP1_0   =BREAKER 1 OPEN
DP2     =IN102
DP2_1   =BREAKER 2 CLOSED DP2_0   =BREAKER 2 OPEN
DP3     =IN103
DP3_1   =BREAKER 3 CLOSED DP3_0   =BREAKER 3 OPEN
DP4     =0
DP4_1   =                 DP4_0   =
DP5     =0
DP5_1   =                 DP5_0   =
DP6     =0
DP6_1   =                 DP6_0   =
DP7     =0
DP7_1   =                 DP7_0   =
DP8     =0
DP8_1   =                 DP8_0   =
DP9     =0
DP9_1   =                 DP9_0   =
DP10    =0
DP10_1  =                 DP10_0  =
DP11    =0
DP11_1  =                 DP11_0  =
DP12    =0
DP12_1  =                 DP12_0  =
DP13    =0
DP13_1  =                 DP13_0  =
DP14    =0
DP14_1  =                 DP14_0  =
DP15    =0
DP15_1  =                 DP15_0  =
DP16    =0
DP16_1  =                 DP16_0  =
```

**NOTE:** SCEUSE is the percent of SELOGIC control equations used in Global settings. GBLCHK is the Global setting checksum used by the relay's diagnostics.

```
Text Labels:
NLB1    =                CLB1    =        SLB1    =        PLB1    =
NLB2    =                CLB2    =        SLB2    =        PLB2    =
NLB3    =MANUAL TRIP 1   CLB3    =RETURN  SLB3    =        PLB3    =TRIP
NLB4    =MANUAL CLOSE 1  CLB4    =RETURN  SLB4    =        PLB4    =CLOSE
NLB5    =                CLB5    =        SLB5    =        PLB5    =
NLB6    =                CLB6    =        SLB6
SCEUSE                   47.8
GBLCHK                   68EB
=>>
```

## SEL-387E Relay SHO P (Show Port Settings)

```
=>>SHO P <Enter>
Port F

PROTO   = SEL
SPEED   = 19200     BITS    = 8         PARITY  = N         STOP    = 1
T_OUT   = 15        AUTO    = N         RTSCTS  = N         FASTOP  = N

=>>
```

## SEL-387E Relay SHO R (Show SER Settings)

```
=>>SHO R <Enter>

SER1    =IN101,IN102,IN103,IN104,IN105,IN106
SER2    =OUT101,OUT102,OUT103,OUT104,OUT105,OUT106,OUT107
SER3    =0
SER4    =0

ALIAS1  =NA
ALIAS2  =NA
ALIAS3  =NA
ALIAS4  =NA
ALIAS5  =NA
ALIAS6  =NA
ALIAS7  =NA
ALIAS8  =NA
ALIAS9  =NA
ALIAS10 =NA
ALIAS11 =NA
ALIAS12 =NA
ALIAS13 =NA
ALIAS14 =NA
ALIAS15 =NA
ALIAS16 =NA
ALIAS17 =NA
ALIAS18 =NA
ALIAS19 =NA
ALIAS20 =NA
=>>
```

## SEL-387E Relay Default Settings (5 A)

```
=>>SHO <Enter>
Group 1


RID     =XFMR 1
TID     =STATION A
E87W1   = Y         E87W2   = Y         E87W3   = Y
EOC1    = Y         EOC2    = Y         EOC3    = Y         EOCC    = N
E24     = Y         E27     = Y         E59     = Y
E81     = N
ESLS1   = N         ESLS2   = N         ESLS3   = N

W1CT    = Y         W2CT    = Y         W3CT    = Y
CTR1    = 120       CTR2    = 240       CTR3    = 400
MVA     = 100.0     ICOM    = Y
W1CTC   = 11        W2CTC   = 11        W3CTC   = 0

VWDG1   = 230.00    VWDG2   = 138.00    VWDG3   = 13.80
PTR     = 2000      COMPANG = 0         VIWDG   = 1         TPVI    = Y

TAP1    = 2.09      TAP2    = 1.74      TAP3    = 10.46
O87P    = 0.3       SLP1    = 25        SLP2    = 50        IRS1    = 3.0
U87P    = 10.0      PCT2    = 15        PCT5    = 35
TH5P    = OFF       IHBL    = N

E32I    =0

50P11P  = 20.00     50P11D  = 5.00      50P11TC =1
50P12P  = OFF
50P13P  = 0.50      50P14P  = 4.00
51P1P   = 4.00      51P1C   = U2        51P1TD  = 3.00      51P1RS  = Y
51P1TC  =1
```

```
50Q11P  = OFF       50Q12P  = OFF
51Q1P   = 6.00      51Q1C   = U2        51Q1TD  = 3.00      51Q1RS  = Y
51Q1TC  =1

50N11P  = OFF       50N12P  = OFF
51N1P   = OFF
DATC1   = 15        PDEM1P  = 7.00      QDEM1P  = 1.00      NDEM1P  = 1.00

50P21P  = OFF       50P22P  = OFF
50P23P  = 0.50      50P24P  = 3.50
51P2P   = 3.50      51P2C   = U2        51P2TD  = 3.50      51P2RS  = Y
51P2TC  =1

50Q21P  = OFF       50Q22P  = OFF
51Q2P   = 5.25      51Q2C   = U2        51Q2TD  = 3.50      51Q2RS  = Y
51Q2TC  =1

50N21P  = OFF       50N22P  = OFF
51N2P   = OFF
DATC2   = 15        PDEM2P  = 7.00      QDEM2P  = 1.00      NDEM2P  = 1.00

50P31P  = 7.00      50P31D  = 0.00      50P31TC =1
50P32P  = OFF
50P33P  = 0.50      50P34P  = 4.00
51P3P   = 4.00      51P3C   = U2        51P3TD  = 1.30      51P3RS  = Y
51P3TC  =1
50Q31P  = OFF       50Q32P  = OFF
51Q3P   = OFF
50N31P  = OFF       50N32P  = OFF
51N3P   = OFF
DATC3   = 15        PDEM3P  = 7.00      QDEM3P  = 1.00      NDEM3P  = 1.00

VNOM    = 230.00    24WDG   = Y         24D1P   = 105       24D1D   = 1.00
24CCS   = ID        24IP    = 105       24IC    = 2.0       24ITD   = 0.1
24D2P2  = 176       24D2D2  = 3.00      24CR    = 240.00
24TC    =1
27P1P   = 20.0      27P2P   = 0.0
27PP1   = 35.0      27PP2   = 0.0       27V1P   = 0.0
59P1P   = 74.0      59P2P   = OFF
59G1P   = 20.0      59G2P   = OFF       59QP    = OFF
59PP1   = 128.0     59PP2   = OFF       59V1P   = OFF
TDURD   = 9.000     CFD     = 60.000
TR1     =50P11T + 51P1T + 51Q1T + OC1 + LB3
TR2     =51P2T + 51Q2T + OC2
TR3     =50P31 + 51P3T + OC3
TR4     =87R + 87U
ULTR1   =!50P13
ULTR2   =!50P23
ULTR3   =!50P33
ULTR4   =!(50P13 + 50P23 + 50P33)
52A1    =IN101
52A2    =IN102
52A3    =IN103
CL1     =CC1 + LB4 + /IN104
CL2     =CC2 + /IN105
CL3     =CC3 + /IN106
ULCL1   =TRIP1 + TRIP4
ULCL2   =TRIP2 + TRIP4
ULCL3   =TRIP3 + TRIP4
ER      =/50P11 + /51P1 + /51Q1 + /51P2 + /51Q2 + /51P3
OUT101  =TRIP1
OUT102  =TRIP2
OUT103  =TRIP3
OUT104  =TRIP4
OUT105  =CLS1
OUT106  =CLS2
OUT107  =CLS3
OUT201  =0
OUT202  =0
OUT203  =0
OUT204  =0
OUT205  =0
OUT206  =0
OUT207  =0
OUT208  =0
OUT209  =0
OUT210  =0
OUT211  =0
OUT212  =0
SCEUSE     47.8
GR1CHK     68EB
=>>
```

**NOTE:** SCEUSE is the percent of SELOGIC control equations used in this setting group. GRnCHK is the Group setting checksum used by the relay's diagnostics.

# SEL-387E Relay Default Settings (1 A)

```
=>>SHO <Enter>
Group 1


RID     =XFMR 1
TID     =STATION A
E87W1   = Y         E87W2   = Y         E87W3   = Y
EOC1    = Y         EOC2    = Y         EOC3    = Y         EOCC    = N
E24     = Y         E27     = Y         E59     = Y
E81     = N
ESLS1   = N         ESLS2   = N         ESLS3   = N

W1CT    = Y         W2CT    = Y         W3CT    = Y
CTR1    = 600       CTR2    = 1200      CTR3    = 2000
MVA     = 100.0     ICOM    = Y

W1CTC   = 11        W2CTC   = 11        W3CTC   = 0
VWDG1   = 230.00    VWDG2   = 138.00    VWDG3   = 13.80
PTR     = 2000      COMPANG = 0         VIWDG   = 1         TPVI    = Y

TAP1    = 0.42      TAP2    = 0.35      TAP3    = 2.09
O87P    = 0.3       SLP1    = 25        SLP2    = 50        IRS1    = 3.0
U87P    = 10.0      PCT2    = 15        PCT5    = 35
TH5P    = OFF       IHBL    = N

E32I    =0

50P11P  = 4.00      50P11D  = 5.00      50P11TC =1
50P12P  = OFF
50P13P  = 0.10      50P14P  = 0.80
51P1P   = 0.80      51P1C   = U2        51P1TD  = 3.00      51P1RS  = Y
51P1TC  =1

50Q11P  = OFF       50Q12P  = OFF
51Q1P   = 1.20      51Q1C   = U2        51Q1TD  = 3.00      51Q1RS  = Y
51Q1TC  =1

50N11P  = OFF       50N12P  = OFF
51N1P   = OFF
DATC1   = 15        PDEM1P  = 1.40      QDEM1P  = 0.20      NDEM1P  = 0.20


50P21P  = OFF       50P22P  = OFF
50P23P  = 0.10      50P24P  = 0.70
51P2P   = 0.70      51P2C   = U2        51P2TD  = 3.50      51P2RS  = Y
51P2TC  =1

50Q21P  = OFF       50Q22P  = OFF
51Q2P   = 1.05      51Q2C   = U2        51Q2TD  = 3.50      51Q2RS  = Y
51Q2TC  =1

50N21P  = OFF       50N22P  = OFF
51N2P   = OFF
DATC2   = 15        PDEM2P  = 1.40      QDEM2P  = 0.20      NDEM2P  = 0.20

50P31P  = 1.40      50P31D  = 0.00      50P31TC =1

50P32P  = OFF
50P33P  = 0.10      50P34P  = 0.80
51P3P   = 0.80      51P3C   = U2        51P3TD  = 1.30      51P3RS  = Y
51P3TC  =1

50Q31P  = OFF       50Q32P  = OFF
51Q3P   = OFF
50N31P  = OFF       50N32P  = OFF
51N3P   = OFF
DATC3   = 15        PDEM3P  = 1.40      QDEM3P  = 0.20      NDEM3P  = 0.20


VNOM    = 230.00    24WDG   = Y         24D1P   = 105       24D1D   = 1.00
24CCS   = ID        24IP    = 105       24IC    = 2.0       24ITD   = 0.1
24D2P2  = 176       24D2D2  = 3.00      24CR    = 240.00
24TC    =1

27P1P   = 20.0      27P2P   = 0.0
27PP1   = 35.0      27PP2   = 0.0       27V1P   = 0.0

59P1P   = 74.0      59P2P   = OFF
59G1P   = 20.0      59G2P   = OFF       59QP    = OFF
59PP1   = 128.0     59PP2   = OFF       59V1P   = OFF

TDURD   = 9.000     CFD     = 60.000
```

```
TR1     =50P11T + 51P1T + 51Q1T + OC1 + LB3
TR2     =51P2T + 51Q2T + OC2
TR3     =50P31 + 51P3T + OC3
TR4     =87R + 87U
ULTR1   =!50P13
ULTR2   =!50P23
ULTR3   =!50P33
ULTR4   =!(50P13 + 50P23 + 50P33)
52A1    =IN101
52A2    =IN102
52A3    =IN103
CL1     =CC1 + LB4 + /IN104
CL2     =CC2 + /IN105
CL3     =CC3 + /IN106
ULCL1   =TRIP1 + TRIP4
ULCL2   =TRIP2 + TRIP4
ULCL3   =TRIP3 + TRIP4
ER      =/50P11 + /51P1 + /51Q1 + /51P2 + /51Q2 + /51P3
OUT101  =TRIP1
OUT102  =TRIP2
OUT103  =TRIP3
OUT104  =TRIP4
OUT105  =CLS1
OUT106  =CLS2
OUT107  =CLS3

OUT201  =0
OUT202  =0
OUT203  =0
OUT204  =0
OUT205  =0
OUT206  =0
OUT207  =0
OUT208  =0
OUT209  =0
OUT210  =0
OUT211  =0
OUT212  =0
```

**NOTE:** SCEUSE is the percent of SELOGIC control equations used in this setting group. GRnCHK is the Group setting checksum used by the relay's diagnostics.

```
SCEUSE     47.8
GR1CHK     6804
=>>
```

The Group settings shown above are the only settings which are different from the 5 A relay settings. The Global, Port, and SER settings remain the same.

# Settings Sheets

The following Settings Sheets may be photocopied, filled out, and used as reference when you are entering settings. Refer to *Section 1: Introduction and Specifications* for information on 5 A nominal and 1 A nominal ordering options and how they influence overcurrent element setting ranges and accuracies.

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# SEL-387E Settings Sheets

## Group Settings (SET Command)

### Configuration Settings

Relay Identifier (30 characters)

**RID** = _____

Terminal Identifier (30 characters)

**TID** = _____

| | | |
|---|---|---|
| Enable Winding 1 in Differential Element (Y, N, Y1) | **E87W1** | = _____ |
| Enable Winding 2 in Differential Element (Y, N, Y1) | **E87W2** | = _____ |
| Enable Winding 3 in Differential Element (Y, N, Y1) | **E87W3** | = _____ |
| Enable Winding 1 O/C Elements and Dmd Thresholds (Y, N) | **EOC1** | = _____ |
| Enable Winding 2 O/C Elements and Dmd Thresholds (Y, N) | **EOC2** | = _____ |
| Enable Winding 3 O/C Elements and Dmd Thresholds (Y, N) | **EOC3** | = _____ |
| Enable Combined O/C Elements (Y, N) | **EOCC** | = _____ |
| Enable Volts/Hertz Protection (Y, N) | **E24** | = _____ |
| Enable Undervoltage Protection (Y, N) | **E27** | = _____ |
| Enable Overvoltage Protection (Y, N) | **E59** | = _____ |
| Enable Frequency Protection (N, 1–6) | **E81** | = _____ |
| Enable SELOGIC® Control Equations Set 1 (Y, N) | **ESLS1** | = _____ |
| Enable SELOGIC Control Equations Set 2 (Y, N) | **ESLS2** | = _____ |
| Enable SELOGIC Control Equations Set 3 (Y, N) | **ESLS3** | = _____ |

### General Data

| | | |
|---|---|---|
| Winding 1 CT Connection (D, Y) | **W1CT** | = _____ |
| Winding 2 CT Connection (D, Y) | **W2CT** | = _____ |
| Winding 3 CT Connection (D, Y) | **W3CT** | = _____ |
| Winding 1 CT Ratio (1–50000) | **CTR1** | = _____ |
| Winding 2 CT Ratio (1–50000) | **CTR2** | = _____ |
| Winding 3 CT Ratio (1–50000) | **CTR3** | = _____ |
| Maximum Power Transformer Capacity (OFF, 0.2–5000 MVA) | **MVA** | = _____ |
| Define Internal CT Connection Compensation (Y, N) | **ICOM** | = _____ |

| | | |
|---|---|---|
| Winding 1 CT Conn. Compensation (0, 1, …, 12) | **W1CTC** | =_____ |
| Winding 2 CT Conn. Compensation (0, 1, …, 12) | **W2CTC** | =_____ |
| Winding 3 CT Conn. Compensation (0, 1, …, 12) | **W3CTC** | =_____ |
| Winding 1 Line-to-Line Voltage (1–1000 kV) | **VWDG1** | =_____ |
| Winding 2 Line-to-Line Voltage (1–1000 kV) | **VWDG2** | =_____ |
| Winding 3 Line-to-Line Voltage (1–1000 kV) | **VWDG3** | =_____ |
| PT Ratio (1–6500) | **PTR** | =_____ |
| Compensation Angle (0–360 degrees) | **COMPANG** | =_____ |
| Voltage-Current Winding (1, 2, 3, 12) | **VIWDG** | =_____ |
| Three-Phase Voltage Input (Y, N) | **TPVI** | =_____ |

## Differential Elements

NOTE: TAP1–TAP3 are auto-set by relay if MVA setting is not OFF.

| | | |
|---|---|---|
| Winding 1 Current Tap (0.5–155.0 A secondary) (5 A)<br>(0.1–31.0 A secondary) (1 A) | **TAP1** | =_____ |
| Winding 2 Current Tap (0.5–155.0 A secondary) (5 A)<br>(0.1–31.0 A secondary) (1 A) | **TAP2** | =_____ |
| Winding 3 Current Tap (0.5–155.0 A secondary) (5 A)<br>(0.1–31.0 A secondary) (1 A) | **TAP3** | =_____ |
| Restrained Element Operating Current PU<br>((0.10–1.00) multiple of tap) | **O87P** | =_____ |
| Restraint Slope 1 Percentage (5–100%) | **SLP1** | =_____ |
| Restraint Slope 2 Percentage (OFF, 25–200%) | **SLP2** | =_____ |
| Restraint Current Slope 1 Limit ((1–20) multiple of tap) | **IRS1** | =_____ |
| Unrestrained Element Current PU ((1–20) multiple of tap) | **U87P** | =_____ |
| Second-Harmonic Blocking Percentage (OFF, 5–100%) | **PCT2** | =_____ |
| Fourth-Harmonic Blocking Percentage (OFF, 5–100%) | **PCT4** | =_____ |
| Fifth-Harmonic Blocking Percentage (OFF, 5–100%) | **PCT5** | =_____ |
| Fifth-Harmonic Alarm Threshold<br>(OFF, (0.02–3.20) multiple of tap) | **TH5P** | =_____ |
| Fifth-Harmonic Alarm TDPU (0–8000 cycles) | **TH5D** | =_____ |
| DC Ratio Blocking (Y, N) | **DCRB** | =_____ |
| Harmonic Restraint (Y, N) | **HRSTR** | =_____ |
| Independent Harmonic Blocking (Y, N) | **IHBL** | =_____ |

## Restricted Earth Fault

Enable 32I (SELOGIC control equation)

**E32I** = _____

| | | |
|---|---|---|
| Operating Quantity from W 1, W 2 (1, 2, 12) | **32IOP** | = _____ |
| Positive-Sequence Current Restraint Factor, I0/I1 (0.02–0.50) | **a0** | = _____ |
| Residual Current Sensitivity Threshold<br>(0.25–15.00 A secondary) (5 A)<br>(0.05–3.00 A secondary) (1 A) | **50GP** | = _____ |

## Winding 1 O/C Elements

### Winding 1 Phase O/C Elements

| | | |
|---|---|---|
| Phase Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P11P** | = _____ |
| Phase Level 1 O/C Delay (0–16000 cycles) | **50P11D** | = _____ |

50P11 Torque Control (SELOGIC control equation)

**50P11TC** = _____

| | | |
|---|---|---|
| Phase Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P12P** | = _____ |

50P12 Torque Control (SELOGIC control equation)

**50P12TC** = _____

| | | |
|---|---|---|
| Phase Inst. O/C Level 3 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P13P** | = _____ |
| Phase Inst. O/C Level 4 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P14P** | = _____ |
| Phase Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51P1P** | = _____ |
| Phase Inv.-Time O/C Curve (U1–U5, C1–C5) | **51P1C** | = _____ |
| Phase Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05–1.00) | **51P1TD** | = _____ |
| Phase Inv.-Time O/C EM Reset (Y, N) | **51P1RS** | = _____ |

51P1 Torque Control (SELOGIC control equation)

**51P1TC** = _____

## Winding 1 Negative-Sequence O/C Elements

NOTE: All negative-sequence element pickup settings are in terms of $3I_2$.

Neg.-Seq. Def.-Time O/C Level 1 PU **50Q11P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Neg.-Seq. Level 1 O/C Delay (0.5–16000 cycles) **50Q11D** =_____

50Q11 Torque Control (SELOGIC control equation)
**50Q11TC** = _____

Neg.-Seq. Inst. O/C Level 2 PU **50Q12P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50Q12 Torque Control (SELOGIC control equation)
**50Q12TC** = _____

Neg.-Seq. Inv.-Time O/C PU **51Q1P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) **51Q1C** =_____

Neg.-Seq. Inv.-Time O/C Time-Dial **51Q1TD** =_____
(US 0.5–15.0, IEC 0.05–1.00)

Neg.-Seq. Inv.-Time O/C EM Reset (Y, N) **51Q1RS** =_____

51Q1 Torque Control (SELOGIC control equation)
**51Q1TC** = _____

## Winding 1 Residual O/C Elements

Residual Def.-Time O/C Level 1 PU **50N11P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Residual Level 1 O/C Delay (0–16000 cycles) **50N11D** =_____

50N11 Torque Control (SELOGIC control equation)
**50N11TC** = _____

Residual Inst. O/C Level 2 PU **50N12P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50N12 Torque Control (SELOGIC control equation)
**50N12TC** = _____

Residual Inv.-Time O/C PU **51N1P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Residual Inv.-Time O/C Curve (U1–U5, C1–C5) **51N1C** =_____

Residual Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05–1.00) **51N1TD** =_____

Residual Inv.-Time O/C EM Reset (Y, N) **51N1RS** =_____

51N1 Torque Control (SELOGIC control equation)

**51N1TC** =_____

### Winding 1 Demand Metering

Demand Meter Time Constant (OFF, 5–255 min) **DATC1** =_____

Phase Demand Meter Threshold **PDEM1P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

Neg.-Seq. Demand Meter Threshold **QDEM1P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

Residual Demand Meter Threshold **NDEM1P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

## Winding 2 O/C Elements

### Winding 2 Phase O/C Elements

Phase Def.-Time O/C Level 1 PU **50P21P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Level 1 O/C Delay (0–16000 cycles) **50P21D** =_____

50P21 Torque Control (SELOGIC control equation)

**50P21TC** =_____

Phase Inst. O/C Level 2 PU **50P22P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50P22 Torque Control (SELOGIC control equation)

**50P22TC** =_____

Phase Inst. O/C Level 3 PU **50P23P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Inst. O/C Level 4 PU **50P24P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Inv.-Time O/C PU **51P2P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Phase Inv.-Time O/C Curve (U1–U5, C1–C5) **51P2C** =_____

Phase Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05–1.00) **51P2TD** =_____

Phase Inv.-Time O/C EM Reset (Y, N) **51P2RS** =_____

51P2 Torque Control (SELOGIC control equation)

**51P2TC** = _____

## Winding 2 Negative-Sequence O/C Elements

NOTE: All negative-sequence element pickup settings are in terms of $3I_2$.

Neg.-Seq. Def.-Time O/C Level 1 PU **50Q21P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Neg.-Seq. Level 1 O/C Delay (0.5–16000 cycles) **50Q21D** =_____

50Q21 Torque Control (SELOGIC control equation)

**50Q21TC** = _____

Neg.-Seq. Inst. O/C Level 2 PU **50Q22P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50Q22 Torque Control (SELOGIC control equation)

**50Q22TC** = _____

Neg.-Seq. Inv.-Time O/C PU **51Q2P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) **51Q2C** =_____

Neg.-Seq. Inv.-Time O/C Time-Dial **51Q2TD** =_____
(US 0.5–15.0, IEC 0.05–1.00)

Neg.-Seq. Inv.-Time O/C EM Reset (Y, N) **51Q2RS** =_____

51Q2 Torque Control (SELOGIC control equation)

**51Q2TC** = _____

## Winding 2 Residual O/C Elements

Residual Def.-Time O/C Level 1 PU **50N21P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Residual Level 1 O/C Delay (0–16000 cycles) **50N21D** =_____

50N21 Torque Control (SELOGIC control equation)

**50N21TC** = _____

Residual Inst. O/C Level 2 PU **50N22P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50N22 Torque Control (SELOGIC control equation)

**50N22TC** = _____

Residual Inv.-Time O/C PU **51N2P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Residual Inv.-Time O/C Curve (U1–U5, C1–C5) **51N2C** =_____

Residual Inv.-Time O/C Time-Dial **51N2TD** =_____
(US 0.5–15.0, IEC 0.05–1.00)

Residual Inv.-Time O/C EM Reset (Y, N) **51N2RS** =_____

51N2 Torque Control (SELOGIC control equation)

**51N2TC** = _____

### Winding 2 Demand Metering

Demand Meter Time Constant (OFF, 5–255 min) **DATC2** =_____

Phase Demand Meter Threshold **PDEM2P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

Neg.-Seq. Demand Meter Threshold **QDEM2P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

Residual Demand Meter Threshold **NDEM2P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

## Winding 3 O/C Elements

### Winding 3 Phase O/C Elements

Phase Def.-Time O/C Level 1 PU **50P31P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Level 1 O/C Delay (0–16000 cycles) **50P31D** =_____

50P31 Torque Control (SELOGIC control equation)

**50P31TC** = _____

Phase Inst. O/C Level 2 PU **50P32P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50P32 Torque Control (SELOGIC control equation)

**50P32TC** = _____

Phase Inst. O/C Level 3 PU **50P33P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Inst. O/C Level 4 PU **50P34P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Inv.-Time O/C PU **51P3P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Phase Inv.-Time O/C Curve (U1–U5, C1–C5) **51P3C** =_____

Phase Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05–1.00) **51P3TD** =_____

Phase Inv.-Time O/C EM Reset (Y, N) **51P3RS** =_____

51P3 Torque Control (SELOGIC control equation)

**51P3TC** = _____

## Winding 3 Negative-Sequence O/C Elements

NOTE: All negative-sequence element pickup settings are in terms of $3I_2$.

Neg.-Seq. Def.-Time O/C Level 1 PU **50Q31P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Neg.-Seq. Level 1 O/C Delay (0.5–16000.0 cycles) **50Q31D** =_____

50Q31 Torque Control (SELOGIC control equation)

**50Q31TC** = _____

Neg.-Seq. Inst. O/C Level 2 PU **50Q32P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50Q32 Torque Control (SELOGIC control equation)

**50Q32TC** = _____

Neg.-Seq. Inv.-Time O/C PU **51Q3P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) **51Q3C** =_____

Neg.-Seq. Inv.-Time O/C Time-Dial **51Q3TD** =_____
(US 0.5–15.0, IEC 0.05–1.00)

Neg.-Seq. Inv.-Time O/C EM Reset (Y, N) **51Q3RS** =_____

51Q3 Torque Control (SELOGIC control equation)

**51Q3TC** = _____

## Winding 3 Residual O/C Elements

Residual Def.-Time O/C Level 1 PU **50N31P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

Residual Level 1 O/C Delay (0–16000 cycles) **50N31D** =_____

50N31 Torque Control (SELOGIC control equation)

**50N31TC** = _____

Residual Inst. O/C Level 2 PU **50N32P** =_____
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20.00 A secondary) (1 A)

50N32 Torque Control (SELOGIC control equation)

**50N32TC** = _____

Residual Inv.-Time O/C PU **51N3P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

Residual Inv.-Time O/C Curve (U1-U5, C1-C5) **51N3C** =_____

Residual Inv.-Time O/C Time-Dial **51N3TD** =_____
(US 0.5–15.0, IEC 0.05-1.00)

Residual Inv.-Time O/C EM Reset (Y, N) **51N3RS** =_____

51N3 Torque Control (SELOGIC control equation)
**51N3TC** = _____

### Winding 3 Demand Metering

Demand Meter Time Constant (OFF, 5–255 min) **DATC3** =_____

Phase Demand Meter Threshold **PDEM3P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

Neg.-Seq. Demand Meter Threshold **QDEM3P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

Residual Demand Meter Threshold **NDEM3P** =_____
(0.5–16.0 A secondary) (5 A)
(0.1–3.2 A secondary) (1 A)

## Combined O/C Elements

NOTE: The combined overcurrent elements uses a normalization factor which scales the secondary current magnitude to the larger of the two winding CT Ratios. See 51PC1 and 51NC1 Combined Overcurrent Elements on page 3.33 for details and examples of the combined overcurrent elements.

### W1-W2 Phase O/C Elements

W1–W2 Phase Inv.-Time O/C PU **51PC1P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

W1–W2 Phase Inv.-Time O/C Curve (U1–U5, C1–C5) **51PC1C** =_____

W1–W2 Phase Inv.-Time O/C Time-Dial **51PC1TD** =_____
(US 0.5–15.0, IEC 0.05–1.00)

W1–W2 Phase Inv.-Time O/C EM Reset (Y, N) **51PC1RS** =_____

### W1-W2 Residual O/C Element

W1–W2 Residual Inv.-Time O/C PU **51NC1P** =_____
(OFF, 0.5–16.0 A secondary) (5 A)
(OFF, 0.1–3.2 A secondary) (1 A)

W1–W2 Residual Inv.-Time O/C Curve (U1–U5, C1–C5) **51NC1C** =_____

| | | |
|---|---|---|
| W1–W2 Residual Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05-1.00) | **51NC1TD** | =_____ |
| W1–W2 Residual Inv.-Time O/C EM Reset (Y, N) | **51NC1RS** | =_____ |

## 24 Elements

| | | |
|---|---|---|
| Protected Winding L-L Voltage (0.20–800.00 kV primary) | **VNOM** | =_____ |
| Transformer Winding Connection (D, Y) | **24WDG** | =_____ |
| Level 1 Volts/Hertz Pickup (100–200%) | **24D1P** | =_____ |
| Level 1 Time Delay (0.04–400.00 seconds) | **24D1D** | =_____ |
| Level 2 Composite Curve Shape (OFF, DD, ID, I, U) | **24CCS** | =_____ |
| Level 2 Inv.-Time Pickup (100–200%) | **24IP** | =_____ |
| Level 2 Inv.-Time Curve (0.5, 1.0, 2.0) | **24IC** | =_____ |
| Level 2 Inv.-Time Factor (0.1–10.0 seconds) | **24ITD** | =_____ |
| Level 2 Pickup One (100–200%) | **24D2P1** | =_____ |
| Level 2 Time Delay One (0.04–400.00 seconds) | **24D2D1** | =_____ |
| Level 2 Pickup Two (101–200%) | **24D2P2** | =_____ |
| Level 2 Time Delay Two (0.04–400.00 seconds) | **24D2D2** | =_____ |
| Level 2 Reset Time (0.00–400.00 seconds) | **24CR** | =_____ |

24 Element Torque-Control (SELOGIC control equation)

**24TC** =_____

## 27 Elements

| | | |
|---|---|---|
| Level 1 Phase U/V PU (OFF, 0.1–300.0 V secondary) | **27P1P** | =_____ |
| Level 2 Phase U/V PU (OFF, 0.1–300.0 V secondary) | **27P2P** | =_____ |
| Level 1 Phase-to-Phase U/V PU (OFF, 0.1–520.0 V secondary) | **27PP1** | =_____ |
| Level 2 Phase-to-Phase U/V PU (OFF, 0.1–520.0 V secondary) | **27PP2** | =_____ |
| Pos.-Seq. U/V PU (OFF, 0.1–100.0 V secondary) | **27V1P** | =_____ |

## 59 Elements

| | | |
|---|---|---|
| Level 1 Phase O/V PU (OFF, 0.0–300.0 V secondary) | **59P1P** | =_____ |
| Level 2 Phase O/V PU (OFF, 0.0–300.0 V secondary) | **59P2P** | =_____ |
| Level 1 Residual O/V PU (OFF, 0.0–300.0 V secondary) | **59G1P** | =_____ |
| Level 2 Residual O/V PU (OFF, 0.0–300.0 V secondary) | **59G2P** | =_____ |
| Neg.-Seq. U/V PU (OFF, 0.0–100.0 V secondary) | **59QP** | =_____ |
| Level 1 Phase-to-Phase O/V PU (OFF, 0.0–520.0 V secondary) | **59PP1** | =_____ |

| | | |
|---|---|---|
| Level 2 Phase-to-Phase O/V PU (OFF, 0.0–520.0 V secondary) | **59PP2** | =_____ |
| Pos.-Seq.(V1) O/V PU (OFF, 0.0–100.0 V secondary) | **59V1P** | =_____ |

## 81 Elements

| | | |
|---|---|---|
| Undervoltage Block (20.0–150.0 V secondary) | **27B81P** | =_____ |
| Level 1 Pickup (OFF, 40.10–65.00 Hz) | **81D1P** | =_____ |
| Level 1 Time Delay (0.04–300.00 seconds) | **81D1D** | =_____ |
| Level 2 Pickup (OFF, 40.10–65.00 Hz) | **81D2P** | =_____ |
| Level 2 Time Delay (0.04–300.00 seconds) | **81D2D** | =_____ |
| Level 3 Pickup (OFF, 40.10–65.00 Hz) | **81D3P** | =_____ |
| Level 3 Time Delay (0.04–300.00 seconds) | **81D3D** | =_____ |
| Level 4 Pickup (OFF, 40.10–65.00 Hz) | **81D4P** | =_____ |
| Level 4 Time Delay (0.04–300.00 seconds) | **81D4D** | =_____ |
| Level 5 Pickup (OFF, 40.10–65.00 Hz) | **81D5P** | =_____ |
| Level 5 Time Delay (0.04–300.00 seconds) | **81D5D** | =_____ |
| Level 6 Pickup (OFF, 40.10–65.00 Hz) | **81D6P** | =_____ |
| Level 6 Time Delay (0.04–300.00 seconds) | **81D6D** | =_____ |

## Miscellaneous Timers

| | | |
|---|---|---|
| Minimum Trip Duration Time Delay (4–8000 cycles) | **TDURD** | =_____ |
| Close Failure Logic Time Delay (OFF, 0–8000 cycles) | **CFD** | =_____ |

## SELOGIC Control Equations Set 1

Set 1 Variable 1 (SELOGIC control equation)

**S1V1** = _____

| | | |
|---|---|---|
| S1V1 Timer Pickup (0–999999 cycles) | **S1V1PU** | =_____ |
| S1V1 Timer Dropout (0–999999 cycles) | **S1V1DO** | =_____ |

Set 1 Variable 2 (SELOGIC control equation)

**S1V2** = _____

| | | |
|---|---|---|
| S1V2 Timer Pickup (0–999999 cycles) | **S1V2PU** | =_____ |
| S1V2 Timer Dropout (0–999999 cycles) | **S1V2DO** | =_____ |

Set 1 Variable 3 (SELOGIC control equation)

**S1V3** = _____

| | | |
|---|---|---|
| S1V3 Timer Pickup (0–999999 cycles) | **S1V3PU** | =_____ |
| S1V3 Timer Dropout (0–999999 cycles) | **S1V3DO** | =_____ |

Set 1 Variable 4 (SELOGIC control equation)

**S1V4** = _____

S1V4 Timer Pickup (0–999999 cycles) **S1V4PU** = _____

S1V4 Timer Dropout (0–999999 cycles) **S1V4DO** = _____

Set 1 Latch Bit 1 SET Input (SELOGIC control equation)

**S1SLT1** = _____

Set 1 Latch Bit 1 RESET Input (SELOGIC control equation)

**S1RLT1** = _____

Set 1 Latch Bit 2 SET Input (SELOGIC control equation)

**S1SLT2** = _____

Set 1 Latch Bit 2 RESET Input (SELOGIC control equation)

**S1RLT2** = _____

Set 1 Latch Bit 3 SET Input (SELOGIC control equation)

**S1SLT3** = _____

Set 1 Latch Bit 3 RESET Input (SELOGIC control equation)

**S1RLT3** = _____

Set 1 Latch Bit 4 SET Input (SELOGIC control equation)

**S1SLT4** = _____

Set 1 Latch Bit 4 RESET Input (SELOGIC control equation)

**S1RLT4** = _____

## SELOGIC Control Equations Set 2

Set 2 Variable 1 (SELOGIC control equation)

**S2V1** = _____

S2V1 Timer Pickup (0–999999 cycles) **S2V1PU** = _____

S2V1 Timer Dropout (0–999999 cycles) **S2V1DO** = _____

Set 2 Variable 2 (SELOGIC control equation)

**S2V2** = _____

S2V2 Timer Pickup (0–999999 cycles) **S2V2PU** = _____

S2V2 Timer Dropout (0–999999 cycles) **S2V2DO** = _____

Set 2 Variable 3 (SELOGIC control equation)

**S2V3** = _____

S2V3 Timer Pickup (0–999999 cycles) **S2V3PU** = _____

S2V3 Timer Dropout (0–999999 cycles) **S2V3DO** = _____

Set 2 Variable 4 (SELOGIC control equation)

**S2V4** = _____

S2V4 Timer Pickup (0–999999 cycles) **S2V4PU** =_____

S2V4 Timer Dropout (0–999999 cycles) **S2V4DO** =_____

Set 2 Latch Bit 1 SET Input (SELOGIC control equation)
**S2SLT1** = _____

Set 2 Latch Bit 1 RESET Input (SELOGIC control equation)
**S2RLT1** = _____

Set 2 Latch Bit 2 SET Input (SELOGIC control equation)
**S2SLT2** = _____

Set 2 Latch Bit 2 RESET Input (SELOGIC control equation)
**S2RLT2** = _____

Set 2 Latch Bit 3 SET Input (SELOGIC control equation)
**S2SLT3** = _____

Set 2 Latch Bit 3 RESET Input (SELOGIC control equation)
**S2RLT3** = _____

Set 2 Latch Bit 4 SET Input (SELOGIC control equation)
**S2SLT4** = _____

Set 2 Latch Bit 4 RESET Input (SELOGIC control equation)
**S2RLT4** = _____

## SELOGIC Control Equation Set 3

Set 3 Variable 1 (SELOGIC control equation)
**S3V1** = _____

S3V1 Timer Pickup (0–999999 cycles) **S3V1PU** =_____

S3V1 Timer Dropout (0–999999 cycles) **S3V1DO** =_____

Set 3 Variable 2 (SELOGIC control equation)
**S3V2** = _____

S3V2 Timer Pickup (0–999999 cycles) **S3V2PU** =_____

S3V2 Timer Dropout (0–999999 cycles) **S3V2DO** =_____

Set 3 Variable 3 (SELOGIC control equation)
**S3V3** = _____

S3V3 Timer Pickup (0–999999 cycles) **S3V3PU** =_____

S3V3 Timer Dropout (0–999999 cycles) **S3V3DO** =_____

Set 3 Variable 4 (SELOGIC control equation)
**S3V4** = _____

S3V4 Timer Pickup (0–999999 cycles) **S3V4PU** =_____

S3V4 Timer Dropout (0–999999 cycles) **S3V4DO** =_____

Set 3 Variable 5 (SELOGIC control equation)

**S3V5** = _____

S3V5 Timer Pickup (0–999999 cycles) **S3V5PU** = _____

S3V5 Timer Dropout (0–999999 cycles) **S3V5DO** = _____

Set 3 Variable 6 (SELOGIC control equation)

**S3V6** = _____

S3V6 Timer Pickup (0–999999 cycles) **S3V6PU** = _____

S3V6 Timer Dropout (0–999999 cycles) **S3V6DO** = _____

Set 3 Variable 7 (SELOGIC control equation)

**S3V7** = _____

S3V7 Timer Pickup (0–999999 cycles) **S3V7PU** = _____

S3V7 Timer Dropout (0–999999 cycles) **S3V7DO** = _____

Set 3 Variable 8 (SELOGIC control equation)

**S3V8** = _____

S3V8 Timer Pickup (0–999999 cycles) **S3V8PU** = _____

S3V8 Timer Dropout (0–999999 cycles) **S3V8DO** = _____

Set 3 Latch Bit 1 SET Input (SELOGIC control equation)

**S3SLT1** = _____

Set 3 Latch Bit 1 RESET Input (SELOGIC control equation)

**S3RLT1** = _____

Set 3 Latch Bit 2 SET Input (SELOGIC control equation)

**S3SLT2** = _____

Set 3 Latch Bit 2 RESET Input (SELOGIC control equation)

**S3RLT2** = _____

Set 3 Latch Bit 3 SET Input (SELOGIC control equation)

**S3SLT3** = _____

Set 3 Latch Bit 3 RESET Input (SELOGIC control equation)

**S3RLT3** = _____

Set 3 Latch Bit 4 SET Input (SELOGIC control equation)

**S3SLT4** = _____

Set 3 Latch Bit 4 RESET Input (SELOGIC control equation)

**S3RLT4** = _____

Set 3 Latch Bit 5 SET Input (SELOGIC control equation)

**S3SLT5** = _____

Set 3 Latch Bit 5 RESET Input (SELOGIC control equation)

**S3RLT5** = _____

Set 3 Latch Bit 6 SET Input (SELOGIC control equation)

**S3SLT6** = _____

Set 3 Latch Bit 6 RESET Input (SELOGIC control equation)

**S3RLT6** = _____

Set 3 Latch Bit 7 SET Input (SELOGIC control equation)

**S3SLT7** = _____

Set 3 Latch Bit 7 RESET Input (SELOGIC control equation)

**S3RLT7** = _____

Set 3 Latch Bit 8 SET Input (SELOGIC control equation)

**S3SLT8** = _____

Set 3 Latch Bit 8 RESET Input (SELOGIC control equation)

**S3RLT8** = _____

## Trip Logic

**TR1** = _____

**TR2** = _____

**TR3** = _____

**TR4** = _____

**ULTR1** = _____

**ULTR2** = _____

**ULTR3** = _____

**ULTR4** = _____

## Close Logic

**52A1** = _____

**52A2** = _____

**52A3** = _____

**CL1** = _____

**CL2** = _____

**CL3** = _____

**ULCL1** = _____

**ULCL2** = _____

**ULCL3** = _____

## Event Report Triggering

**ER** = _____

Date_____

## Output Contact Logic (Standard Outputs)

**OUT101** = _____

**OUT102** = _____

**OUT103** = _____

**OUT104** = _____

**OUT105** = _____

**OUT106** = _____

**OUT107** = _____

## Output Contact Logic (Extra Interface Board 2 or 6)

**OUT201** = _____

**OUT202** = _____

**OUT203** = _____

**OUT204** = _____

**OUT205** = _____

**OUT206** = _____

**OUT207** = _____

**OUT208** = _____

**OUT209** = _____

**OUT210** = _____

**OUT211** = _____

**OUT212** = _____

## Output Contact Logic (Extra Interface Board 4)

**OUT201** = _____

**OUT202** = _____

**OUT203** = _____

**OUT204** = _____

# Global Settings (Set G Command)

## Relay Settings

| | | |
|---|---|---|
| Length of Event Report (15, 29, 60 cycles) | **LER** | =_____ |
| Length of Pre-fault in Event Report (1 to (LER-1)) | **PRE** | =_____ |
| Nominal Frequency (50, 60 Hz) | **NFREQ** | =_____ |
| Phase Rotation (ABC, ACB) | **PHROT** | =_____ |
| Phase Potential Connection (D, Y) | **DELTA_Y** | =_____ |
| Date Format (MDY, YMD) | **DATE_F** | =_____ |
| Display Update Rate (1–60 seconds) (1–60) | **SCROLD** | =_____ |
| Front Panel Time-out (0–30 minutes) | **FP_TO** | =_____ |
| Group Change Delay (0–900 seconds) | **TGR** | =_____ |

## Battery Monitor

| | | |
|---|---|---|
| DC Battery Voltage Level 1 (OFF, 20–300 Vdc) | **DC1P** | =_____ |
| DC Battery Voltage Level 2 (OFF, 20–300 Vdc) | **DC2P** | =_____ |
| DC Battery Voltage Level 3 (OFF, 20–300 Vdc) | **DC3P** | =_____ |
| DC Battery Voltage Level 4 (OFF, 20–300 Vdc) | **DC4P** | =_____ |

## Breaker 1 Monitor

BKR1 Trigger Equation (SELOGIC control equation)

**BKMON1** = _____

| | | |
|---|---|---|
| Close/Open Set Point 1 max (1–65000 operations) | **B1COP1** | =_____ |
| kA Interrupted Set Point 1 min (0.1–999.0 kA primary) | **B1KAP1** | =_____ |
| Close/Open Set Point 2 max (1–65000 operations) | **B1COP2** | =_____ |
| kA Interrupted Set Point 2 min (0.1–999.0 kA primary) | **B1KAP2** | =_____ |
| Close/Open Set Point 3 max (1–65000 operations) | **B1COP3** | =_____ |
| kA Interrupted Set Point 3 min (0.1–999.0 kA primary) | **B1KAP3** | =_____ |

## Breaker 2 Monitor

BKR2 Trigger Equation (SELOGIC control equation)

**BKMON2** = _____

| | | |
|---|---|---|
| Close/Open Set Point 1 max (1–65000 operations) | **B2COP1** | =_____ |
| kA Interrupted Set Point 1 min (0.1–999.0 kA primary) | **B2KAP1** | =_____ |
| Close/Open Set Point 2 max (1–65000 operations) | **B2COP2** | =_____ |

| | | |
|---|---|---|
| kA Interrupted Set Point 2 min (0.1–999.0 kA primary) | **B2KAP2** | =_____ |
| Close/Open Set Point 3 max (1–65000 operations) | **B2COP3** | =_____ |
| kA Interrupted Set Point 3 min (0.1–999.0 kA primary) | **B2KAP3** | =_____ |

## Breaker 3 Monitor

BKR3 Trigger Equation (SELOGIC control equation)

**BKMON3** = _____

| | | |
|---|---|---|
| Close/Open Set Point 1 max (1–65000 operations) | **B3COP1** | =_____ |
| kA Interrupted Set Point 1 min (0.1–999.0 kA primary) | **B3KAP1** | =_____ |
| Close/Open Set Point 2 max (1–65000 operations) | **B3COP2** | =_____ |
| kA Interrupted Set Point 2 min (0.1–999.0 kA primary) | **B3KAP2** | =_____ |
| Close/Open Set Point 3 max (1–65000 operations) | **B3COP3** | =_____ |
| kA Interrupted Set Point 3 min (0.1–999.0 kA primary) | **B3KAP3** | =_____ |

## Through-Fault Event Monitor

| | | |
|---|---|---|
| Enable Through-Fault Event Winding (N, 1, 2, 3) | **ETHRU** | =_____ |

NOTE: Changing setting ETHRU resets/clears through-fault event information.

Through-Fault Event Trigger (SELOGIC control equation)

**THRU** = _____

| | | |
|---|---|---|
| Through-Fault $I^2t$ Alarm Threshold (OFF, 0–4294967 $(kA)^2$ seconds) | **ISQT** | =_____ |

## Analog Input Labels

| | | |
|---|---|---|
| Rename Current Input IAW1 (1–4 characters) | **IAW1** | =_____ |
| Rename Current Input IBW1 (1–4 characters) | **IBW1** | =_____ |
| Rename Current Input ICW1 (1–4 characters) | **ICW1** | =_____ |
| Rename Current Input IAW2 (1–4 characters) | **IAW2** | =_____ |
| Rename Current Input IBW2 (1–4 characters) | **IBW2** | =_____ |
| Rename Current Input ICW2 (1–4 characters) | **ICW2** | =_____ |
| Rename Current Input IAW3 (1–4 characters) | **IAW3** | =_____ |
| Rename Current Input IBW3 (1–4 characters) | **IBW3** | =_____ |
| Rename Current Input ICW3 (1–4 characters) | **ICW3** | =_____ |
| Rename Voltage Input VAWX (1–4 characters) | **VAWX** | =_____ |
| Rename Voltage Input VBWX (1–4 characters) | **VBWX** | =_____ |
| Rename Voltage Input VCWX (1–4 characters) | **VCWX** | =_____ |

## Setting Group Selection

Select Setting Group 1 (SELOGIC control equation)

**SS1** = _____

Select Setting Group 2 (SELOGIC control equation)

**SS2** = _____

Select Setting Group 3 (SELOGIC control equation)

**SS3** = _____

Select Setting Group 4 (SELOGIC control equation)

**SS4** = _____

Select Setting Group 5 (SELOGIC control equation)

**SS5** = _____

Select Setting Group 6 (SELOGIC control equation)

**SS6** = _____

## Front Panel

Energize LEDA (SELOGIC control equation)

**LEDA** = _____

Energize LEDB (SELOGIC control equation)

**LEDB** = _____

Energize LEDC (SELOGIC control equation)

**LEDC** = _____

Show Display Point 1 (SELOGIC control equation)

**DP1** = _____

DP1 Label 1 (16 characters) (Enter NA to Null) **DP1_1** = _____

DP1 Label 0 (16 characters) (Enter NA to Null) **DP1_0** = _____

Show Display Point 2 (SELOGIC control equation)

**DP2** = _____

DP2 Label 1 (16 characters) (Enter NA to Null) **DP2_1** = _____

DP2 Label 0 (16 characters) (Enter NA to Null) **DP2_0** = _____

Show Display Point 3 (SELOGIC control equation)

**DP3** = _____

DP3 Label 1 (16 characters) (Enter NA to Null) **DP3_1** = _____

DP3 Label 0 (16 characters) (Enter NA to Null) **DP3_0** = _____

Show Display Point 4 (SELOGIC control equation)

**DP4** = _____

DP4 Label 1 (16 characters) (Enter NA to Null) **DP4_1** = _____

DP4 Label 0 (16 characters) (Enter NA to Null) **DP4_0** = _____

Show Display Point 5 (SELOGIC control equation)

**DP5** = _____

DP5 Label 1 (16 characters) (Enter NA to Null) **DP5_1** = _____

DP5 Label 0 (16 characters) (Enter NA to Null) **DP5_0** = _____

Show Display Point 6 (SELOGIC control equation)

**DP6** = _____

DP6 Label 1 (16 characters) (Enter NA to Null) **DP6_1** = _____

DP6 Label 0 (16 characters) (Enter NA to Null) **DP6_0** = _____

Show Display Point 7 (SELOGIC control equation)

**DP7** = _____

DP7 Label 1 (16 characters) (Enter NA to Null) **DP7_1** = _____

DP7 Label 0 (16 characters) (Enter NA to Null) **DP7_0** = _____

Show Display Point 8 (SELOGIC control equation)

**DP8** = _____

DP8 Label 1 (16 characters) (Enter NA to Null) **DP8_1** = _____

DP8 Label 0 (16 characters) (Enter NA to Null) **DP8_0** = _____

Show Display Point 9 (SELOGIC control equation)

**DP9** = _____

DP9 Label 1 (16 characters) (Enter NA to Null) **DP9_1** = _____

DP9 Label 0 (16 characters) (Enter NA to Null) **DP9_0** = _____

Show Display Point 10 (SELOGIC control equation)

**DP10** = _____

DP10 Label 1 (16 characters) (Enter NA to Null) **DP10_1** = _____

DP10 Label 0 (16 characters) (Enter NA to Null) **DP10_0** = _____

Show Display Point 11 (SELOGIC control equation)

**DP11** = _____

DP11 Label 1 (16 characters) (Enter NA to Null) **DP11_1** = _____

DP11 Label 0 (16 characters) (Enter NA to Null) **DP11_0** = _____

Show Display Point 12 (SELOGIC control equation)
**DP12** = _____

DP12 Label 1 (16 characters) (Enter NA to Null) **DP12_1** = _____

DP12 Label 0 (16 characters) (Enter NA to Null) **DP12_0** = _____

Show Display Point 13 (SELOGIC control equation)
**DP13** = _____

DP13 Label 1 (16 characters) (Enter NA to Null) **DP13_1** = _____

DP13 Label 0 (16 characters) (Enter NA to Null) **DP13_0** = _____

Show Display Point 14 (SELOGIC control equation)
**DP14** = _____

DP14 Label 1 (16 characters) (Enter NA to Null) **DP14_1** = _____

DP14 Label 0 (16 characters) (Enter NA to Null) **DP14_0** = _____

Show Display Point 15 (SELOGIC control equation)
**DP15** = _____

DP15 Label 1 (16 characters) (Enter NA to Null) **DP15_1** = _____

DP15 Label 0 (16 characters) (Enter NA to Null) **DP15_0** = _____

Show Display Point 16 (SELOGIC control equation)
**DP16** = _____

DP16 Label 1 (16 characters) (Enter NA to Null) **DP16_1** = _____

DP16 Label 0 (16 characters) (Enter NA to Null) **DP16_0** = _____

## Text Labels

Local Bit LB1 Name (14 characters) (Enter NA to Null) **NLB1** = _____

Clear Local Bit LB1 Label (7 characters) (Enter NA to Null) **CLB1** = _____

Set Local Bit LB1 Label (7 characters) (Enter NA to Null) **SLB1** = _____

Pulse Local Bit LB1 Label (7 characters) (Enter NA to Null) **PLB1** = _____

Local Bit LB2 Name (14 characters) (Enter NA to Null) **NLB2** = _____

Clear Local Bit LB2 Label (7 characters) (Enter NA to Null) **CLB2** = _____

Set Local Bit LB2 Label (7 characters) (Enter NA to Null) **SLB2** = _____

Pulse Local Bit LB2 Label (7 characters) (Enter NA to Null) **PLB2** = _____

Local Bit LB3 Name (14 characters) (Enter NA to Null) **NLB3** = _____

Clear Local Bit LB3 Label (7 characters) (Enter NA to Null) **CLB3** = _____

Set Local Bit LB3 Label (7 characters) (Enter NA to Null) **SLB3** = _____

Pulse Local Bit LB3 Label (7 characters) (Enter NA to Null) **PLB3** = _____

| | | |
|---|---|---|
| Local Bit LB4 Name (14 characters) (Enter NA to Null) | **NLB4** | =_____ |
| Clear Local Bit LB4 Label (7 characters) (Enter NA to Null) | **CLB4** | =_____ |
| Set Local Bit LB4 Label (7 characters) (Enter NA to Null) | **SLB4** | =_____ |
| Pulse Local Bit LB4 Label (7 characters) (Enter NA to Null) | **PLB4** | =_____ |
| Local Bit LB5 Name (14 characters) (Enter NA to Null) | **NLB5** | =_____ |
| Clear Local Bit LB5 Label (7 characters) (Enter NA to Null) | **CLB5** | =_____ |
| Set Local Bit LB5 Label (7 characters) (Enter NA to Null) | **SLB5** | =_____ |
| Pulse Local Bit LB5 Label (7 characters) (Enter NA to Null) | **PLB5** | =_____ |
| Local Bit LB6 Name (14 characters) (Enter NA to Null) | **NLB6** | =_____ |
| Clear Local Bit LB6 Label (7 characters) (Enter NA to Null) | **CLB6** | =_____ |
| Set Local Bit LB6 Label (7 characters) (Enter NA to Null) | **SLB6** | =_____ |
| Pulse Local Bit LB6 Label (7 characters) (Enter NA to Null) | **PLB6** | =_____ |
| Local Bit LB7 Name (14 characters) (Enter NA to Null) | **NLB7** | =_____ |
| Clear Local Bit LB7 Label (7 characters) (Enter NA to Null) | **CLB7** | =_____ |
| Set Local Bit LB7 Label (7 characters) (Enter NA to Null) | **SLB7** | =_____ |
| Pulse Local Bit LB7 Label (7 characters) (Enter NA to Null) | **PLB7** | =_____ |
| Local Bit LB8 Name (14 characters) (Enter NA to Null) | **NLB8** | =_____ |
| Clear Local Bit LB8 Label (7 characters) (Enter NA to Null) | **CLB8** | =_____ |
| Set Local Bit LB8 Label (7 characters) (Enter NA to Null) | **SLB8** | =_____ |
| Pulse Local Bit LB8 Label (7 characters) (Enter NA to Null) | **PLB8** | =_____ |
| Local Bit LB9 Name (14 characters) (Enter NA to Null) | **NLB9** | =_____ |
| Clear Local Bit LB9 Label (7 characters) (Enter NA to Null) | **CLB9** | =_____ |
| Set Local Bit LB9 Label (7 characters) (Enter NA to Null) | **SLB9** | =_____ |
| Pulse Local Bit LB9 Label (7 characters) (Enter NA to Null) | **PLB9** | =_____ |
| Local Bit LB10 Name (14 characters) (Enter NA to Null) | **NLB10** | =_____ |
| Clear Local Bit LB10 Label (7 characters) (Enter NA to Null) | **CLB10** | =_____ |
| Set Local Bit LB10 Label (7 characters) (Enter NA to Null) | **SLB10** | =_____ |
| Pulse Local Bit LB10 Label (7 characters) (Enter NA to Null) | **PLB10** | =_____ |
| Local Bit LB11 Name (14 characters) (Enter NA to Null) | **NLB11** | =_____ |
| Clear Local Bit LB11 Label (7 characters) (Enter NA to Null) | **CLB11** | =_____ |
| Set Local Bit LB11 Label (7 characters) (Enter NA to Null) | **SLB11** | =_____ |
| Pulse Local Bit LB11 Label (7 characters) (Enter NA to Null) | **PLB11** | =_____ |

| | | |
|---|---|---|
| Local Bit LB12 Name (14 characters) (Enter NA to Null) | **NLB12** | = _____ |
| Clear Local Bit LB12 Label (7 characters) (Enter NA to Null) | **CLB12** | = _____ |
| Set Local Bit LB12 Label (7 characters) (Enter NA to Null) | **SLB12** | = _____ |
| Pulse Local Bit LB12 Label (7 characters) (Enter NA to Null) | **PLB12** | = _____ |
| Local Bit LB13 Name (14 characters) (Enter NA to Null) | **NLB13** | = _____ |
| Clear Local Bit LB13 Label (7 characters) (Enter NA to Null) | **CLB13** | = _____ |
| Set Local Bit LB13 Label (7 characters) (Enter NA to Null) | **SLB13** | = _____ |
| Pulse Local Bit LB13 Label (7 characters) (Enter NA to Null) | **PLB13** | = _____ |
| Local Bit LB14 Name (14 characters) (Enter NA to Null) | **NLB14** | = _____ |
| Clear Local Bit LB14 Label (7 characters) (Enter NA to Null) | **CLB14** | = _____ |
| Set Local Bit LB14 Label (7 characters) (Enter NA to Null) | **SLB14** | = _____ |
| Pulse Local Bit LB14 Label (7 characters) (Enter NA to Null) | **PLB14** | = _____ |
| Local Bit LB15 Name (14 characters) (Enter NA to Null) | **NLB15** | = _____ |
| Clear Local Bit LB15 Label (7 characters) (Enter NA to Null) | **CLB15** | = _____ |
| Set Local Bit LB15 Label (7 characters) (Enter NA to Null) | **SLB15** | = _____ |
| Pulse Local Bit LB15 Label (7 characters) (Enter NA to Null) | **PLB15** | = _____ |
| Local Bit LB16 Name (14 characters) (Enter NA to Null) | **NLB16** | = _____ |
| Clear Local Bit LB16 Label (7 characters) (Enter NA to Null) | **CLB16** | = _____ |
| Set Local Bit LB16 Label (7 characters) (Enter NA to Null) | **SLB16** | = _____ |
| Pulse Local Bit LB16 Label (7 characters) (Enter NA to Null) | **PLB16** | = _____ |

# Sequential Events Recorder Settings (SET R Command)

## Trigger Conditions

Trigger SER (24 Relay Word bits per SER*n* equation, 96 total)

**SER1** = _____

**SER2** = _____

**SER3** = _____

**SER4** = _____

## Relay Word Bit Aliases

Syntax: 'Relay-Word Bit' 'Up to 15 characters'. Use NA to disable setting.

**ALIAS1** = _____

**ALIAS2** = _____

**ALIAS3** = _____

**ALIAS4** = _____

**ALIAS5** = _____

**ALIAS6** = _____

**ALIAS7** = _____

**ALIAS8** = _____

**ALIAS9** = _____

**ALIAS10** = _____

**ALIAS11** = _____

**ALIAS12** = _____

**ALIAS13** = _____

**ALIAS14** = _____

**ALIAS15** = _____

**ALIAS16** = _____

**ALIAS17** = _____

**ALIAS18** = _____

**ALIAS19** = _____

**ALIAS20** = _____

NOTE: RTSCTS setting does not appear if PROTO = LMD or DNP. PREFIX, ADDR, and SETTLE do not appear if PROTO=SEL or DNP. Only TPORT and TIDLE settings appear if PROTO = TELNET. See Appendix C: SEL Distributed Port Switch Protocol for details on LMD protocol and see Appendix G: Distributed Network Protocol (DNP3) for details on DNP protocol. To enable Telnet-to-relay communications on PORT 5 and PORT 6, the PORT 1 PROTO setting must be set to TELNET. Setting PROTO = TELNET disabled PORT 1 for EIA-485 communications.

## Port 1 (SET P 1) Rear Panel, EIA-485 Plus IRIG-B

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP, TELNET) | **PROTO** | =_____ |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | =_____ |
| LMD Address (1–99) | **ADDR** | =_____ |
| LMD Settling Time (0–30 seconds) | **SETTLE** | =_____ |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | =_____ |
| Data Bits (7, 8) | **BITS** | =_____ |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | =_____ |
| Stop Bits (1, 2) | **STOP** | =_____ |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | =_____ |
| Send auto messages to port (Y, N) | **AUTO** | =_____ |
| Enable hardware handshaking (Y, N) | **RTSCTS** | =_____ |
| Fast Operate Enable (Y, N) | **FASTOP** | =_____ |
| Telnet Port for Relay Access (1–65534) | **TPORT** | =_____ |
| Telnet Port Time-Out (1–30 minutes) | **TIDLE** | =_____ |

## Port 2 (SET P 2) Rear Panel, EIA-232 With IRIG-B

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP) | **PROTO** | =_____ |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | =_____ |
| LMD Address (1–99) | **ADDR** | =_____ |
| LMD Settling Time (0–30 seconds) | **SETTLE** | =_____ |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | =_____ |
| Data Bits (7, 8) | **BITS** | =_____ |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | =_____ |
| Stop Bits (1, 2) | **STOP** | =_____ |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | =_____ |
| Send auto messages to port (Y, N) | **AUTO** | =_____ |
| Enable hardware handshaking (Y, N) | **RTSCTS** | =_____ |
| Fast Operate Enable (Y, N) | **FASTOP** | =_____ |

## Port 3 (SET P 3) Rear Panel, EIA-232

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP) | **PROTO** | =_____ |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | =_____ |
| LMD Address (1–99) | **ADDR** | =_____ |
| LMD Settling Time (0–30 seconds) | **SETTLE** | =_____ |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | =_____ |
| Data Bits (7, 8) | **BITS** | =_____ |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | =_____ |
| Stop Bits (1, 2) | **STOP** | =_____ |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | =_____ |
| Send auto messages to port (Y, N) | **AUTO** | =_____ |
| Enable hardware handshaking (Y, N) | **RTSCTS** | =_____ |
| Fast Operate Enable (Y, N) | **FASTOP** | =_____ |

## Port 4 (SET P 4) Front Panel, EIA-232

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP) | **PROTO** | =_____ |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | =_____ |
| LMD Address (1–99) | **ADDR** | =_____ |
| LMD Settling Time (0–30 seconds) | **SETTLE** | =_____ |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | =_____ |
| Data Bits (7, 8) | **BITS** | =_____ |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | =_____ |
| Stop Bits (1, 2) | **STOP** | =_____ |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | =_____ |
| Send auto messages to port (Y, N) | **AUTO** | =_____ |
| Enable hardware handshaking (Y, N) | **RTSCTS** | =_____ |
| Fast Operate Enable (Y, N) | **FASTOP** | =_____ |

## Ethernet Port Settings (Port 5 and Port 6 Only)

| | | |
|---|---|---|
| IP Address (xxx.xxx.xxx.xxx) | **IPADDR** | = _____ |
| Subnet Mask (xxx.xxx.xxx.xxx) | **SUBNETM** | = _____ |
| Default Router (xxx.xxx.xxx.xxx) | **DEFRTR** | = _____ |
| Enable TCP Keep-Alive (Y, N) | **ETCPKA** | = _____ |

### If ETCPKA = Y

| | | |
|---|---|---|
| TCP Keep-Alive Idle Range (1–20 s) | **KAIDLE** | = _____ |
| TCP Keep-Alive Interval Range (1–20 s) | **KAINTV** | = _____ |
| TCP Keep-Alive Count Range (1–20 s) | **KACNT** | = _____ |
| Operating Mode (FIXED, FAILOVER) | **NETMODE** | = _____ |

### If NETMODE = FAILOVER

| | | |
|---|---|---|
| Failover Time-Out (OFF, 0.10–65.00 sec) | **FTIME** | = _____ |
| Enable Telnet (Y, N) | **ETELNET** | = _____ |

### If ETELNET = Y

| | | |
|---|---|---|
| Telnet Port for Card Access (1–65534) | **TPORTC** | = _____ |
| Telnet Port Time-Out (1–30 min) | **TIDLE** | = _____ |
| Enable FTP Server (Y, N) | **EFTPSERV** | = _____ |

### If EFTPSERV = Y

| | | |
|---|---|---|
| FTP Username (20 characters) | **FTPUSER** | = _____ |
| FTP Connect Banner | **FTPCBAN** | = _____ |
| FTP Idle Time-Out (5–255 min) | **FTPIDLE** | = _____ |
| Enable HTTP TCP/IP Server (Y, N) | **EHTTP** | = _____ |

### If EHTTP = Y

| | | |
|---|---|---|
| TCP/IP Port (1–65535) | **HTTPPORT** | = _____ |
| HTTP Web Server Time-Out (1–30 min) | **HTTPIDLE** | = _____ |

### If IEC 61850 is Available

| | | |
|---|---|---|
| Enable IEC 61850 Protocol (Y, N) | **E61850** | = _____ |
| Enable IEC 61850 GSE (Y, N) | **EGSE** | = _____ |

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# SEL-387E Settings Sheets Example

## Group Settings (SET Command)

### Configuration Settings

Relay Identifier (30 characters)

**RID** = XFMR1

Terminal Identifier (30 characters)

**TID** = STATION A

| | | |
|---|---|---|
| Enable Winding 1 in Differential Element (Y, N, Y1) | **E87W1** | = Y |
| Enable Winding 2 in Differential Element (Y, N, Y1) | **E87W2** | = Y |
| Enable Winding 3 in Differential Element (Y, N, Y1) | **E87W3** | = Y |
| Enable Winding 1 O/C Elements and Dmd Thresholds (Y, N) | **EOC1** | = Y |
| Enable Winding 2 O/C Elements and Dmd Thresholds (Y, N) | **EOC2** | = Y |
| Enable Winding 3 O/C Elements and Dmd Thresholds (Y, N) | **EOC3** | = Y |
| Enable Combined O/C Elements (Y, N) | **EOCC** | = N |
| Enable Volts/Hertz Protection (Y, N) | **E24** | = Y |
| Enable Undervoltage Protection (Y, N) | **E27** | = Y |
| Enable Overvoltage Protection (Y, N) | **E59** | = Y |
| Enable Frequency Protection (N, 1–6) | **E81** | = N |
| Enable SELOGIC® Control Equations Set 1 (Y, N) | **ESLS1** | = N |
| Enable SELOGIC Control Equations Set 2 (Y, N) | **ESLS2** | = N |
| Enable SELOGIC Control Equations Set 3 (Y, N) | **ESLS3** | = N |

### General Data

| | | |
|---|---|---|
| Winding 1 CT Connection (D, Y) | **W1CT** | = Y |
| Winding 2 CT Connection (D, Y) | **W2CT** | = Y |
| Winding 3 CT Connection (D, Y) | **W3CT** | = Y |
| Winding 1 CT Ratio (1–50000) *(The first value applies to a 5 A relay, the second value applies to a 1 A relay.)* | **CTR1** | = 120; 600 |
| Winding 2 CT Ratio (1–50000) *(The first value applies to a 5 A relay, the second value applies to a 1 A relay.)* | **CTR2** | = 240; 1200 |
| Winding 3 CT Ratio (1–50000) *(The first value applies to a 5 A relay, the second value applies to a 1 A relay.)* | **CTR3** | = 400; 2000 |

| | | |
|---|---|---|
| Maximum Power Transformer Capacity (OFF, 0.2–5000 MVA) | **MVA** | = 100 |
| Define Internal CT Connection Compensation (Y, N) | **ICOM** | = Y |
| Winding 1 CT Conn. Compensation (0, 1, …, 12) | **W1CTC** | = 11 |
| Winding 2 CT Conn. Compensation (0, 1, …, 12) | **W2CTC** | = 11 |
| Winding 3 CT Conn. Compensation (0, 1, …, 12) | **W3CTC** | = 0 |
| Winding 1 Line-to-Line Voltage (1–1000 kV) | **VWDG1** | = 230 |
| Winding 2 Line-to-Line Voltage (1–1000 kV) | **VWDG2** | = 138 |
| Winding 3 Line-to-Line Voltage (1–1000 kV) | **VWDG3** | = 13.8 |
| PT Ratio (1–6500) | **PTR** | = 2000 |
| Compensation Angle (0–360 degrees) | **COMPANG** | = 0 |
| Voltage-Current Winding (1, 2, 3, 12) | **VIWDG** | = 1 |
| Three-Phase Voltage Input (Y, N) | **TPVI** | = Y |

## Differential Elements

NOTE: TAP1–TAP3 are auto-set by relay if MVA setting is not OFF.

| | | |
|---|---|---|
| Winding 1 Current Tap (0.5–155.0 A secondary) (5 A)<br>(0.1–31.0 A secondary) (1 A) | **TAP1** | = 2.09<br>= 0.42 |
| Winding 2 Current Tap (0.5–155.0 A secondary) (5 A)<br>(0.1–31.0 A secondary) (1 A) | **TAP2** | = 1.74<br>= 0.35 |
| Winding 3 Current Tap (0.5–155.0 A secondary) (5 A)<br>(0.1–31.0 A secondary) (1 A) | **TAP3** | = 10.46<br>= 2.09 |
| Restrained Element Operating Current PU<br>((0.10–1.00) multiple of tap) | **O87P** | = 0.30 |
| Restraint Slope 1 Percentage (5–100%) | **SLP1** | = 25 |
| Restraint Slope 2 Percentage (OFF, 25–200%) | **SLP2** | = 50 |
| Restraint Current Slope 1 Limit ((1–20) multiple of tap) | **IRS1** | = 3 |
| Unrestrained Element Current PU ((1–20) multiple of tap) | **U87P** | = 10 |
| Second-Harmonic Blocking Percentage (OFF, 5–100%) | **PCT2** | = 15 |
| Fourth-Harmonic Blocking Percentage (OFF, 5–100%) | **PCT4** | = 15 |
| Fifth-Harmonic Blocking Percentage (OFF, 5–100%) | **PCT5** | = 35 |
| Fifth-Harmonic Alarm Threshold<br>(OFF, (0.02–3.20) multiple of tap) | **TH5P** | = OFF |
| Fifth-Harmonic Alarm TDPU (0–8000 cycles) | **TH5D** | = 30 |
| DC Ratio Blocking (Y, N) | **DCRB** | = N |

| | | |
|---|---|---|
| Harmonic Restraint (Y, N) | **HRSTR** | = Y |
| Independent Harmonic Blocking (Y, N) | **IHBL** | = N |

## Restricted Earth Fault

Enable 32I (SELOGIC control equation)

**E32I** = 0

| | | |
|---|---|---|
| Operating Quantity from W 1, W 2 (1, 2, 12) | **32IOP** | = 1 |
| Positive-Sequence Current Restraint Factor, I0/I1 (0.02–0.50) | **a0** | = 0.10 |
| Residual Current Sensitivity Threshold<br>(0.25–15.00 A secondary) (5 A)<br>(0.05–3.00 A secondary) (1 A) | **50GP** | = 0.10<br>= 0.10 |

## Winding 1 O/C Elements

### Winding 1 Phase O/C Elements

| | | |
|---|---|---|
| Phase Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P11P** | = 20.00<br>= 4.00 |
| Phase Level 1 O/C Delay (0–16000 cycles) | **50P11D** | = 5 |

50P11 Torque Control (SELOGIC control equation)

**50P11TC** = 1

| | | |
|---|---|---|
| Phase Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P12P** | = OFF<br>= OFF |

50P12 Torque Control (SELOGIC control equation)

**50P12TC** = 1

| | | |
|---|---|---|
| Phase Inst. O/C Level 3 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P13P** | = 0.50<br>= 0.10 |
| Phase Inst. O/C Level 4 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P14P** | = 4.00<br>= 0.80 |
| Phase Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51P1P** | = 4.00<br>= 0.80 |
| Phase Inv.-Time O/C Curve (U1–U5, C1–C5) | **51P1C** | = U2 |
| Phase Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05–1.00) | **51P1TD** | = 3.00 |
| Phase Inv.-Time O/C EM Reset (Y, N) | **51P1RS** | = Y |

51P1 Torque Control (SELOGIC control equation)

**51P1TC** = 1

## Winding 1 Negative-Sequence O/C Elements

NOTE: All negative-sequence element pickup settings are in terms of $3I_2$.

| | | |
|---|---|---|
| Neg.-Seq. Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50Q11P** | = OFF<br>= OFF |
| Neg.-Seq. Level 1 O/C Delay (0.5–16000 cycles) | **50Q11D** | = 5 |
| 50Q11 Torque Control (SELOGIC control equation)<br>**50Q11TC** = 1 | | |
| Neg.-Seq. Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50Q12P** | = OFF<br>= OFF |
| 50Q12 Torque Control (SELOGIC control equation)<br>**50Q12TC** = 1 | | |
| Neg.-Seq. Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51Q1P** | = 6.00<br>= 1.20 |
| Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) | **51Q1C** | = U2 |
| Neg.-Seq. Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05–1.00) | **51Q1TD** | = 3.00 |
| Neg.-Seq. Inv.-Time O/C EM Reset (Y, N) | **51Q1RS** | = Y |
| 51Q1 Torque Control (SELOGIC control equation)<br>**51Q1TC** = 1 | | |

## Winding 1 Residual O/C Elements

| | | |
|---|---|---|
| Residual Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50N11P** | = OFF<br>= OFF |
| Residual Level 1 O/C Delay (0–16000 cycles) | **50N11D** | = 5 |
| 50N11 Torque Control (SELOGIC control equation)<br>**50N11TC** = 1 | | |
| Residual Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50N12P** | = OFF<br>= OFF |
| 50N12 Torque Control (SELOGIC control equation)<br>**50N12TC** = 1 | | |
| Residual Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51N1P** | = OFF<br>= OFF |
| Residual Inv.-Time O/C Curve (U1–U5, C1–C5) | **51N1C** | = U2 |
| Residual Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05–1.00) | **51N1TD** | = 1.00 |

| | | |
|---|---|---|
| Residual Inv.-Time O/C EM Reset (Y, N) | **51N1RS** | = Y |

51N1 Torque Control (SELOGIC control equation)

**51N1TC** = 1

## Winding 1 Demand Metering

| | | |
|---|---|---|
| Demand Meter Time Constant (OFF, 5–255 min) | **DATC1** | = 15 |
| Phase Demand Meter Threshold<br>(0.5–16.0 A secondary) (5 A)<br>(0.1–3.2 A secondary) (1 A) | **PDEM1P** | = 7.00<br>= 1.40 |
| Neg.-Seq. Demand Meter Threshold<br>(0.5–16.0 A secondary) (5 A)<br>(0.1–3.2 A secondary) (1 A) | **QDEM1P** | = 1.00<br>= 0.20 |
| Residual Demand Meter Threshold<br>(0.5–16.0 A secondary) (5 A)<br>(0.1–3.2 A secondary) (1 A) | **NDEM1P** | = 1.00<br>= 0.20 |

# Winding 2 O/C Elements

## Winding 2 Phase O/C Elements

| | | |
|---|---|---|
| Phase Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P21P** | = OFF<br>= OFF |
| Phase Level 1 O/C Delay (0–16000 cycles) | **50P21D** | = 5 |

50P21 Torque Control (SELOGIC control equation)

**50P21TC** = 1

| | | |
|---|---|---|
| Phase Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P22P** | = OFF<br>= OFF |

50P22 Torque Control (SELOGIC control equation)

**50P22TC** = 1

| | | |
|---|---|---|
| Phase Inst. O/C Level 3 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P23P** | = 0.50<br>= 0.10 |
| Phase Inst. O/C Level 4 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50P24P** | = 3.50<br>= 0.70 |
| Phase Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51P2P** | = 3.50<br>= 0.70 |
| Phase Inv.-Time O/C Curve (U1–U5, C1–C5) | **51P2C** | = U2 |
| Phase Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05–1.00) | **51P2TD** | = 3.50 |
| Phase Inv.-Time O/C EM Reset (Y, N) | **51P2RS** | = Y |

51P2 Torque Control (SELOGIC control equation)

**51P2TC** = 1

## Winding 2 Negative-Sequence O/C Elements

**NOTE:** All negative-sequence element pickup settings are in terms of $3I_2$.

| | | |
|---|---|---|
| Neg.-Seq. Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50Q21P** | = OFF<br>= OFF |
| Neg.-Seq. Level 1 O/C Delay (0.5–16000 cycles) | **50Q21D** | = 5 |
| 50Q21 Torque Control (SELOGIC control equation)<br>**50Q21TC** = 1 | | |
| Neg.-Seq. Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50Q22P** | = OFF<br>= OFF |
| 50Q22 Torque Control (SELOGIC control equation)<br>**50Q22TC** = 1 | | |
| Neg.-Seq. Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51Q2P** | = 5.25<br>= 1.05 |
| Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) | **51Q2C** | = U2 |
| Neg.-Seq. Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05–1.00) | **51Q2TD** | = 3.50 |
| Neg.-Seq. Inv.-Time O/C EM Reset (Y, N) | **51Q2RS** | = Y |
| 51Q2 Torque Control (SELOGIC control equation)<br>**51Q2TC** = 1 | | |

## Winding 2 Residual O/C Elements

| | | |
|---|---|---|
| Residual Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50N21P** | = OFF<br>= OFF |
| Residual Level 1 O/C Delay (0–16000 cycles) | **50N21D** | = 5 |
| 50N21 Torque Control (SELOGIC control equation)<br>**50N21TC** = 1 | | |
| Residual Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50N22P** | = OFF<br>= OFF |
| 50N22 Torque Control (SELOGIC control equation)<br>**50N22TC** = | | |
| Residual Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51N2P** | = OFF<br>= OFF |
| Residual Inv.-Time O/C Curve (U1–U5, C1–C5) | **51N2C** | = U2 |
| Residual Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05–1.00) | **51N2TD** | = 1.00 |

Residual Inv.-Time O/C EM Reset (Y, N) **51N2RS** = Y

51N2 Torque Control (SELOGIC control equation)

**51N2TC** = 1

## Winding 2 Demand Metering

Demand Meter Time Constant (OFF, 5–255 min) **DATC2** = 15

Phase Demand Meter Threshold **PDEM2P** = 7.00
(0.5–16.0 A secondary) (5 A) = 1.40
(0.1–3.2 A secondary) (1 A)

Neg.-Seq. Demand Meter Threshold **QDEM2P** = 1.00
(0.5–16.0 A secondary) (5 A) = 0.20
(0.1–3.2 A secondary) (1 A)

Residual Demand Meter Threshold **NDEM2P** = 1.00
(0.5–16.0 A secondary) (5 A) = 0.20
(0.1–3.2 A secondary) (1 A)

# Winding 3 O/C Elements

## Winding 3 Phase O/C Elements

Phase Def.-Time O/C Level 1 PU **50P31P** = 7.00
(OFF, 0.25–100.00 A secondary) (5 A) = 1.40
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Level 1 O/C Delay (0–16000 cycles) **50P31D** = 0

50P31 Torque Control (SELOGIC control equation)

**50P31TC** = 1

Phase Inst. O/C Level 2 PU **50P32P** = OFF
(OFF, 0.25–100.00 A secondary) (5 A) = OFF
(OFF, 0.05–20.00 A secondary) (1 A)

50P32 Torque Control (SELOGIC control equation)

**50P32TC** = 1

Phase Inst. O/C Level 3 PU **50P33P** = 0.50
(OFF, 0.25–100.00 A secondary) (5 A) = 0.10
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Inst. O/C Level 4 PU **50P34P** = 4.00
(OFF, 0.25–100.00 A secondary) (5 A) = 0.80
(OFF, 0.05–20.00 A secondary) (1 A)

Phase Inv.-Time O/C PU **51P3P** = 4.00
(OFF, 0.5–16.0 A secondary) (5 A) = 0.80
(OFF, 0.1–3.2 A secondary) (1 A)

Phase Inv.-Time O/C Curve (U1–U5, C1–C5) **51P3C** = U2

Phase Inv.-Time O/C Time-Dial (US 0.5–15.0, IEC 0.05–1.00) **51P3TD** = 1.30

Phase Inv.-Time O/C EM Reset (Y, N) **51P3RS** = Y

51P3 Torque Control (SELOGIC control equation)

**51P3TC** = 1

## Winding 3 Negative-Sequence O/C Elements

NOTE: All negative-sequence element pickup settings are in terms of 3I2.

| | | |
|---|---|---|
| Neg.-Seq. Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50Q31P** | = OFF<br>= OFF |
| Neg.-Seq. Level 1 O/C Delay (0.5–16000.0 cycles) | **50Q31D** | = 5 |

50Q31 Torque Control (SELOGIC control equation)

**50Q31TC** = 1

| | | |
|---|---|---|
| Neg.-Seq. Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50Q32P** | = OFF<br>= OFF |

50Q32 Torque Control (SELOGIC control equation)

**50Q32TC** = 1

| | | |
|---|---|---|
| Neg.-Seq. Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51Q3P** | = OFF<br>= OFF |
| Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) | **51Q3C** | = U2 |
| Neg.-Seq. Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05–1.00) | **51Q3TD** | = 3.00 |
| Neg.-Seq. Inv.-Time O/C EM Reset (Y, N) | **51Q3RS** | = Y |

51Q3 Torque Control (SELOGIC control equation)

**51Q3TC** = 1

## Winding 3 Residual O/C Elements

| | | |
|---|---|---|
| Residual Def.-Time O/C Level 1 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50N31P** | = OFF<br>= OFF |
| Residual Level 1 O/C Delay (0–16000 cycles) | **50N31D** | = 5 |

50N31 Torque Control (SELOGIC control equation)

**50N31TC** = 1

| | | |
|---|---|---|
| Residual Inst. O/C Level 2 PU<br>(OFF, 0.25–100.00 A secondary) (5 A)<br>(OFF, 0.05–20.00 A secondary) (1 A) | **50N32P** | = OFF<br>= OFF |

50N32 Torque Control (SELOGIC control equation)

**50N32TC** = 1

| | | |
|---|---|---|
| Residual Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51N3P** | = OFF<br>= OFF |
| Residual Inv.-Time O/C Curve (U1–U5, C1–C5) | **51N3C** | = U2 |
| Residual Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05-1.00) | **51N3TD** | = 1.00 |

| | | |
|---|---|---|
| Residual Inv.-Time O/C EM Reset (Y, N) | **51N3RS** | = Y |

51N3 Torque Control (SELOGIC control equation)

**51N3TC** = 1

### Winding 3 Demand Metering

| | | |
|---|---|---|
| Demand Meter Time Constant (OFF, 5–255 min) | **DATC3** | = 15 |
| Phase Demand Meter Threshold<br>(0.5–16.0 A secondary) (5 A)<br>(0.1–3.2 A secondary) (1 A) | **PDEM3P** | = 7.00<br>= 1.40 |
| Neg.-Seq. Demand Meter Threshold<br>(0.5–16.0 A secondary) (5 A)<br>(0.1–3.2 A secondary) (1 A) | **QDEM3P** | = 1.00<br>= 0.20 |
| Residual Demand Meter Threshold<br>(0.5–16.0 A secondary) (5 A)<br>(0.1–3.2 A secondary) (1 A) | **NDEM3P** | = 1.00<br>= 0.20 |

## Combined O/C Elements

NOTE: The combined overcurrent elements uses a normalization factor which scales the secondary current magnitude to the larger of the two winding CT Ratios. See 51PC1 and 51NC1 Combined Overcurrent Elements on page 3.33 for details and examples of the combined overcurrent elements.

### W1-W2 Phase O/C Elements

| | | |
|---|---|---|
| W1–W2 Phase Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51PC1P** | = 4.00<br>= 0.80 |
| W1–W2 Phase Inv.-Time O/C Curve (U1–U5, C1–C5) | **51PC1C** | = U2 |
| W1–W2 Phase Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05–1.00) | **51PC1TD** | = 3.00 |
| W1–W2 Phase Inv.-Time O/C EM Reset (Y, N) | **51PC1RS** | = Y |

### W1-W2 Residual O/C Element

| | | |
|---|---|---|
| W1–W2 Residual Inv.-Time O/C PU<br>(OFF, 0.5–16.0 A secondary) (5 A)<br>(OFF, 0.1–3.2 A secondary) (1 A) | **51NC1P** | = 1.00<br>= 0.20 |
| W1–W2 Residual Inv.-Time O/C Curve (U1–U5, C1–C5) | **51NC1C** | = U2 |
| W1–W2 Residual Inv.-Time O/C Time-Dial<br>(US 0.5–15.0, IEC 0.05-1.00) | **51NC1TD** | = 3.00 |
| W1–W2 Residual Inv.-Time O/C EM Reset (Y, N) | **51NC1RS** | = Y |

## 24 Elements

| | | |
|---|---|---|
| Protected Winding L-L Voltage (0.20–800.00 kV primary) | **VNOM** | = 230.00 |
| Transformer Winding Connection (D, Y) | **24WDG** | = Y |

| | | |
|---|---|---|
| Level 1 Volts/Hertz Pickup (100–200%) | **24D1P** | = 105 |
| Level 1 Time Delay (0.04–400.00 seconds) | **24D1D** | = 1.00 |
| Level 2 Composite Curve Shape (OFF, DD, ID, I, U) | **24CCS** | = ID |
| Level 2 Inv.-Time Pickup (100–200%) | **24IP** | = 105 |
| Level 2 Inv.-Time Curve (0.5, 1.0, 2.0) | **24IC** | = 2.0 |
| Level 2 Inv.-Time Factor (0.1–10.0 seconds) | **24ITD** | = 0.1 |
| Level 2 Pickup One (100–200%) | **24D2P1** | = 175 |
| Level 2 Time Delay One (0.04–400.00 seconds) | **24D2D1** | = 3.00 |
| Level 2 Pickup Two (101–200%) | **24D2P2** | = 176 |
| Level 2 Time Delay Two (0.04–400.00 seconds) | **24D2D2** | = 3.00 |
| Level 2 Reset Time (0.00–400.00 seconds) | **24CR** | = 240.00 |

24 Element Torque-Control (SELOGIC control equation)

**24TC** = 1

## 27 Elements

| | | |
|---|---|---|
| Level 1 Phase U/V PU (OFF, 0.1–300.0 V secondary) | **27P1P** | = 20.0 |
| Level 2 Phase U/V PU (OFF, 0.1–300.0 V secondary) | **27P2P** | = 0.0 |
| Level 1 Phase-to-Phase U/V PU (OFF, 0.1–520.0 V secondary) | **27PP1** | = 35.0 |
| Level 2 Phase-to-Phase U/V PU (OFF, 0.1–520.0 V secondary) | **27PP2** | = 0.0 |
| Pos.-Seq. U/V PU (OFF, 0.1–100.0 V secondary) | **27V1P** | = 0.0 |

## 59 Elements

| | | |
|---|---|---|
| Level 1 Phase O/V PU (OFF, 0.0–300.0 V secondary) | **59P1P** | = 74.0 |
| Level 2 Phase O/V PU (OFF, 0.0–300.0 V secondary) | **59P2P** | = OFF |
| Level 1 Residual O/V PU (OFF, 0.0–300.0 V secondary) | **59G1P** | = 20.0 |
| Level 2 Residual O/V PU (OFF, 0.0–300.0 V secondary) | **59G2P** | = OFF |
| Neg.-Seq. U/V PU (OFF, 0.0–100.0 V secondary) | **59QP** | = OFF |
| Level 1 Phase-to-Phase O/V PU (OFF, 0.0–520.0 V secondary) | **59PP1** | = 128.0 |
| Level 2 Phase-to-Phase O/V PU (OFF, 0.0–520.0 V secondary) | **59PP2** | = OFF |
| Pos.-Seq.(V1) O/V PU (OFF, 0.0–100.0 V secondary) | **59V1P** | = OFF |

## 81 Elements

| | | |
|---|---|---|
| Undervoltage Block (20.0–150.0 V secondary) | **27B81P** | = 40.00 |
| Level 1 Pickup (OFF, 40.10–65.00 Hz) | **81D1P** | = OFF |

| | | |
|---|---|---|
| Level 1 Time Delay (0.04–300.00 seconds) | **81D1D** | = 300.00 |
| Level 2 Pickup (OFF, 40.10–65.00 Hz) | **81D2P** | = OFF |
| Level 2 Time Delay (0.04–300.00 seconds) | **81D2D** | = 300.00 |
| Level 3 Pickup (OFF, 40.10–65.00 Hz) | **81D3P** | = OFF |
| Level 3 Time Delay (0.04–300.00 seconds) | **81D3D** | = 300.00 |
| Level 4 Pickup (OFF, 40.10–65.00 Hz) | **81D4P** | = OFF |
| Level 4 Time Delay (0.04–300.00 seconds) | **81D4D** | = 300.00 |
| Level 5 Pickup (OFF, 40.10–65.00 Hz) | **81D5P** | = OFF |
| Level 5 Time Delay (0.04–300.00 seconds) | **81D5D** | = 300.00 |
| Level 6 Pickup (OFF, 40.10–65.00 Hz) | **81D6P** | = OFF |
| Level 6 Time Delay (0.04–300.00 seconds) | **81D6D** | = 300.00 |

## Miscellaneous Timers

| | | |
|---|---|---|
| Minimum Trip Duration Time Delay (4–8000 cycles) | **TDURD** | = 9 |
| Close Failure Logic Time Delay (OFF, 0–8000 cycles) | **CFD** | = 60 |

## SELogic Control Equations Set 1

Set 1 Variable 1 (SELogic control equation)

**S1V1** = 0

| | | |
|---|---|---|
| S1V1 Timer Pickup (0–999999 cycles) | **S1V1PU** | = 0 |
| S1V1 Timer Dropout (0–999999 cycles) | **S1V1DO** | = 0 |

Set 1 Variable 2 (SELogic control equation)

**S1V2** = 0

| | | |
|---|---|---|
| S1V2 Timer Pickup (0–999999 cycles) | **S1V2PU** | = 0 |
| S1V2 Timer Dropout (0–999999 cycles) | **S1V2DO** | = 0 |

Set 1 Variable 3 (SELogic control equation)

**S1V3** = 0

| | | |
|---|---|---|
| S1V3 Timer Pickup (0–999999 cycles) | **S1V3PU** | = 0 |
| S1V3 Timer Dropout (0–999999 cycles) | **S1V3DO** | = 0 |

Set 1 Variable 4 (SELogic control equation)

**S1V4** = 0

| | | |
|---|---|---|
| S1V4 Timer Pickup (0–999999 cycles) | **S1V4PU** | = 0 |
| S1V4 Timer Dropout (0–999999 cycles) | **S1V4DO** | = 0 |

Set 1 Latch Bit 1 SET Input (SELOGIC control equation)

**S1SLT1** = 0 _____

Set 1 Latch Bit 1 RESET Input (SELOGIC control equation)

**S1RLT1** = 0 _____

Set 1 Latch Bit 2 SET Input (SELOGIC control equation)

**S1SLT2** = 0 _____

Set 1 Latch Bit 2 RESET Input (SELOGIC control equation)

**S1RLT2** = 0 _____

Set 1 Latch Bit 3 SET Input (SELOGIC control equation)

**S1SLT3** = 0 _____

Set 1 Latch Bit 3 RESET Input (SELOGIC control equation)

**S1RLT3** = 0 _____

Set 1 Latch Bit 4 SET Input (SELOGIC control equation)

**S1SLT4** = 0 _____

Set 1 Latch Bit 4 RESET Input (SELOGIC control equation)

**S1RLT4** = 0 _____

## SELOGIC Control Equations Set 2

Set 2 Variable 1 (SELOGIC control equation)

**S2V1** = 0 _____

S2V1 Timer Pickup (0–999999 cycles) **S2V1PU** = 0 _____

S2V1 Timer Dropout (0–999999 cycles) **S2V1DO** = 0 _____

Set 2 Variable 2 (SELOGIC control equation)

**S2V2** = 0 _____

S2V2 Timer Pickup (0–999999 cycles) **S2V2PU** = 0 _____

S2V2 Timer Dropout (0–999999 cycles) **S2V2DO** = 0 _____

Set 2 Variable 3 (SELOGIC control equation)

**S2V3** = 0 _____

S2V3 Timer Pickup (0–999999 cycles) **S2V3PU** = 0 _____

S2V3 Timer Dropout (0–999999 cycles) **S2V3DO** = 0 _____

Set 2 Variable 4 (SELOGIC control equation)

**S2V4** = 0 _____

S2V4 Timer Pickup (0–999999 cycles) **S2V4PU** = 0 _____

S2V4 Timer Dropout (0–999999 cycles) **S2V4DO** = 0 _____

Set 2 Latch Bit 1 SET Input (SELOGIC control equation)
**S2SLT1** = 0

Set 2 Latch Bit 1 RESET Input (SELOGIC control equation)
**S2RLT1** = 0

Set 2 Latch Bit 2 SET Input (SELOGIC control equation)
**S2SLT2** = 0

Set 2 Latch Bit 2 RESET Input (SELOGIC control equation)
**S2RLT2** = 0

Set 2 Latch Bit 3 SET Input (SELOGIC control equation)
**S2SLT3** = 0

Set 2 Latch Bit 3 RESET Input (SELOGIC control equation)
**S2RLT3** = 0

Set 2 Latch Bit 4 SET Input (SELOGIC control equation)
**S2SLT4** = 0

Set 2 Latch Bit 4 RESET Input (SELOGIC control equation)
**S2RLT4** = 0

## SELOGIC Control Equation Set 3

Set 3 Variable 1 (SELOGIC control equation)
**S3V1** = 0

S3V1 Timer Pickup (0–999999 cycles) **S3V1PU** = 0

S3V1 Timer Dropout (0–999999 cycles) **S3V1DO** = 0

Set 3 Variable 2 (SELOGIC control equation)
**S3V2** = 0

S3V2 Timer Pickup (0–999999 cycles) **S3V2PU** = 0

S3V2 Timer Dropout (0–999999 cycles) **S3V2DO** = 0

Set 3 Variable 3 (SELOGIC control equation)
**S3V3** =0

S3V3 Timer Pickup (0–999999 cycles) **S3V3PU** = 0

S3V3 Timer Dropout (0–999999 cycles) **S3V3DO** = 0

Set 3 Variable 4 (SELOGIC control equation)
**S3V4** = 0

S3V4 Timer Pickup (0–999999 cycles) **S3V4PU** = 0

S3V4 Timer Dropout (0–999999 cycles) **S3V4DO** = 0

Set 3 Variable 5 (SELOGIC control equation)
**S3V5** = 0

S3V5 Timer Pickup (0–999999 cycles) **S3V5PU** = 0

S3V5 Timer Dropout (0–999999 cycles) **S3V5DO** = 0

Set 3 Variable 6 (SELOGIC control equation)
**S3V6** = 0

S3V6 Timer Pickup (0–999999 cycles) **S3V6PU** = 0

S3V6 Timer Dropout (0–999999 cycles) **S3V6DO** = 0

Set 3 Variable 7 (SELOGIC control equation)
**S3V7** = 0

S3V7 Timer Pickup (0–999999 cycles) **S3V7PU** = 0

S3V7 Timer Dropout (0–999999 cycles) **S3V7DO** = 0

Set 3 Variable 8 (SELOGIC control equation)
**S3V8** = 0

S3V8 Timer Pickup (0–999999 cycles) **S3V8PU** = 0

S3V8 Timer Dropout (0–999999 cycles) **S3V8DO** = 0

Set 3 Latch Bit 1 SET Input (SELOGIC control equation)
**S3SLT1** = 0

Set 3 Latch Bit 1 RESET Input (SELOGIC control equation)
**S3RLT1** = 0

Set 3 Latch Bit 2 SET Input (SELOGIC control equation)
**S3SLT2** = 0

Set 3 Latch Bit 2 RESET Input (SELOGIC control equation)
**S3RLT2** = 0

Set 3 Latch Bit 3 SET Input (SELOGIC control equation)
**S3SLT3** = 0

Set 3 Latch Bit 3 RESET Input (SELOGIC control equation)
**S3RLT3** = 0

Set 3 Latch Bit 4 SET Input (SELOGIC control equation)
**S3SLT4** = 0

Set 3 Latch Bit 4 RESET Input (SELOGIC control equation)
**S3RLT4** = 0

Set 3 Latch Bit 5 SET Input (SELOGIC control equation)
**S3SLT5** = 0

Set 3 Latch Bit 5 RESET Input (SELOGIC control equation)
**S3RLT5** = 0

Set 3 Latch Bit 6 SET Input (SELOGIC control equation)

**S3SLT6** = 0

Set 3 Latch Bit 6 RESET Input (SELOGIC control equation)

**S3RLT6** = 0

Set 3 Latch Bit 7 SET Input (SELOGIC control equation)

**S3SLT7** = 0

Set 3 Latch Bit 7 RESET Input (SELOGIC control equation)

**S3RLT7** = 0

Set 3 Latch Bit 8 SET Input (SELOGIC control equation)

**S3SLT8** = 0

Set 3 Latch Bit 8 RESET Input (SELOGIC control equation)

**S3RLT8** = 0

## Trip Logic

**TR1** = 50P11T+51P15+51Q1T+OC1

**TR2** = 51P2T+51Q2T+OC2

**TR3** = 50P31+51Q3T+OC3

**TR4** = 87R+87U+24C2T

**ULTR1** = !50P13

**ULTR2** = !50P23

**ULTR3** = !50P33

**ULTR4** = !(50P13+50P23+50P33)

## Close Logic

**52A1** = IN101

**52A2** = IN102

**52A3** = IN103

**CL1** = CC1+/IN104

**CL2** = CC2+/IN105

**CL3** = CC3+/IN106

**ULCL1** = TRIP1+TRIP4

**ULCL2** = TRIP2+TRIP4

**ULCL3** = TRIP3+TRIP4

## Event Report Triggering

**ER** = /50P11+/51P1+/51Q1+/51P2+/51Q2+/51P3

## Output Contact Logic (Standard Outputs)

**OUT101** = TRIP1
**OUT102** = TRIP2
**OUT103** = TRIP3
**OUT104** = TRIP4
**OUT105** = CLA1
**OUT106** = CLS2
**OUT107** = CLS3

## Output Contact Logic (Extra Interface Board 2 or 6)

**OUT201** = 0
**OUT202** = 0
**OUT203** = 0
**OUT204** = 0
**OUT205** = 0
**OUT206** = 0
**OUT207** = 0
**OUT208** = 0
**OUT209** = 0
**OUT210** = 0
**OUT211** = 0
**OUT212** = 0

## Output Contact Logic (Extra Interface Board 4)

**OUT201** = 0
**OUT202** = 0
**OUT203** = 0
**OUT204** = 0

# Global Settings (Set G Command)

## Relay Settings

| | | |
|---|---|---|
| Length of Event Report (15, 29, 60 cycles) | **LER** | = 15 |
| Length of Pre-fault in Event Report (1 to (LER-1)) | **PRE** | = 4 |
| Nominal Frequency (50, 60 Hz) | **NFREQ** | = 60 or 50 |
| Phase Rotation (ABC, ACB) | **PHROT** | = ABC or ACB |
| Phase Potential Connection (D, Y) | **DELTA_Y** | = Y |
| Date Format (MDY, YMD) | **DATE_F** | = MDY |
| Display Update Rate (1–60 seconds) (1–60) | **SCROLD** | = 2 |
| Front Panel Time-out (0–30 minutes) | **FP_TO** | = 15 |
| Group Change Delay (0–900 seconds) | **TGR** | = 3 |

## Battery Monitor

| | | |
|---|---|---|
| DC Battery Voltage Level 1 (OFF, 20–300 Vdc) | **DC1P** | = OFF |
| DC Battery Voltage Level 2 (OFF, 20–300 Vdc) | **DC2P** | = OFF |
| DC Battery Voltage Level 3 (OFF, 20–300 Vdc) | **DC3P** | = OFF |
| DC Battery Voltage Level 4 (OFF, 20–300 Vdc) | **DC4P** | = OFF |

## Breaker 1 Monitor

BKR1 Trigger Equation (SELOGIC control equation)

**BKMON1** = TRIP1 + TRIP4

| | | |
|---|---|---|
| Close/Open Set Point 1 max (1–65000 operations) | **B1COP1** | = 10000 |
| kA Interrupted Set Point 1 min (0.1–999.0 kA primary) | **B1KAP1** | = 1.2 |
| Close/Open Set Point 2 max (1–65000 operations) | **B1COP2** | = 150 |
| kA Interrupted Set Point 2 min (0.1–999.0 kA primary) | **B1KAP2** | = 8.0 |
| Close/Open Set Point 3 max (1–65000 operations) | **B1COP3** | = 12 |
| kA Interrupted Set Point 3 min (0.1–999.0 kA primary) | **B1KAP3** | = 20.0 |

## Breaker 2 Monitor

BKR2 Trigger Equation (SELOGIC control equation)

**BKMON2** = TRIP2 + TRIP4

| | | |
|---|---|---|
| Close/Open Set Point 1 max (1–65000 operations) | **B2COP1** | = 10000 |
| kA Interrupted Set Point 1 min (0.1–999.0 kA primary) | **B2KAP1** | = 1.2 |
| Close/Open Set Point 2 max (1–65000 operations) | **B2COP2** | = 150 |

| | | |
|---|---|---|
| kA Interrupted Set Point 2 min (0.1–999.0 kA primary) | **B2KAP2** | = 8.0 |
| Close/Open Set Point 3 max (1–65000 operations) | **B2COP3** | = 12 |
| kA Interrupted Set Point 3 min (0.1–999.0 kA primary) | **B2KAP3** | = 20.0 |

## Breaker 3 Monitor

BKR3 Trigger Equation (SELOGIC control equation)

**BKMON3** = TRIP3 + TRIP4

| | | |
|---|---|---|
| Close/Open Set Point 1 max (1–65000 operations) | **B3COP1** | = 10000 |
| kA Interrupted Set Point 1 min (0.1–999.0 kA primary) | **B3KAP1** | = 1.2 |
| Close/Open Set Point 2 max (1–65000 operations) | **B3COP2** | = 150 |
| kA Interrupted Set Point 2 min (0.1–999.0 kA primary) | **B3KAP2** | = 8.0 |
| Close/Open Set Point 3 max (1–65000 operations) | **B3COP3** | = 12 |
| kA Interrupted Set Point 3 min (0.1–999.0 kA primary) | **B3KAP3** | = 20.0 |

## Through-Fault Event Monitor

| | | |
|---|---|---|
| Enable Through-Fault Event Winding (N, 1, 2, 3) | **ETHRU** | = N |

NOTE: Changing setting ETHRU resets/clears through-fault event information.

Through-Fault Event Trigger (SELOGIC control equation)

**THRU** = 0

| | | |
|---|---|---|
| Through-Fault $I^2t$ Alarm Threshold (OFF, 0–4294967 $(kA)^2$ seconds) | **ISQT** | = OFF |

## Analog Input Labels

| | | |
|---|---|---|
| Rename Current Input IAW1 (1–4 characters) | **IAW1** | = IAW1 |
| Rename Current Input IBW1 (1–4 characters) | **IBW1** | = IBW1 |
| Rename Current Input ICW1 (1–4 characters) | **ICW1** | = ICW1 |
| Rename Current Input IAW2 (1–4 characters) | **IAW2** | = IAW2 |
| Rename Current Input IBW2 (1–4 characters) | **IBW2** | = IBW2 |
| Rename Current Input ICW2 (1–4 characters) | **ICW2** | = ICW2 |
| Rename Current Input IAW3 (1–4 characters) | **IAW3** | = IAW3 |
| Rename Current Input IBW3 (1–4 characters) | **IBW3** | = IBW3 |
| Rename Current Input ICW3 (1–4 characters) | **ICW3** | = ICW3 |
| Rename Voltage Input VAWX (1–4 characters) | **VAWX** | = VAWX |
| Rename Voltage Input VBWX (1–4 characters) | **VBWX** | = VBWX |
| Rename Voltage Input VCWX (1–4 characters) | **VCWX** | = VCWX |

## Setting Group Selection

Select Setting Group 1 (SELOGIC control equation)

**SS1** = 0

Select Setting Group 2 (SELOGIC control equation)

**SS2** = 0

Select Setting Group 3 (SELOGIC control equation)

**SS3** = 0

Select Setting Group 4 (SELOGIC control equation)

**SS4** = 0

Select Setting Group 5 (SELOGIC control equation)

**SS5** = 0

Select Setting Group 6 (SELOGIC control equation)

**SS6** = 0

## Front Panel

Energize LEDA (SELOGIC control equation)

**LEDA** = OCA + 87E1

Energize LEDB (SELOGIC control equation)

**LEDB** = OCB + 87E2

Energize LEDC (SELOGIC control equation)

**LEDC** = OCC + 87E3

Show Display Point 1 (SELOGIC control equation)

**DP1** = IN101

DP1 Label 1 (16 characters) (Enter NA to Null) **DP1_1** = BREAKER 1 CLOSED

DP1 Label 0 (16 characters) (Enter NA to Null) **DP1_0** = BREAKER 1 OPEN

Show Display Point 2 (SELOGIC control equation)

**DP2** = IN102

DP2 Label 1 (16 characters) (Enter NA to Null) **DP2_1** = BREAKER 2 CLOSED

DP2 Label 0 (16 characters) (Enter NA to Null) **DP2_0** = BREAKER 2 OPEN

Show Display Point 3 (SELOGIC control equation)

**DP3** = IN103

DP3 Label 1 (16 characters) (Enter NA to Null) **DP3_1** = BREAKER 3 CLOSED

DP3 Label 0 (16 characters) (Enter NA to Null) **DP3_0** = BREAKER 3 OPEN

Show Display Point 4 (SELOGIC control equation)

**DP4** = 0 _____

DP4 Label 1 (16 characters) (Enter NA to Null) **DP4_1** = _____

DP4 Label 0 (16 characters) (Enter NA to Null) **DP4_0** = _____

Show Display Point 5 (SELOGIC control equation)

**DP5** = 0 _____

DP5 Label 1 (16 characters) (Enter NA to Null) **DP5_1** = _____

DP5 Label 0 (16 characters) (Enter NA to Null) **DP5_0** = _____

Show Display Point 6 (SELOGIC control equation)

**DP6** = 0 _____

DP6 Label 1 (16 characters) (Enter NA to Null) **DP6_1** = _____

DP6 Label 0 (16 characters) (Enter NA to Null) **DP6_0** = _____

Show Display Point 7 (SELOGIC control equation)

**DP7** = 0 _____

DP7 Label 1 (16 characters) (Enter NA to Null) **DP7_1** = _____

DP7 Label 0 (16 characters) (Enter NA to Null) **DP7_0** = _____

Show Display Point 8 (SELOGIC control equation)

**DP8** = 0 _____

DP8 Label 1 (16 characters) (Enter NA to Null) **DP8_1** = _____

DP8 Label 0 (16 characters) (Enter NA to Null) **DP8_0** = _____

Show Display Point 9 (SELOGIC control equation)

**DP9** = 0 _____

DP9 Label 1 (16 characters) (Enter NA to Null) **DP9_1** = _____

DP9 Label 0 (16 characters) (Enter NA to Null) **DP9_0** = _____

Show Display Point 10 (SELOGIC control equation)

**DP10** = 0 _____

DP10 Label 1 (16 characters) (Enter NA to Null) **DP10_1** = _____

DP10 Label 0 (16 characters) (Enter NA to Null) **DP10_0** = _____

Show Display Point 11 (SELOGIC control equation)

**DP11** = 0 _____

DP11 Label 1 (16 characters) (Enter NA to Null) **DP11_1** = _____

DP11 Label 0 (16 characters) (Enter NA to Null) **DP11_0** = _____

Show Display Point 12 (SELOGIC control equation)
**DP12** = 0 _____

DP12 Label 1 (16 characters) (Enter NA to Null) **DP12_1** = _____

DP12 Label 0 (16 characters) (Enter NA to Null) **DP12_0** = _____

Show Display Point 13 (SELOGIC control equation)
**DP13** = 0 _____

DP13 Label 1 (16 characters) (Enter NA to Null) **DP13_1** = _____

DP13 Label 0 (16 characters) (Enter NA to Null) **DP13_0** = _____

Show Display Point 14 (SELOGIC control equation)
**DP14** = 0 _____

DP14 Label 1 (16 characters) (Enter NA to Null) **DP14_1** = _____

DP14 Label 0 (16 characters) (Enter NA to Null) **DP14_0** = _____

Show Display Point 15 (SELOGIC control equation)
**DP15** = 0 _____

DP15 Label 1 (16 characters) (Enter NA to Null) **DP15_1** = _____

DP15 Label 0 (16 characters) (Enter NA to Null) **DP15_0** = _____

Show Display Point 16 (SELOGIC control equation)
**DP16** = 0 _____

DP16 Label 1 (16 characters) (Enter NA to Null) **DP16_1** = _____

DP16 Label 0 (16 characters) (Enter NA to Null) **DP16_0** = _____

## Text Labels

Local Bit LB1 Name (14 characters) (Enter NA to Null) **NLB1** = _____

Clear Local Bit LB1 Label (7 characters) (Enter NA to Null) **CLB1** = _____

Set Local Bit LB1 Label (7 characters) (Enter NA to Null) **SLB1** = _____

Pulse Local Bit LB1 Label (7 characters) (Enter NA to Null) **PLB1** = _____

Local Bit LB2 Name (14 characters) (Enter NA to Null) **NLB2** = _____

Clear Local Bit LB2 Label (7 characters) (Enter NA to Null) **CLB2** = _____

Set Local Bit LB2 Label (7 characters) (Enter NA to Null) **SLB2** = _____

Pulse Local Bit LB2 Label (7 characters) (Enter NA to Null) **PLB2** = _____

Local Bit LB3 Name (14 characters) (Enter NA to Null) **NLB3** = MANUAL TRIP 1

Clear Local Bit LB3 Label (7 characters) (Enter NA to Null) **CLB3** = RETURN

Set Local Bit LB3 Label (7 characters) (Enter NA to Null) **SLB3** = _____

Pulse Local Bit LB3 Label (7 characters) (Enter NA to Null) **PLB3** = TRIP

| | | |
|---|---|---|
| Local Bit LB4 Name (14 characters) (Enter NA to Null) | **NLB4** | = MANUAL CLOSE 1 |
| Clear Local Bit LB4 Label (7 characters) (Enter NA to Null) | **CLB4** | = RETURN |
| Set Local Bit LB4 Label (7 characters) (Enter NA to Null) | **SLB4** | = |
| Pulse Local Bit LB4 Label (7 characters) (Enter NA to Null) | **PLB4** | = CLOSE |
| Local Bit LB5 Name (14 characters) (Enter NA to Null) | **NLB5** | = |
| Clear Local Bit LB5 Label (7 characters) (Enter NA to Null) | **CLB5** | = |
| Set Local Bit LB5 Label (7 characters) (Enter NA to Null) | **SLB5** | = |
| Pulse Local Bit LB5 Label (7 characters) (Enter NA to Null) | **PLB5** | = |
| Local Bit LB6 Name (14 characters) (Enter NA to Null) | **NLB6** | = |
| Clear Local Bit LB6 Label (7 characters) (Enter NA to Null) | **CLB6** | = |
| Set Local Bit LB6 Label (7 characters) (Enter NA to Null) | **SLB6** | = |
| Pulse Local Bit LB6 Label (7 characters) (Enter NA to Null) | **PLB6** | = |
| Local Bit LB7 Name (14 characters) (Enter NA to Null) | **NLB7** | = |
| Clear Local Bit LB7 Label (7 characters) (Enter NA to Null) | **CLB7** | = |
| Set Local Bit LB7 Label (7 characters) (Enter NA to Null) | **SLB7** | = |
| Pulse Local Bit LB7 Label (7 characters) (Enter NA to Null) | **PLB7** | = |
| Local Bit LB8 Name (14 characters) (Enter NA to Null) | **NLB8** | = |
| Clear Local Bit LB8 Label (7 characters) (Enter NA to Null) | **CLB8** | = |
| Set Local Bit LB8 Label (7 characters) (Enter NA to Null) | **SLB8** | = |
| Pulse Local Bit LB8 Label (7 characters) (Enter NA to Null) | **PLB8** | = |
| Local Bit LB9 Name (14 characters) (Enter NA to Null) | **NLB9** | = |
| Clear Local Bit LB9 Label (7 characters) (Enter NA to Null) | **CLB9** | = |
| Set Local Bit LB9 Label (7 characters) (Enter NA to Null) | **SLB9** | = |
| Pulse Local Bit LB9 Label (7 characters) (Enter NA to Null) | **PLB9** | = |
| Local Bit LB10 Name (14 characters) (Enter NA to Null) | **NLB10** | = |
| Clear Local Bit LB10 Label (7 characters) (Enter NA to Null) | **CLB10** | = |
| Set Local Bit LB10 Label (7 characters) (Enter NA to Null) | **SLB10** | = |
| Pulse Local Bit LB10 Label (7 characters) (Enter NA to Null) | **PLB10** | = |
| Local Bit LB11 Name (14 characters) (Enter NA to Null) | **NLB11** | = |
| Clear Local Bit LB11 Label (7 characters) (Enter NA to Null) | **CLB11** | = |
| Set Local Bit LB11 Label (7 characters) (Enter NA to Null) | **SLB11** | = |
| Pulse Local Bit LB11 Label (7 characters) (Enter NA to Null) | **PLB11** | = |

| | | |
|---|---|---|
| Local Bit LB12 Name (14 characters) (Enter NA to Null) | **NLB12** | = _____ |
| Clear Local Bit LB12 Label (7 characters) (Enter NA to Null) | **CLB12** | = _____ |
| Set Local Bit LB12 Label (7 characters) (Enter NA to Null) | **SLB12** | = _____ |
| Pulse Local Bit LB12 Label (7 characters) (Enter NA to Null) | **PLB12** | = _____ |
| Local Bit LB13 Name (14 characters) (Enter NA to Null) | **NLB13** | = _____ |
| Clear Local Bit LB13 Label (7 characters) (Enter NA to Null) | **CLB13** | = _____ |
| Set Local Bit LB13 Label (7 characters) (Enter NA to Null) | **SLB13** | = _____ |
| Pulse Local Bit LB13 Label (7 characters) (Enter NA to Null) | **PLB13** | = _____ |
| Local Bit LB14 Name (14 characters) (Enter NA to Null) | **NLB14** | = _____ |
| Clear Local Bit LB14 Label (7 characters) (Enter NA to Null) | **CLB14** | = _____ |
| Set Local Bit LB14 Label (7 characters) (Enter NA to Null) | **SLB14** | = _____ |
| Pulse Local Bit LB14 Label (7 characters) (Enter NA to Null) | **PLB14** | = _____ |
| Local Bit LB15 Name (14 characters) (Enter NA to Null) | **NLB15** | = _____ |
| Clear Local Bit LB15 Label (7 characters) (Enter NA to Null) | **CLB15** | = _____ |
| Set Local Bit LB15 Label (7 characters) (Enter NA to Null) | **SLB15** | = _____ |
| Pulse Local Bit LB15 Label (7 characters) (Enter NA to Null) | **PLB15** | = _____ |
| Local Bit LB16 Name (14 characters) (Enter NA to Null) | **NLB16** | = _____ |
| Clear Local Bit LB16 Label (7 characters) (Enter NA to Null) | **CLB16** | = _____ |
| Set Local Bit LB16 Label (7 characters) (Enter NA to Null) | **SLB16** | = _____ |
| Pulse Local Bit LB16 Label (7 characters) (Enter NA to Null) | **PLB16** | = _____ |

# Sequential Events Recorder Settings (SET R Command)

## Trigger Conditions

Trigger SER (24 Relay Word bits per SER*n* equation, 96 total)

**SER1** = IN101 IN102 IN103 IN104 IN105 IN106

**SER2** = OUT101 OUT102 OUT103 OUT104 OUT105 OUT106 OUT107

**SER3** = 0

**SER4** = 0

## Relay Word Bit Aliases

Syntax: 'Relay-Word Bit' 'Up to 15 characters'. Use NA to disable setting.

**ALIAS1** = NA

**ALIAS2** = NA

**ALIAS3** = NA

**ALIAS4** = NA

**ALIAS5** = NA

**ALIAS6** = NA

**ALIAS7** = NA

**ALIAS8** = NA

**ALIAS9** = NA

**ALIAS10** = NA

**ALIAS11** = NA

**ALIAS12** = NA

**ALIAS13** = NA

**ALIAS14** = NA

**ALIAS15** = NA

**ALIAS16** = NA

**ALIAS17** = NA

**ALIAS18** = NA

**ALIAS19** = NA

**ALIAS20** = NA

NOTE: RTSCTS setting does not appear if PROTO=LMD or DNP. PREFIX, ADDR, and SETTLE do not appear if PROTO=SEL or DNP. Only TPORT and TIDLE settings appear if PROTO=TELNET. See Appendix C: SEL Distributed Port Switch Protocol for details on LMD protocol and see Appendix G: Distributed Network Protocol (DNP3) for details on DNP protocol. To enable Telnet-to-relay communications on PORT 5 and PORT 6, the PORT 1 PROTO setting must be set to TELNET. Setting PROTO = TELNET disabled PORT 1 for EIA-485 communications.

## Port 1 (SET P 1) Rear Panel, EIA-485 Plus IRIG-B

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP, TELNET) | **PROTO** | = SEL |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | = |
| LMD Address (1–99) | **ADDR** | = |
| LMD Settling Time (0–30 seconds) | **SETTLE** | = |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | = 2400 |
| Data Bits (7, 8) | **BITS** | = 8 |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | = N |
| Stop Bits (1, 2) | **STOP** | = 1 |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | = 5 |
| Send auto messages to port (Y, N) | **AUTO** | = N |
| Enable hardware handshaking (Y, N) | **RTSCTS** | = N |
| Fast Operate Enable (Y, N) | **FASTOP** | = N |
| Telnet Port for Relay Access (1–65534) | **TPORT** | = |
| Telnet Port Time-Out (1–30 minutes) | **TIDLE** | = |

## Port 2 (SET P 2) Rear Panel, EIA-232 With IRIG-B

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP) | **PROTO** | = SEL |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | = |
| LMD Address (1–99) | **ADDR** | = |
| LMD Settling Time (0–30 seconds) | **SETTLE** | = |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | = 2400 |
| Data Bits (7, 8) | **BITS** | = 8 |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | = N |
| Stop Bits (1, 2) | **STOP** | = 1 |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | = 5 |
| Send auto messages to port (Y, N) | **AUTO** | = N |
| Enable hardware handshaking (Y, N) | **RTSCTS** | = N |
| Fast Operate Enable (Y, N) | **FASTOP** | = N |

## Port 3 (SET P 3) Rear Panel, EIA-232

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP) | **PROTO** | = SEL |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | = |
| LMD Address (1–99) | **ADDR** | = |
| LMD Settling Time (0–30 seconds) | **SETTLE** | = |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | = 2400 |
| Data Bits (7, 8) | **BITS** | = 8 |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | = N |
| Stop Bits (1, 2) | **STOP** | = 1 |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | = 5 |
| Send auto messages to port (Y, N) | **AUTO** | = N |
| Enable hardware handshaking (Y, N) | **RTSCTS** | = N |
| Fast Operate Enable (Y, N) | **FASTOP** | = N |

## Port 4 (SET P 4) Front Panel, EIA-232

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP) | **PROTO** | = SEL |
| LMD Prefix (@, #, $, %, &) | **PREFIX** | = |
| LMD Address (1–99) | **ADDR** | = |
| LMD Settling Time (0–30 seconds) | **SETTLE** | = |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | = 2400 |
| Data Bits (7, 8) | **BITS** | = 8 |
| Parity Odd, Even, or None (O, E, N) | **PARITY** | = N |
| Stop Bits (1, 2) | **STOP** | = 1 |
| Time-out (for inactivity) (0–30 minutes) | **T_OUT** | = 5 |
| Send auto messages to port (Y, N) | **AUTO** | = N |
| Enable hardware handshaking (Y, N) | **RTSCTS** | = N |
| Fast Operate Enable (Y, N) | **FASTOP** | = N |

## Ethernet Port Settings (Port 5 and Port 6 Only)

| | | |
|---|---|---|
| IP Address (xxx.xxx.xxx.xxx) | **IPADDR** | = _____ |
| Subnet Mask (xxx.xxx.xxx.xxx) | **SUBNETM** | = _____ |
| Default Router (xxx.xxx.xxx.xxx) | **DEFRTR** | = _____ |
| Enable TCP Keep-Alive (Y, N) | **ETCPKA** | = _____ |

### If ETCPKA = Y

| | | |
|---|---|---|
| TCP Keep-Alive Idle Range (1–20 s) | **KAIDLE** | = _____ |
| TCP Keep-Alive Interval Range (1–20 s) | **KAINTV** | = _____ |
| TCP Keep-Alive Count Range (1–20 s) | **KACNT** | = _____ |
| Operating Mode (FIXED, FAILOVER) | **NETMODE** | = _____ |

### If NETMODE = FAILOVER

| | | |
|---|---|---|
| Failover Time-Out (OFF, 0.10–65.00 sec) | **FTIME** | = _____ |
| Enable Telnet (Y, N) | **ETELNET** | = _____ |

### If ETELNET = Y

| | | |
|---|---|---|
| Telnet Port for Card Access (1–65534) | **TPORTC** | = _____ |
| Telnet Port Time-Out (1–30 min) | **TIDLE** | = _____ |
| Enable FTP Server (Y, N) | **EFTPSERV** | = _____ |

### If EFTPSERV = Y

| | | |
|---|---|---|
| FTP Username (20 characters) | **FTPUSER** | = _____ |
| FTP Connect Banner | **FTPCBAN** | = _____ |
| FTP Idle Time-Out (5–255 min) | **FTPIDLE** | = _____ |
| Enable HTTP TCP/IP Server (Y, N) | **EHTTP** | = _____ |

### If EHTTP = Y

| | | |
|---|---|---|
| TCP/IP Port (1–65535) | **HTTPPORT** | = _____ |
| HTTP Web Server Time-Out (1–30 min) | **HTTPIDLE** | = _____ |

### If IEC 61850 is Available

| | | |
|---|---|---|
| Enable IEC 61850 Protocol (Y, N) | **E61850** | = _____ |
| Enable IEC 61850 GSE (Y, N) | **EGSE** | = _____ |

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# Section 7

# Communications

## Overview

The SEL-387E Relay provides:

- Communications with EIA-232 and EIA-485 serial ports
- Communications with Ethernet ports (ordering option)

A communications interface and protocol are required for communicating with the relay. A communications interface is the physical connection on a device. Serial ports that conform to the EIA-232 standard (often called RS-232) use DB-9 or DB-25 connectors as the physical interface, whereas Ethernet ports use RJ45, ST, or LC connectors as the physical interface. Once a physical connection has been established, use a communications protocol to interact with the relay. A communications protocol is a language used to perform operations and collect data.

## Ethernet Interfaces

### Physical Layer Options

The SEL-387E provides optional dual failover Ethernet ports with two physical layer options. Both ports (Port 5 and Port 6) are configured with Port 5 settings. The physical layer options are the following:

- Two 10/100BASE-T ports that support 10/100 Mbps rates on RJ45 connectors
- Two 100BASE-FX ports that support 100 Mbps rates on LC connectors

### Indicators

The green LED is on when the link is operational. The red LED blinks when there is transmit or receive activity.

### Using Redundant Ethernet Ports

The SEL-387E is optionally equipped with two 10/100BASE-TX copper or 100BASE-FX fiber-optic Ethernet ports. Use two Ethernet ports in redundant network architectures or force the relay to use a single Ethernet port even though it is equipped with two ports.

#### Redundant Ethernet Network Using FAILOVER Mode

Make the following settings in Port 5 to configure the relay for FAILOVER mode.

- NETMODE = FAILOVER
- FTIME = desired time-out for the active port before failover to the backup port

Use the internal failover switch to connect the relay to redundant networks as shown in *Figure 7.1*.

**Figure 7.1 Failover Network Topology**

On startup the relay communicates using Port 5. If the relay detects a link failure on Port 5, and the link status on Port 6 is healthy, the relay activates Port 6 after time FTIME. If the link status on Port 5 returns to normal before time FTIME, the failover timer resets and operation continues on Port 5.

Setting FTIME = OFF allows fast port switching (with no intentional delay). Fast port switching can occur within one processing interval (typically 4 ms to 5 ms) and can help with IEC 61850 GOOSE performance.

After failover, while communicating via Port 6, if the relay detects a link failure on Port 6, and the link status on Port 5 is healthy, the relay activates Port 5 after time FTIME.

## Network Connection Using Fixed Connection Mode

Force the relay to use Ethernet Port 5 even when it is equipped with two Ethernet ports by making settings NETMODE = FIXED. Port 6 is disabled when setting NETMODE = FIXED.

## Ethernet Status Relay Word Bits

The SEL-387E Ethernet status is available through the Relay Word bits shown in *Table 7.1*.

**Table 7.1 Ethernet Status Indicator**

| Relay Word Bit | Description |
|---|---|
| P5SEL | Asserts when Port 5 is selected |
| P6SEL | Asserts when Port 6 is selected |
| LNKFAIL | Asserts when the active Ethernet port is down |

## Cables

The following Ethernet cables are compatible with the SEL-387E.

| SEL Part No. | Description |
|---|---|
| SEL-C807 | Duplex Fiber Cable LC/ST or LC/LC |
| SEL-C627 | Shielded Cat 5 Patch Cable RJ45/RJ45 straight through |
| SEL-10C628 | Shielded Cat 5 Patch Cable RJ45/RJ45 crossover |

# Serial Port Interfaces

## Terminal Software

You can use a variety of terminal emulation programs on your personal computer to communicate with the relay.

For the best display, use VT-100 terminal emulation or the closest variation. The default settings for all serial ports are:

Baud Rate = 2400

Data Bits = 8

Parity = N

Stop Bits = 1

To change the port settings, use the **SET P <Enter>** command (see *Section 6: Settings*) or the front-panel SET pushbutton (see *Section 8: Front-Panel Operation*).

## Communications Devices

Devices useful for communications include the following:

- SEL-2032, SEL-2030, and SEL-2020 Communications Processors
- SEL-3530 RTAC

## Physical Layer

The SEL-387E provides EIA-232 and EIA-485 physical layers for serial communications as shown below:

- Three EIA-232 serial ports:
  - One EIA-232 port on the front
  - Two EIA-232 ports on the rear
- One EIA-485 port on the rear

Connect the serial port to a computer serial port for local communications or to a modem for remote communications.

All EIA-232 serial ports support RTS/CTS hardware handshaking. RTS/CTS handshaking is not supported on the EIA-485 Serial Port 1. To enable hardware handshaking, use the **SET P** command (or front-panel SET pushbutton) to set RTSCTS = Y. Disable hardware handshaking by settings RTSCTS = N.

- If RTS_CTS = N, the relay permanently asserts the RTS line.
- If RTS_CTS = Y, the relay deasserts RTS when it is unable to receive characters
- If RTS_CTS = Y, the relay does not send characters until the CTS input is asserted.

The serial port interfaces (DB-9 connectors and screw-terminal connector) support a communications interface, power supply for communications interface converters, and time synchronization source (IRIG-B), as shown in *Table 7.2*.

**Table 7.2 Physical Interfaces**

| Port | Communications Interface | Demodulated IRIG-B | +5 VDC Power Supply |
|---|---|---|---|
| Port 1 | EIA-485 | X | X |
| Port 2 | EIA-232 | X | X |
| Port 3 | EIA-232 | | X |
| Port 4 | EIA-232 | | |

*Figure 7.2* shows the serial port physical interfaces (connectors) on the relay rear panel.

(female chassis connectors as viewed from outside panel)

**Figure 7.2 SEL-387E Relay Serial Port Connectors**

Connector pinout for the EIA-232 ports and terminal functions for the EIA-485 port are as shown in *Table 7.3* and *Table 7.4*, respectively, with descriptions as shown in *Table 7.5*.

**Table 7.3 Pinout Functions for EIA-232 Serial Ports 2, 3, and F**

| Pin Number | Port 2 Rear EIA-232 with IRIG-B | Port 3 Rear EIA-232 | Port 4 Front EIA-232 |
|---|---|---|---|
| 1 | N/C or +5 Vdc[a] | N/C or +5 Vdc[a] | N/C |
| 2 | RXD (In) | RXD (In) | RXD (In) |
| 3 | TXD (Out) | TXD (Out) | TXD (Out) |
| 4 | N/C or +IRIG-B[a] | N/C | N/C |
| 5 | GND | GND | GND |
| 6 | N/C or -IRIG-B[a] | N/C | N/C |
| 7 | RTS (Out) | RTS (Out) | RTS (Out) |
| 8 | CTS (In) | CTS (In) | CTS (In) |
| 9 | GND | GND | GND |

[a] Install a jumper to use the 5 V connection, and remove a solder jumper to disable the IRIG-B input. See Section 2: Installation for more information.

**Table 7.4 Terminal Functions for EIA-485 Serial Port 1**

| Terminal | Function |
|---|---|
| 1 | +TX (Out) |
| 2 | –TX (Out) |
| 3 | +RX (In) |
| 4 | –RX (In) |
| 5 | Shield |
| 6 | N/C |
| 7 | +IRIG-B |
| 8 | –IRIG-B |
| 9 | NA |

**Table 7.5 Serial Communications Port Pin/Terminal Function Definitions**

| Pin Function | Definition |
|---|---|
| N/C | No connection |
| +5 Vdc (0.5 A limit) | 5 Vdc Power Connection |
| RXD, RX | Receive Data |
| TXD, TX | Transmit Data |
| IRIG-B | IRIG-B Time-Code Input |
| GBD | Ground |
| SHIELD | Grounded Shield |
| RTS | Request To Send |
| CTS | Clear To Send |
| DCD | Data Carrier Signal |
| DTR | Data Terminal Ready |
| DSR | Data Set Ready |

Several optional SEL transceivers are available to provide alternative communications interfaces, including EIA-485 and fiber-optic.

### IRIG-B

Refer to *Section 2: Installation*. Note that demodulated IRIG-B time code can be input into Serial Port 1 or Serial Port 2 on any of the SEL-387E models. This is easily handled by connecting Serial Port 2 of the SEL-387E to an SEL-2032 with an SEL-C273A cable (see *Cables on page 7.6*).

Note that demodulated IRIG-B time code can be input into the connector for Serial Port 1. If demodulated IRIG-B time code is input into this connector, it should not be input into Serial Port 2, and vice versa.

## Port Identification

If there is ever uncertainty about the number of the port to which you are connected (1–4), use the command **SHO P <Enter>**. The relay will respond with a message identifying the port number and will list the settings for that port. The **SHO P** command is discussed later in more detail.

## Cables

The following EIA-232 cables are compatible with the SEL-387E. The cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-387E to other devices. SEL provides fiber-optic transceivers and distance as compared to copper links. The equivalent fiber cables are listed following each copper cable description. These and other cables are available from SEL. Contact the factory for more information.

### SEL-387E Relay to Computer

SEL-C234A Cable

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

SEL-C227A Cable

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

## SEL-387E Relay to Modem

SEL-C222 Cable

| SEL-311L Relay<br>9-Pin Male<br>"D" Subconnector | | | **DCE Device<br>25-Pin Male<br>"D" Subconnector | |
|---|---|---|---|---|
| Pin Func. | Pin # | | Pin # | Pin Func. |
| GND | 5 | ——— | 7 | GND |
| TXD | 3 | ——— | 2 | TXD (IN) |
| RTS | 7 | ——— | 20 | DTR (IN) |
| RXD | 2 | ——— | 3 | RXD (OUT) |
| CTS | 8 | ——— | 8 | CD (OUT) |
| GND | 9 | ——— | 1 | GND |

**DCE = Data Communications Equipment (Modem, etc.)

SEL-C220 Cable

| StarComm Modem<br>25-Pin Male<br>"D" Subconnector | | | SEL-311L Relay<br>9-Pin Male<br>"D" Subconnector | |
|---|---|---|---|---|
| Pin Func. | Pin # | | Pin # | Pin Func. |
| GND | 72 | ——— | 5 | GND |
| TXD (IN) | 2 | ——— | 3 | TXD |
| DTR (IN) | 20 | ——— | 7 | RTS |
| RXD (OUT) | 3 | ——— | 2 | RXD |
| CD (OUT) | 8 | ——— | 8 | CTS |
| PWR (IN) | 10 | ——— | 1 | +5 VDC |
| GND | 1 | ——— | 9 | GND |

## SEL-387E Relay to an SEL Communications Processor

SEL-C272A Cable

| SEL-DTA2<br>9-Pin Male<br>"D" Subconnector | | | SEL-311L Relay<br>9-Pin Male<br>"D" Subconnector | |
|---|---|---|---|---|
| Pin Func. | Pin # | | Pin # | Pin Func. |
| RXD | 2 | ——— | 3 | TXD |
| TXD | 3 | ——— | 2 | RXD |
| GND | 5 | ——— | 5 | GND |
| RTS | 7 | ┐ | 7 | RTS |
| CTS | 8 | ┘ | 8 | CTS |

SEL-C273A Cable

| SEL-2032/2030/2020<br>or SEL-2100<br>9-Pin Male<br>"D" Subconnector | | | SEL-311L Relay<br>9-Pin Male<br>"D" Subconnector | |
|---|---|---|---|---|
| Pin Func. | Pin # | | Pin # | Pin Func. |
| RXD | 2 | ——— | 3 | TXD |
| TXD | 3 | ——— | 2 | RXD |
| IRIG+ | 4 | ——— | 4 | IRIG+ |
| GND | 5 | ——— | 5 | GND |
| IRIG- | 6 | ——— | 6 | IRIG- |
| RTS | 7 | ——— | 8 | CTS |
| CTS | 8 | ——— | 7 | RTS |

For communications up to 80 kilometers and for electrical isolation of communications ports, use the SEL-2800 family of fiber-optic transceivers. Contact SEL for more details on these devices.

# Communications Protocols

This section explains the communications protocols used by the SEL-387E. You can set and operate the SEL-387E via the communications ports.

**NOTE:** In this document, commands you type appear in bold/uppercase: **STATUS**. Keys you press appear in bold/brackets: **<Enter>**.

Relay output appears in the following format:

```
XFMR 1                        Date: MM/DD/YY    Time: HH:MM:SS.SSS
```

The communications protocol consists of hardware and software features.

## Serial Port Protocols

### SEL

Set the serial port PROTO setting to SEL (PROTO = SEL) to access the following protocols, which are described in more detail later in this section.

- ASCII
- Compressed ASCII
- Fast Meter
- Fast Operate
- Fast SER (Unsolicited Sequential Events Recorder (SER) Protocol)

### SEL Distributed Port Switch Protocol (LMD)

The SEL Distributed Port Switch Protocol (PROTO = LMD) permits multiple SEL relays to share a common communications channel. See *Appendix C: SEL Distributed Port Switch Protocol* for more information. The same protocols are available as when PROTO = SEL.

### DNP3

Set the serial port PORT setting to DNP (PROTO = DNP) to enable the Distributed Network Protocol (DNP3) protocol, which meets DNP3 Level 2 requirements. See *Appendix G: Distributed Network Protocol (DNP3)* for more information.

## Ethernet Protocols

As with other communications interfaces, you must choose a data exchange protocol that operates over the Ethernet network link to exchange data. The relay supports FTP, Telnet, HTTP (web server), Ping, and IEC 61850 protocols.

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.

## FTP Server

Use the single FTP (File Transfer Protocol) session to access the following files:

| | |
|---|---|
| CFG.XML | Configuration read-only file in XML format |
| ERR.TXT | Error read-only file in text format |
| SET_61850.CID | IEC 61850 CID read-write file |
| .s19 | Firmware upgrade write-only file |

FTP is a standard TCP/IP protocol for exchanging files. A free FTP application is included with most web browser software. You can also obtain a free or inexpensive FTP application from the Internet. When you connect to the relay Ethernet port, you will find files stored in the root (top-level) directory.

## Telnet Server

Use the single Telnet-to-card session (TPORTC default setting is port 1024) to connect to the communications card SEL ASCII protocol and work with the communications card. Use the Telnet-to-host session (TPORTC default setting is port 23) to connect to the relay (host) to use the protocols, which are described in more detail below:

- SEL ASCII
- Compressed ASCII
- Fast Meter
- Fast Operate

**NOTE:** Use the **QUIT** command prior to closing the Telnet-to-Host session to set the relay to Access Level 0. Otherwise, the relay will remain at an elevated access level until TIDLE expires.

Telnet is a terminal connection across a TCP/IP network that operates in a manner very similar to a direct serial port connection to one of the relay ports. As with FTP, Telnet is a part of TCP/IP. A free Telnet application is included with most computer operating systems, or you can obtain low-cost or free Telnet applications on the Internet.

## Web Server (HTTP)

When Port 5 setting EHTTP = Y, the relay serves read-only webpages displaying certain settings, metering, and status reports. The relay embedded web server has been optimized and tested to work with the most popular web browsers, but should work with any standard web browser. As many as three users can access the embedded web server simultaneously. To begin using the embedded read-only web server, launch your web browser, and browse to http://IPADDR, where IPADDR is the Port 5 setting IPADDR (e.g., http://192.168.1.2). The relay responds with a login screen as shown in *Figure 7.3*.

**Figure 7.3 Web Server Login Screen**

Enter **ACC** for the Username, type in the relay Access Level 1 password, then click **Submit**. The only username allowed is ACC. The relay responds with the homepage shown in *Figure 7.4*. While you remain logged into the relay, the webpage displays the approximate time as determined by the relay time-of-day clock, and increments the displayed time once per second based on the clock contained in your PC.

**Figure 7.4 Web Server Homepage and Response to Version Menu Selection**

Click on any menu selection from the left pane to retrieve various reports. Some menus expand to reveal more menus, such as the **Show Settings** menu shown in *Figure 7.5*.

**Figure 7.5 Web Server Show Settings Screen**

The Meter Reports screens update automatically about every five seconds.

To log out, either close the web browser window or click on **Logout** in the banner bar near the top of the webpage.

### Ping Server

Use a Ping client with the relay Ping server to verify that your network configuration is correct.

Ping is an application based on ICMP over an IP network. A free Ping application is included with most computer operating systems.

### IEC 61850

Use as many as six sessions of MMS over a TCP network to exchange data with the relay. Use GOOSE to do real-time data exchange with as many as 16 incoming messages and 8 outgoing messages. For more details on the IEC 61850 protocol, see *Appendix H: IEC 61850 Communications*.

## General Protocols

### SEL ASCII Protocol

SEL ASCII protocol provides an interface that is compatible with terminals or terminal emulators that support ASCII. The protocol is described in more detail in *SEL ASCII Protocol Details on page 7.12*.

### SEL Compressed ASCII Protocol

SEL Compressed ASCII protocol provides compressed versions of some of the relay ASCII commands. SEL Compressed ASCII protocol is always available on any serial port. The protocol is described in *Appendix E: Compressed ASCII Commands*.

### SEL Fast Meter Protocol

SEL Fast Meter protocol supports binary messages to transfer metering messages. SEL Fast Meter protocol is always available on any serial port. The protocol is described in *Appendix D: Configuration, Fast Meter, and Fast Operate Commands*.

### SEL Fast Operate Protocol

SEL Fast Operate protocol supports binary messages to control Relay Word bits. SEL Fast Operate protocol is available on any serial port. Turn it off by setting FAST_OP = N, a SET P setting. The protocol is described in *Appendix D: Configuration, Fast Meter, and Fast Operate Commands*.

### SEL Fast SER Protocol

SEL Fast SER protocol provides SER events to an automated data collection system. SEL Fast SER protocol is described in *Appendix F: Unsolicited SER Protocol*.

## SEL ASCII Protocol Details

The following software protocol is designed for manual and automatic communications.

1. All commands received by the relay must be of the form:

   <command><CR> or <command><CR><LF>

   A command transmitted to the relay should consist of the following:

   - A command followed by either a carriage return or a carriage return and line feed.
   - You must separate arguments from the command by spaces, commas, semicolons, colons, or slashes.
   - You may truncate commands to the first three characters. **EVENT 1 <Enter>** would become **EVE 1 <Enter>**.
   - Upper- and lowercase characters may be used without distinction, except in passwords.

2. The relay transmits all messages in the following format:

   <STX><CR><LF>

   <MESSAGE LINE 1><CR><LF>

   <MESSAGE LINE 2><CR><LF>

   .

   .

   <LAST MESSAGE LINE><CR><LF>

   <ETX> <PROMPT>

   Each message begins with the start of transmission character STX (ASCII character 02) and ends with the end of transmission character ETX (ASCII character 03).

3. The relay indicates how full its receive buffer is through an XON/XOFF protocol.

   The relay transmits XON (ASCII hex 11) when the buffer drops below 40 percent full.

   The relay transmits XOFF (ASCII hex 13) when the buffer is over 80 percent full. Automatic transmission sources should monitor for the XOFF character so they do not overwrite the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and may resume when the relay sends XON.

4. You can use an XON/XOFF procedure to control the relay during data transmission. When the relay receives an **XOFF** command during transmission, it pauses until it receives an **XON** command. If there is no message in progress when the relay receives an **XOFF** command, it blocks transmission of any message presented to its buffer.

   The CAN character (ASCII hex 18) aborts a pending transmission. This is useful in terminating an unwanted transmission.

5. Control characters can be sent from most keyboards with the following keystrokes:

   XON: **<Ctrl + Q>** (hold down the Control key and press Q)

   XOFF: **<Ctrl + S>** (hold down the Control key and press S)

   CAN: **<Ctrl + X>** (hold down the Control key and press X)

## Automatic Messages

The SEL-387E generates automatic messages and sends them out the serial port(s) with the SET P setting AUTO = Y. Four different automatic messages can be displayed:

- Relay startup message
- Setting group change message
- Relay self-test warning or failure
- Event summary message

## Relay Startup Message

Immediately after power is applied, the relay transmits the following automatic message:

```
XFMR 1                                  Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
SEL-387E
=
```

## Setting Group Change Message

The SEL-387E has six different setting groups for the SET settings. The active group is selected by the SS1 through SS6 SELOGIC® control equation variable bits, or by the **GRO *n*** serial port command, or the front-panel **GROUP** pushbutton. At the moment when the active group is changed, the following automatic message is generated.

```
XFMR 1                                  Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

Active Group = N
=>>
```

**NOTE:** The SET G settings SS1 through SS6 take precedence over the **GRO n** command.

- RID and TID settings for the new active group
- Date and time of group change
- Active setting group now being used

## Relay Self-Test Warning or Failure

The relay automatically generates a status report whenever the self-tests declare a failure state and some warning states.

```
XFMR 1                                  Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
FID=SEL-387E-R700-V0-Z101003-D20060616
SELF TESTS
W=Warn    F=Fail
       IAW1     IBW1     ICW1     IAW2     IBW2     ICW2
OS      123      123      123      123      123      123
       IAW3     IBW3     ICW3     VAWX     VBWX     VCWX
OS      123      123      123      123      123      123
       +5V_PS   +5V_REG  -5V_REG  +12V_PS  -12V_PS  +15V_PS  -15V_PS
PS      1.12     1.12    -1.12    12.12    -12.12    12.12   -12.12
       TEMP     RAM      ROM      A/D      CR_RAM   EEPROM   IO_BRD
MB      26.0    OK       OK       OK       OK       OK       OK
       RAM      ROM      PORT 5   PORT 6   FPGA     BOARD    DPRAM     PS
CC     N/A      N/A      N/A      N/A      N/A      FAIL     N/A       N/A
Relay Enabled

=>>
```

- RID and TID settings for the active group
- Date and time the failure or warning was detected
- Firmware identification string
- Individual self-test results
- Relay protection enabled or disabled indication

### Event Summary Message

An automatic message is generated each time an event is triggered. The message is a summary of the event.

```
XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

Event: TRIG
Targets:
Winding 1 Currents (A Sec), ABC:   123.0   123.0   123.0
Winding 2 Currents (A Sec), ABC:   123.0   123.0   123.0
Winding 3 Currents (A Sec), ABC:   123.0   123.0   123.0
Winding X Voltages (V Sec), ABC:   123.0   123.0   123.0
Volts/Hertz Percent:  0.0
=>>
```

- RID and TID settings for the active group
- Date and time the event was triggered
- The event type
- Target information
- All phase currents and voltages

## Access Levels

Commands can be issued to the relay via the serial port to view metering values, change relay settings, etc. The available ASCII serial port commands are listed in *Figure 7.6* and summarized by level in the *SEL-387E Relay Command Summary*. A multilevel password system provides security against unauthorized access. This access scheme allows you to give personnel access to only those functions they require.

The relay supports five access levels. Each level has an associated screen prompt and password. The relay is shipped with the default factory passwords shown in the table under **PAS** (Passwords) later in this section. Below are the access level hierarchy, the access level prompts, and commands allowed in each of the five access levels:

| Access Level | Prompt | Commands Allowed |
|---|---|---|
| 0 (lowest) | = | 0 |
| 1 | => | 0, 1 |
| B | ==> | 0, B |
| 2 | =>> | 0, 1, B, 2 |
| C (highest) | ==>> | 0, 1, B, 2, C |

*Figure 7.6* summarizes the access levels, prompts, and commands available from each access level and commands for moving between access levels.

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. The relay responds with `Invalid Command` to commands not listed or if a command is not followed by the correct number or letter.

### Access Level 0

Once serial port communications are established with the relay, the Access Level 0 prompt (=) appears. If a different prompt appears, the relay was left in a different access level or the terminal emulation you are using is translating the characters differently. VT-100 emulation is recommended.

The *only* commands that can be executed at Access Level 0 are the **ACC** and **QUI** commands (see *Figure 7.6*). Enter the **ACC** command at the Access Level 0 prompt to go to Access Level 1.

## Access Level 1

After you issue the **ACC** command and enter the password, if it is required [see *PAS (Passwords) on page 7.26* for default factory passwords], the relay will be in Access Level 1. The prompt for Access Level 1 appears (=>).

Many commands can be executed from Access Level 1 for viewing relay information. The **BAC** command allows the relay to go to Access Level B. The **2AC** command allows the relay to go to Access Level 2.

## Access Level B (Breaker Level)

After you issue the **BAC** command and enter the password, if it is required [see *PAS (Passwords)* for default factory passwords], the relay pulses the ALARM contact and will be in Access Level B (breaker access level). The Access Level B prompt appears (==>).

Many commands can be executed from Access Level B for viewing relay information and controlling the breaker. While in Access Level B, any of the commands available in the lower Access Levels 0 and 1 can be executed.

## Access Level 2

After you issue the **2AC** command and enter the password, if it is required [see *PAS (Passwords)* for default factory passwords], the relay pulses the ALARM contact and will be in Access Level 2. The Access Level 2 prompt appears (=>>).

This is the highest normal access level. All commands listed in this manual, for any access level, can be executed from Access Level 2 for viewing relay information, controlling the breaker, and changing settings. Firmware upgrades to Flash memory (see *Appendix B: SEL-300 Series Relays Firmware Upgrade Instructions*) are also performed from this level.

## Access Level C

After you issue the **CAL** command and enter the password, if it is required [see *PAS (Passwords)* for default factory passwords], the relay pulses the ALARM contact and will be in Access Level C. The Access Level C prompt appears (==>>).

This is the highest access level. It contains commands that are not intended for normal relay operation. Only use Access Level C to change its default password. For a list of commands available at Access Level C, please contact SEL.

## Command Summary

**Figure 7.6 Access Level Relationships**

## Relay Command Explanations

SEL ASCII commands require three characters, and some commands require certain parameters. Each command is defined in alphabetical order. Examples are shown for some commands following their definitions. Text you type appears in bold, and keyboard keys you push appear in bold with brackets. For example, to enter Access Level 1 from Access Level 0, type **ACC <Enter>**.

### 2AC (Access Level 2)

Access Levels 1, B

Use the **2AC** command to enter Access Level 2. The default password for Level 2 is shown in the table under *PAS (Passwords) on page 7.26*. Use the **PAS** command from Access Level 2 to change passwords. Install main board jumper **JMP6A** to disable password protection. With **JMP6A** installed, the relay will not display a request for the password but will immediately execute the command.

The following display indicates successful access to Level 2:

```
=>2AC <Enter>
Password: ? @@@@@ <Enter>

XFMR 1                              Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A


Level 2
=>>
```

You may use any command from the =>> prompt. The relay pulses the ALARM contact for one second after any Level 2 access attempt, unless an alarm condition already exists.

### ACC (Access Level 1)

Access Levels 0, B, 2

Use the **ACC** command to enter Access Level 1. The default password for Level 1 is shown in the table under *PAS (Passwords)*. Use the **PAS** command from Access Level 2 to change passwords. Install main board jumper **JMP6A** to disable password protection.

The following display indicates successful access to Level 1:

```
=ACC <Enter>
Password: ? @@@@@ <Enter>

XFMR 1                                  Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A


Level 1
=>
```

### BAC (Access Level B)

Access Levels 1, 2

Use the **BAC** command to enter Access Level B. The default password for Level B is shown in the table under *PAS (Passwords)*. Use the **PAS** command from Access Level 2 to change this password. Install main board jumper **JMP6A** to disable password protection.

The following display indicates successful access to Level B:

```
=>BAC <Enter>
Password: ?  @@@@@ <Enter>

XFMR 1                              Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

Breaker Level
==>
```

The relay pulses the ALARM contact closed for one second after any Level B access attempt, unless an alarm condition already exists.

## BRE (Breaker Report)

Access Levels 1, B, 2

Use the **BRE** command to display a report of breaker operation information. The breaker report provides trip counter and trip current information for as many as three breakers. The summary of the operations provides valuable breaker diagnostic information at a glance. An example breaker report follows. Refer to *Section 5: Metering and Monitoring* for further information. If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the report as set.

```
=>>BRE <Enter>
XFMR 1                                  Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
BREAKER 1
Int Trips=     12345   IAW1=     12345  IBW1=    12345  ICW1=    12345 kA(pri)
Ext Trips=     12345   IAW1=     12345  IBW1=    12345  ICW1=    12345 kA(pri)
Percent Wear:          POLE1=      123  POLE2=     123  POLE3=     123

BREAKER 2
Int Trips=     12345   IAW2=     12345  IBW2=    12345  ICW2=    12345 kA(pri)
Ext Trips=     12345   IAW2=     12345  IBW2=    12345  ICW2=    12345 kA(pri)
Percent Wear:         POLE1=      123  POLE2=     123  POLE3=     123

BREAKER 3
Int Trips=     12345   IAW3=     12345  IBW1=     12345  ICW3=     12345 kA(pri)
Ext Trips=     12345   IAW3=     12345  IBW1=     12345  ICW3=     12345 kA(pri)
Percent Wear:          POLE1=      123  POLE2=      123  POLE3=      123

LAST BREAKER MONITOR RESET FOR     Bkr1:  MM/DD/YY       HH:MM:SS.SSS
                                   Bkr2:  MM/DD/YY       HH:MM:SS.SSS
                                   Bkr3:  MM/DD/YY       HH:MM:SS.SSS
=>>
```

## BRE R n (Breaker Reset)

Access Levels B, 2

The **BRE R *n*** command resets the trip counter, trip current data, and contact wear percentages for Breaker *n*. Issue **BRE R A** to reset all Breaker Monitors at one time. Use the **BRE** command to verify resetting of the data.

## BRE W n (Breaker Wear Pre-Set)

Access Levels B, 2

This command is used to pre-set the amount of contact wear for Breaker *n*, on the assumption that the breaker experienced some fault duty before the relay was installed. The command prompts for percentage wear for each pole of the breaker. Percentage wear information must be entered as integer values, from 0 to 100 percent. Values over 100 will not be accepted. The data are stored in EEPROM and are nonvolatile. The procedure is shown below.

```
=>>BRE W 1 <Enter>
Breaker Wear Percent Preload

Breaker 1: Pole 1 % = 123 ?
Breaker 1: Pole 2 % = 123 ?
Breaker 1: Pole 3 % = 123 ?
Are you sure (Y/N) ?
=>>
```

After entering the values, use the **BRE** command to verify that the data have been accepted properly.

## CAL Command

Access Level 2

See *ACC (Access Level 1) on page 7.18* for a discussion about using passwords and changing access levels.

## CEV (Compressed Event)

Access Levels 1, B, 2

SEL-5601-2 SYNCHROWAVE® Event Software is available for graphical analysis of event reports. The **CEV** command is a compressed (no formatting) version of the **EVE** command. Use the **CEV** command to download events for SYNCHROWAVE Event.

The **CEV** command can generate both winding and differential reports.

The command syntax is **CEV [*n* S*x* C]**. All parameters are optional. Enter them in any order.

Letter *n* specifies the event number.

S*x* specifies samples per cycle. The *x* value can be 64 for raw reports. Digital elements will be displayed at the resolution specified by S*x*, to a maximum of eight samples per cycle.

If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the report as set.

Refer to *Appendix E: Compressed ASCII Commands* for a complete description of the command, as well as additional Compressed ASCII commands: **CAS**, **CBR**, **CHI**, **CST**, and **CTA**.

## CLO n (Close)

Access Levels B, 2

The **CLO *n*** command asserts the CC*n* Relay Word bit. This bit must be included in the CL*n* Close Logic setting for Breaker *n*, in order for closing to take place. This logic is described in *Section 4: Control Logic*.

To close the circuit breaker with this command, type **CLO *n* <Enter>**. The prompting message `Close Breaker n (Y/N) ?` is displayed. Then `Are you sure (Y/N)?` Typing **N <Enter>** after either of the above prompts aborts the closing operation with the message `Command Aborted`. If both questions are answered **Y <Enter>**, the breaker will be closed, an automatic message summarizing the close operation will be sent, and an Event Report will be created.

If the main board jumper **JMP6B** is not in place, the relay responds: `Aborted: Breaker Jumper Not in Place.`

## CON n (Control RBn)

Access Level 2

This command is used to control the Relay Word bit **RB*n***, or Remote Bit *n*, *n* having a value of 1 to 16. The relay responds with **CONTROL RB*n***. The user must then respond with one of the following: **SRB *n* <Enter>** (Set Remote Bit *n*), or **CRB *n* <Enter>** (Clear Remote Bit *n*), or **PRB *n* <Enter>** (Pulse Remote Bit *n*). The latter asserts **RB*n*** for one processing interval, one-eighth cycle. The Remote Bits permit design of SELOGIC control equations that can be set, cleared, or momentarily activated via a remote command.

## COP m n (Copy Settings)

Access Level 2

The **COP *m n*** command copies settings and logic from setting Group m to Group n (m and n can be any combination of 1 through 6). After entering the settings into one setting group with the **SET** command, copy it to the other groups with the **COP** command. Use the **SET** command to modify copied setting groups. The ALARM output contact closes momentarily when you change settings in an active setting group but not in an inactive setting group.

```
=>>COP 1 3 <Enter>
COPY 1 to 3
Are you sure (Y/N) ? Y <Enter>

Please wait...
Settings copied
=>>
```

## DAT (Date)

Access Levels 1, B, 2

**NOTE:** After setting the date, allow at least 60 seconds before powering down the relay or the new setting may be lost.

The **DAT** command displays or sets the date stored by the internal calendar/clock. Simply typing **DAT <Enter>** displays the date. Set the date by typing **DATE d1 <Enter>** where d1 is either mm/dd/yy or yy/mm/dd depending on the SET G date format setting DATE_F. The following example views the current date, verifies the DATE_F setting, and changes the date. Note that single-digit numbers may be entered without leading zeros, as in the 9 in 11/9/96.

```
=>>DAT <Enter>
11/11/96
=>>SHO G DATE_F <Enter>

RELAY SETTINGS
DATE_F = MDY       FP_TO = 5         TGR    = 5

=>>DAT 11/9/96 <Enter>
11/09/96
=>>
```

## EVE (Event Reports)

Access Levels 1, B, 2

Use the **EVENT** command to view event reports. See *Section 9: Analyzing Events* for further details on retrieving event reports.

## GRO and GRO n (Setting Group)

Access Levels 1, B, 2

The **GRO** command, at Access Level 1, displays the setting group variable for the currently active setting group. Changing the variable is not permitted. The **GRO *n*** command, at Levels B and 2, designates what the setting group variable is to be (*n* = 1 to 6), thereby asking the relay to change to the setting group so designated. The relay will only make the change if the setting group selection SELOGIC control equations (SS1 through SS6) are not assigned or are not asserted. The following example verifies the existing group variable, changes it, and then waits for the automatic message when the setting group changes. The variable must be changed for a certain number of seconds as specified by the TGR setting (under SET G) before the new settings are enabled.

```
=>>GRO <Enter>
Active Group = N
=>>GRO 2 <Enter>
Change to Group 2
Are you sure (Y/N) ? Y <Enter>
=>>
```

**NOTE:** The relay will be disabled momentarily while the change in groups takes place.

The **GRO** command does not clear the event report buffer. If the active group is changed, the relay pulses the ALARM output contacts and generates the following automatic message:

```
XFMR 1                                  Date: 03/13/97    Time: 14:33:49.109
STATION A

Active Group = 2
=>>
```

## HIS (History of Events)

Access Levels 1, B, 2

The **HIS** command displays the 99 most recent event summaries in reverse chronological order (most recent event at the top, with lowest event number "#"). The number of full Event Reports completely saved in Flash memory depends on the SET G setting LER as follows:

| LER Setting | Number of Event Reports Stored |
|---|---|
| 15 cycles | 18–21 |
| 29 cycles | 12–14 |
| 60 cycles | 7 |

Each summary shows the date, time, event type, active setting group at the time of the event, and relay targets.

Event types, in decreasing order of precedence, are: TRIP*n* (*n* = 1 to 4), CLS*m* (*m* = 1 to 4), ER (SELOGIC control equations event trigger), PULSE (user-initiated momentary contact operation), and TRIG (user-initiated triggering of

an Event Report). If more than one event type occurs during the same event, the type with highest precedence will be displayed in the EVENT field of each line of the display.

Enter **HIS *n***, where *n* is a positive number (1 through 99), to limit the history report to the most recent *n* events. The history is stored in nonvolatile memory, so it is retained through power failures.

The date and time are saved (time to the nearest millisecond) and referenced to the trigger row of data in the Event Report.

An example of the display appears below. In this example, seven events have occurred since the history was last cleared:

```
=>>HIS <Enter>

XFMR 1                                          Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

#       DATE        TIME      EVENT   GRP   TARGETS


1     01/06/96  00:18:10.333  TRIP1    1
2     01/04/96  09:08:20.058  TRIG     1
3     01/04/96  08:53:55.429  TRIP3    1    50/51 A B W3
4     01/01/96  00:18:10.258  TRIP1    1
5     01/01/96  00:18:08.095  TRIP3    1    50/51 A B W3
6     12/09/95  22:41:33.108  ER       1
7     12/09/95  22:27:47.870  TRIP3    1    50/51 A B W3

=>>
```

If an event has not occurred since the history was last cleared, the headings are displayed with the message: `History Buffer Empty`.

## HIS C (Clear History and Events)

Access Levels 1, B, 2

The **HIS C** command clears the history and associated events from nonvolatile Flash memory. The clearing process may take as long as 30 seconds under normal operation. It may be even longer if the relay is busy processing a fault or other protection logic. The following is an example of the **HIS C** command. The relay will pause after the word `Clearing` until the buffer is completely clear, and then it will display the rest of the information.

```
=>>HIS C <Enter>
Clear History Buffer
Are you sure (Y/N) ? Y <Enter>
Clearing Complete (Relay pauses after the word Clearing)
=>>
```

### Note: Clear the Event Buffer With Care

Automated clearing of the event buffer should be limited to reduce the possibility of wearing out the nonvolatile memory. Limit automated **HIS C** commands to once per week or less.

## ID

Access Levels 0, 1, B, 2

Enter **ID** over a serial port to obtain relay information and configuration information. Each line of the **ID** command report contains an identification code and a line checksum. The SEL-387E presents these codes in the following order:

- FID: reports the Firmware Identification string
- BFID: reports the Boot Firmware Identification string
- CID: reports the checksum of the firmware
- DEVID: reports the device identification (DID setting)
- DEVCODE: reports the Modbus® device code
- CONFIG: reports the device configuration (e.g., nominal current and nominal frequency)

## INI (Initialize Interface Board)

Access Levels 1, B, 2

The **INI** command reports the number and type of interface boards in the relay from Access Levels 1 and B. If the number or type of interface boards has changed since the last time the relay turned on, **INI** will confirm from Access Level 2 that the interface boards present are correct.

```
=>>INI <Enter>
I/O BOARD       INPUTS    OUTPUTS
Main              6         7
1                 No Board Connected
2                 No Board Connected

=>>
```

## IRI (IRIG-B Synchronization)

Access Levels 1, B, 2

The **IRI** command forces the relay to read the demodulated IRIG-B time-code input at the time of the command.

**NOTE:** Normally, it is not necessary to synchronize using this command because the relay automatically synchronizes approximately once a minute. The **IRIG** command is provided to prevent delays during testing and installation checkout.

If the relay reads the time code successfully, it updates the internal clock/calendar time and date to the time-code reading. The relay then transmits a message with relay settings RID and TID, and the date and time.

```
=>IRI <Enter>
XFMR 1                          Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
=>
```

If no IRIG-B signal is present or the code cannot be read successfully, the relay sends the error message `IRIG-B DATA ERROR`.

## MET (Metering Report)

Access Levels 1, B, 2

The **MET** command displays currents, voltages, demand currents and power, peak demand currents and power, or differential data, depending on the command statement. There are several choices for the **MET** command, listed briefly below. Refer to *Section 5: Metering and Monitoring* for a complete description of the metering reports.

| | |
|---|---|
| **MET** | Displays winding voltage and current metering data, in primary amperes |
| **MET D** | Displays winding demand meter data, in primary amperes |
| **MET DIF** | Displays differential current metering data, in multiples of tap |
| **MET E** | Display energy metering data (see *MET E (Energy Metering)*) |
| **MET H** | Displays harmonic spectrum of currents and voltages (see *MET H (Harmonic Metering)*) |
| **MET P** | Displays peak demand meter data, in primary amperes |
| **MET RD *n*** | Resets demand meter for Winding *n* (*n* = 1, 2, 3, A) |
| **MET RE** | Resets the Energy metering data |
| **MET RP *n*** | Resets peak demand meter values for Winding *n* (*n* = 1, 2, 3, A) |
| **MET SEC** | Displays winding current metering data, with magnitude and phase angle, in secondary and voltage quantities |

Use the **MET XXX *n*** command, where *n* is a positive integer, to repeat the MET XXX report *n* times. For example, to display a series of eight meter readings, type **MET 8 <Enter>**.

If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the report as set.

## MET E (Energy Metering)

Access Levels 1, B, 2

The **MET E** command initiates the energy metering function. The element runs every second, using the average value of the last 16 cycles of the previous second to calculate energy quantities. This function is explained more fully in *Section 5: Metering and Monitoring*, where a sample report also is shown.

## MET H (Harmonic Metering)

Access Levels 1, B, 2

The **MET H** command is different from the normal metering functions, in that it uses one full cycle of unfiltered data, at 64 samples per cycle, to provide a snapshot of total harmonic content of all 12 analog inputs. It uses a Fast Fourier Transform technique to provide secondary quantities for all harmonics from 1 (fundamental) to 15.

This function is explained more fully in *Section 5: Metering and Monitoring*, where a sample report also is shown. If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the report as set.

## OPE n (Open)

Access Levels B, 2

The **OPE *n*** command asserts the OC*n* Relay Word bit. This bit must be included in the TR*n* trip logic setting for Breaker *n* in order for opening to take place. This logic is described in *Section 4: Control Logic*.

To open circuit Breaker *n* by this command, type **OPE *n* <Enter>**. The prompt `Open Breaker n (Y/N)?` is displayed. Then `Are you sure (Y/N) ?` is displayed. Typing **N <Enter>** after either of the above prompts aborts the opening operation with the message `Command Aborted`. If both questions are answered **Y <Enter>**, the breaker will be opened, an automatic message summarizing the trip will be sent, an Event Report will be created, and the **TRIP** LED on the front panel will light. This must be turned off by a **TAR R** command or by the **TARGET RESET** pushbutton on the front panel.

If the main board jumper **JMP6B** is not in place, the relay responds: `Aborted: Breaker Jumper Not in Place.`

## PAS (Passwords)

Access Level 2, C

**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.

**Table 7.6 Factory Default Passwords for Access Levels 1, B, 2, and C**

| Access Level | Factory Default Password |
|---|---|
| 1 | OTTER |
| B | EDITH |
| 2 | TAIL |
| C | CLARKE |

The **PASsword** command allows you to change existing Level 1, B, and 2 passwords at Access Level 2 and allows you to change the Level C password from Level C. To change passwords, enter **PAS *x***, where *x* is the access level whose password is being changed. The relay will prompt for the old password, new password, and a confirmation of the new password.

To change the password for Access Level 1, enter the following:

```
=>>PAS 1 <Enter>

Old Password: *********

New Password: ******
Confirm New Password: ******

Password Changed
=>>
```

The new password will not echo on the screen, and passwords cannot be viewed from the device. Record the new password in a safe place for future reference.

If the passwords are lost or you wish to operate the relay without password protection, put the main board Access jumper in place (Access jumper = ON). Refer to *Figure 2.15* for Access jumper information. With the Access jumper in place, issue the **PAS *x*** command at Access Level 2. The relay will prompt for a new password and a confirmation of the new password.

Passwords may include as many as 12 characters. See *Table 7.7* for valid characters. Upper- and lowercase letters are treated as different characters. Strong passwords consist of 12 characters, with at least one special character or digit and mixed-case sensitivity, but do not form a name, date, acronym, or word. Passwords formed in this manner are less susceptible to password guessing and automated attacks. Examples of valid, distinct strong passwords include:

- Ot3579A24.68
- Ih2d&s4u-Iwg
- .387e.Nt9g-t

**Table 7.7 Valid Password Characters**

| | |
|---|---|
| **Alpha** | ABCDEFGHIJKLMNOPQRSTUVWXYZ<br>abcdefghijklmnopqrstuvwxyz |
| **Numeric** | 0123456789 |
| **Special** | ! " # $ % & ' ( ) * , - . / : ; < = > ? @ [ \ ] ^ _ ` { \| } ~ |

The relay shall issue a weak password warning if the new password does not include at least one special character, number, lowercase letter, and uppercase letter.

```
=>>PAS 1 <Enter>

Old Password: *********

New Password: ******
Confirm New Password: ******

Password Changed
=>>

CAUTION:  This password can be strengthened.  Strong passwords do not include a name,
    date, acronym, or word.  They consist of the maximum allowable characters, with
    at least one special character, number, lower-case letter, and upper-case
    letter.  A change in password is recommended.

=>>
```

## PUL n (Pulse)

Access Levels B, 2

**NOTE:** The **PUL** command is useful during testing to verify operation of output contacts, but it should not be used while the relay is in service. During the entire time the specified output contact is being pulsed, all other output contacts are frozen in their existing states and are not permitted to change. This could prevent a trip or other critical output from being issued during the specified PUL time interval.

The **PUL *n k*** command asserts the selected output contact *n* for *k* seconds. The *k* parameter is optional. If *k* is not specified, the output contact is pulsed for one second. Main board breaker jumper **JMP6B** must be in place. After issuing the **PUL** command, the relay asks for confirmation of the operation and then asks if you are sure. An invalid output contact name or incorrect k value produces an error message.

Parameter *n* may be any existing output contact element name such as OUT107. Parameter *k* must be a number ranging from 1 to 30 seconds.

```
=>>PUL OUT107 3 <Enter>
Pulse contact OUT107 for 3 second(s) (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
=>>
```

## QUI (Quit)

Access Levels 0, 1, B, 2

The **QUI** command returns the relay to Access Level 0 from Level 1, B, or 2. The command displays the relay settings RID, TID, date, and time of **QUI** command execution.

Use the **QUI** command when you finish communicating with the relay, to prevent unauthorized access. The relay automatically returns to Access Level 0 after a certain inactivity time dependent on the SET P setting T_OUT.

```
==>QUI <Enter>

XFMR 1                        Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

=
```

## RES (RESET51—Reset Inverse-Time O/C Elements)

Access Level 2

The **RES** command clears the inverse-time overcurrent element accumulators (phase, negative-sequence, and residual) for all three windings. It also clears the combined overcurrent phase and residual inverse-time elements. This command is useful in testing the inverse-time elements, because it mimics the action of immediately returning an electromechanical disk to the starting position. This command can save time in waiting for some units to reset according to their electromechanical reset equations in *Section 3: Protection Functions*.

The relay will ask `Reset 51 Elements (Y/N) ?` when given the **RES** command. If No, it will abort the command. If Yes, it will respond `All Time-Overcurrent Element Accumulators Cleared.` This command is not likely to have much use in normal in-service relay operation.

## SER (Sequential Events Recorder)

Access Levels 1, B, 2

The **SER** command displays the last 512 sequential events records. To limit the number of records displayed, use number or date parameters with the SER command. **SER d1** shows only events triggered on the date specified by d1. **SER d1 d2** shows only events triggered on or between the specified dates. SER m shows the most recent m events. **SER *m n*** shows event records *m* through *n*. The following is an example of the SER report. See *Section 9: Analyzing Events* for a complete description of the report.

```
=>>SER 2/26/97 2/27/97 <Enter>

XFMR 1                                  Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

FID=SEL-387E-R700-V0-Z101003-D20060616
#      DATE         TIME       ELEMENT          STATE

4     2/26/97   10:33:54.873   TRIP3           Asserted
3     2/26/97   10:33:55.373   TRIP3           Deasserted
2     2/27/97   10:34:06.872   CLS3            Asserted
1     2/27/97   10:34:07.372   CLS3            Deasserted

=>>
```

## SER C (Clear Sequential Events Recorder)

Access Levels 1, B, 2

Clear the sequential events records from relay memory with the **SER C** command. The process may take as long as 30 seconds under normal operation or longer if the relay is busy processing a fault or protection logic.

```
=>>SER C <Enter>
Clear the SER
Are you sure (Y/N) ? Y <Enter>
Clearing Complete

=>>
```

### Note: Clear the SER Buffer With Care

Automated clearing of the SER buffer should be limited to reduce the possibility of wearing out the nonvolatile memory. Limit automated **SER C** commands to once per week or less.

## SET (Edit Group 1 through 6 Settings)

Access Level 2

Configure the relay using the **SET** command. The entire syntax of the **SET** command follows:

**SET *n Setting* TERSE <Enter>**

All parameters are optional and perform the following functions:

- ***n*** specifies the setting group (1 through 6). The default is the active setting group.
- ***Setting*** specifies the setting name with which to begin. The default is the first setting.
- **TERSE** eliminates the display of the group settings at the end of the setting procedure. The command will function properly if just **TE** is entered, instead of the full word.

If a setting is hidden because that section of the settings is turned OFF, you cannot jump to that setting. TERSE is very useful when making small changes to the settings. For example, the following procedure is recommended when making a change to one setting:

Change the CTR1 Setting

```
=>>SET CTR1 TE <Enter>
Group 1


GENERAL DATA
Wdg 1 CT Ratio (1-50000)                          CTR1    = 120       ? 160 <Enter>
Wdg 2 CT Ratio (1-50000)                          CTR2    = 240       ? END <Enter>
Save Changes? Y <Enter>
Settings saved
```

Verify the CTR1 Setting

```
=>>SHO CTR1 <Enter>
Group 1


GENERAL DATA
CTR1    = 160       CTR2    = 240       CTR3    = 400
MVA     = 100.0     ICOM    = Y
W1CTC   = 11        W2CTC   = 11        W3CTC   = 0
VWDG1   = 230.00    VWDG2   = 138.00    VWDG3   = 13.80
PTR     = 100       VIWDG   = 1         TPVI    = Y
```

Issue <Ctrl + X> to Stop Scrolling

```
=>>
```

*Table 7.8* lists the editing keys that you can use with the **SET** command.

**Table 7.8 Editing Keys for SET Commands**

| Press Key(s) | Results |
|---|---|
| **^ <Enter>** | Moves to previous entry in a setting category until you get to the first entry in the category, and then it moves to previous category. |
| **< <Enter>** | Moves to previous settings category when making group settings. |
| **> <Enter>** | Moves to next settings category when making group settings. |
| **<Enter>** | Moves to next entry. |
| **END <Enter>** | Exits editing session and displays all settings (if TERSE not used). Prompts: `SAVE CHANGES (Y/N)?` Type **Y <Enter>** to save changes and exit, **N <Enter>** to exit without saving. |
| **<Ctrl + X>** | Aborts editing session without saving changes. |
| **OFF <Enter>** | Flags a setting as not applicable. Only applies to certain settings. |

After you enter a setting, you are prompted for the next setting. Press **<Enter>** to move from setting to setting. The settings are arranged into families of related settings to simplify setting changes. You can start at a specific setting by entering the setting name as a parameter.

The relay checks each entry to ensure that it is within the allowable input range. If it is not, an `Out of Range` message is generated, and the relay prompts for the setting again.

When you have made all the necessary setting changes, it is not necessary to scroll through the remaining settings. Type **END <Enter>** at the next setting prompt to display the new settings and request confirmation.

Answer **Y <Enter>** to the confirmation request to approve the new settings. If you violate a rule for setting relationships, a fail message is displayed, and the settings prompt moves to the first setting that affects the failure. While the active settings are updated, the relay is disabled, the ALARM output contacts close, and all timers and relay elements reset. The relay logic is fully functional while editing settings. The relay is disabled for approximately one second when settings are saved.

Refer to individual elements in *Section 3: Protection Functions* and to *Section 6: Settings* for information on settings.

## SET G (Edit Global Settings)

Access Level 2

Configure the relay Global Settings using the **SET G** command. The Global Settings include Event Report parameters, frequency, phase rotation, date format, front-panel time-out, the group switching time delay, dc battery monitor thresholds, breaker monitor settings, analog input labels, SS*n* setting group variables, and definition of front-panel programmable LED and Display Point variables. The entire syntax of the **SET G** command follows:

**SET G *Setting* TERSE <Enter>**

The two parameters are optional and perform the following functions:

- ***Setting*** specifies the setting name with which to begin. The default is the first setting.
- **TERSE** eliminates the display of the Global Settings at the end of the setting procedure. The command will function properly if just **TE** is entered, instead of the full word.

The **SET G** procedure works just like the **SET** procedure. *Table 7.8* lists the editing keys that you can use with the **SET** command.

Refer to individual elements in *Section 3: Protection Functions* and to *Section 6: Settings* for information on settings.

## SET P (Edit Port Settings)

Access Level 2

Configure the relay port settings using the **SET P** command. The port settings include the communication and protocol settings. The entire syntax of the **SET P** command follows:

**SET P *n Setting* TERSE <Enter>**

The two parameters are optional and perform the following functions:

- ***n*** specifies the serial port number (1, 2, 3, 4, or 5). Default is the port issuing the command.
- ***Setting*** specifies the setting name with which to begin. The default is the first setting.
- **TERSE** eliminates the display of the port settings at the end of the setting procedure. The command will function properly if just **TE** is entered, instead of the full word.

The **SET P** procedure works just like the **SET** procedure. *Table 7.8* lists the editing keys that you can use with the **SET** command.

The settings for each communications port are:

| | |
|---|---|
| PROTO: | Protocol can be SEL, LMD, DNP, or TELNET (Port 1 only). |
| PREFIX: | If PROTO is LMD, prefix can be @, #, $, %, or &. |
| ADDR: | If PROTO is LMD, ADDR can be any integer 1 through 99. |
| SETTLE: | If PROTO is LMD, the settling time can be 0 to 30 seconds. |

| | |
|---|---|
| TPORT: | If PROTO is TELNET, TPORT can be any integer 1 through 65534. |
| TIDLE: | If PROTO is TELNET, the port inactivity time can be 1 through 30 minutes. |
| SPEED: | Baud can be set to 300, 1200, 2400, 4800, 9600, or 19200. |
| BITS: | Data can be 7 or 8 bits. |
| PARITY: | Can be O, E, or N (Odd, Even, None). |
| STOP: | Bits can be 1 or 2. |
| T_OUT: | Port inactivity time-out can be 0 through 30 minutes. T_OUT = 0 setting means port will never time-out. Time-out returns port to Access Level 0. |
| AUTO: | Send auto messages to the port; Yes or No. |
| RTSCTS: | Enable hardware handshaking; Yes or No (only if PROTO=SEL). |
| FASTOP: | Enable Fast Operate function; Yes or No. |

Refer to individual elements in *Section 3: Protection Functions* and to *Section 6: Settings* for information on settings.

## SET R (Edit SER Settings)

Access Level 2

Configure the Sequential Events Recorder settings using the **SET R** command. The settings are the four sequential events record trigger conditions (SER1 to SER4) and the ALIAS1 to ALIAS20 settings for renaming Relay Word bits for the SER report. The entire syntax of the **SET R** command follows:

**SET R *Setting* TERSE <Enter>**

The two parameters are optional and perform the following functions:

- ***Setting*** specifies the setting name with which to begin. The default is the first setting.
- **TERSE** eliminates the display of the new settings at the end of the setting procedure. The command will function properly if just **TE** is entered, instead of the full word.

The **SET R** procedure works just like the **SET** procedure. *Table 7.8* lists the editing keys that you can use with the **SET** command.

Refer to *Section 6: Settings* for setting worksheets. Refer to *Section 9: Analyzing Events* for more details on default settings and data retrieval.

### Note: Make Sequential Events Recorder (SER) Settings With Care

The relay triggers a row in the Sequential Events Recorder (SER) event report for any change of state in any one of the elements listed in the SER1, SER2, SER3, or SER4 trigger settings. Nonvolatile memory is used to store the latest 512 rows of the SER event report so they can be retained during power loss. The nonvolatile memory is rated for a finite number of “writes.” Exceeding the limit can result in an EEPROM self-test failure. *An average of 1 state change every 3 minutes can be made for a 25-year relay service life.*

## SHO (Show Group 1 through 6 Settings)

Access Levels 1, B, 2

**SHO** displays the relay settings of the currently selected group. The entire syntax of the **SHO** command follows:

**SHO *n Setting* A <Enter>**

- ***n*** specifies the setting group (1 through 6). The default is the active setting group.
- ***Setting*** specifies the setting name with which to begin. The default is the first setting.
- If ***Setting* = A**, then hidden settings are shown in addition to the regular settings.

Control characters provide control over the scrolling of the data:

| | | |
|---|---|---|
| Temporarily Stop Scrolling: | **<Ctrl + Q >** | (hold down the Control key and press Q) |
| Restart Scrolling: | **<Ctrl + S>** | (hold down the Control key and press S) |
| Cancel Scrolling Completely: | **<Ctrl + X>** | (hold down the Control key and press X) |

Settings cannot be entered or modified with this command. Change settings with the **SET** command from Access Level 2. Refer to individual elements in *Section 3: Protection Functions* and to *Section 6: Settings* for information on settings.

## SHO G (Show Global Settings)

Access Levels 1, B, 2

**SHO G** displays the relay Global settings of the currently selected group. The Global settings include Event Report parameters, frequency, phase rotation, date format, front-panel time-out, the group switching time delay, dc battery monitor thresholds, breaker monitor settings, analog input labels, SS*n* setting group variables, and definition of front-panel programmable LED and Display Point variables. The syntax of the **SHO G** command follows:

**SHO G *Setting* <Enter>**

*Setting* specifies the setting name with which to begin. The default is the first setting.

Settings cannot be entered or modified with this command. Change settings with the **SET G** command from Access Level 2. Refer to individual elements in *Section 3: Protection Functions* and to *Section 6: Settings* for information on settings.

## SHO P (Show Port Settings)

Access Levels 1, B, 2

**SHO P** displays the relay serial port settings. The port settings include the communications and protocol settings. The syntax of the **SHO P** command follows:

**SHO P *n Setting* <Enter>**

The two parameters are optional and perform the following functions:

- *n* specifies the serial port number (1, 2, 3, 4, or 5). Default is the port issuing the command.
- *Setting* specifies the setting name with which to begin. The default is the first setting.

Entering **SHO P <Enter>** is an easy way to identify the port to which you are presently connected.

Settings cannot be entered or modified with this command. Change settings with the **SET P** command from Access Level 2. The following example shows the factory default settings. Refer to *Section 6: Settings* for Settings Sheets.

## SHO R (Show SER Settings)

Access Levels 1, B, 2

**SHO R** displays the Sequential Events Recorder settings. The syntax of the **SHO R** command follows:

**SHO R *Setting* <Enter>**

*Setting* specifies the setting name with which to begin. The default is the first setting.

Settings cannot be entered or modified with this command. Change settings with the **SET R** command from Access Level 2. Refer to individual elements in *Section 3: Protection Functions* and to *Section 6: Settings* for information on settings.

## STA (Status Report)

Access Levels 1, B, 2

The **STA** command displays a report of the self-test diagnostics. The relay automatically executes the **STA** command whenever the self-test software enters a warning or failure state. You may repeat the **STA** command by appending a number as a repeat count parameter. Type **STA 4 <Enter>** to view the status information four times.

If a warning or failure state occurs, the next time the **STA** command is issued, the warning state is reported. If a warning or failure occurs, it will not be cleared until relay power is cycled and the problem is fixed. Saving relay settings also warm boots relay logic. This may clear some warnings, but do not ignore warnings; contact the factory.

The **STA C <Enter>** command also clears any out-of-tolerance condition from the status report and reboots the relay. Do not ignore the warning; contact the factory.

If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the report as set. For the STA report format, see the example following *Status Monitor Report Function (STATUS Command) on page 5.19*.

## TAR (Show Relay Word Targets On Screen)

Access Levels 1, B, 2

The **TAR** command displays the default row of the Relay Word showing the Relay Word bit names and their value, which is either a logical 1 (asserted) or logical 0 (deasserted). The syntax of the **TAR** command follows:

**TAR *n k* X <Enter>**

- ***n*** specifies a new default Relay Word row by entering the row number or the specific Relay Word bit name (except names of target elements in rows 0 and 1). If *n* is not specified, the last default row is displayed.
- ***k*** specifies a repeat count for the command. The default is 1.
- **X** allows viewing a Relay Word row without changing the default row.

The default row number can also be changed by the **TAR F** command, but each serial port has independent defaults. The default row number returns to 0 when the port times out, the **QUI** command is executed, **TAR 0** command is executed, or the **TAR R** command is executed.

The **TAR** command does not remap the front-panel LEDs. See the **TAR F** command.

The following examples demonstrate the **TAR** command:

```
=>>TAR <Enter> Default Row is 0

EN      TRIP    INST    87-1    87-2    87-3    24      81
1       0       0       0       0       1       0       0
=>>TAR 8 <Enter> Display and Change Default to Row 8

50N21   50N21T  50N22   51N2    51N2T   51N2R   NDEM2   OC2
0       0       0       0       0       1       0       0
=>>TAR <Enter> Default Row is 8

50N21   50N21T  50N22   51N2    51N2T   51N2R   NDEM2   OC2
0       0       0       0       0       1       0       0
=>>TAR 8 5 <Enter> Display Row 8 Five Times

50N21   50N21T  50N22   51N2    51N2T   51N2R   NDEM2   OC2
0       0       0       0       0       1       0       0
0       0       0       0       0       1       0       0
0       0       0       0       0       1       0       0
0       0       0       0       0       1       0       0
0       0       0       0       0       1       0       0
=>>TAR RB4 X <Enter> Display Row 24 (RB4) But Do Not Change Default

RB1     RB2     RB3     RB4     RB5     RB6     RB7     RB8
0       0       0       0       1       0       0       0
=>>TAR <Enter>

50N21   50N21T  50N22   51N2    51N2T   51N2R   NDEM2   OC2
0       0       0       0       0       1       0       0
=>>TAR R <Enter> Reset Default to Row 0

EN      TRIP    INST    87-1    87-2    87-3    24      81
1       0       0       0       0       0       0       0
=>>
```

Refer to *Section 4: Control Logic* for a list of the Relay Word bits and their corresponding rows.

## TAR F n (Show Relay Word Targets on Front-Panel LEDs)

Access Levels 1, B, 2

The **TAR F** command works like the **TAR** command, but it also remaps the second row of target LEDs on the front panel to follow the default row. This may be useful, for example, in testing situations where a display on the relay front-panel LEDs of element pickup or operation may be desired. The syntax of the **TAR F** command follows:

**TAR F *n k* X <Enter>**

- ***n*** specifies a new default Relay Word row by entering the number or the specific Relay Word bit name. If *n* is not specified, the last default row is displayed.
- ***k*** specifies a repeat count of the command for the serial port display. The default is 1.
- **X** allows remapping of the LEDs to a Relay Word row without changing the default row.

The default row number returns to 0 when the serial port times out, the **QUI** command is executed, or the **TAR R** command is executed.

The front-panel LEDs remain remapped until the front panel times out, the **TAR R** command is executed, or the TARGET RESET button is pushed.

Refer to *Section 4: Control Logic* for a list of the Relay Word bits and their corresponding rows.

## TAR R (Reset Targets)

Access Levels 1, B, 2

The **TAR R** command resets the default row for the **TAR** and **TAR F** commands to 0, and remaps the second row of front-panel LEDs to display Row 1, which is the standard target display. It also resets any tripping front-panel targets.

Use the **TAR R** command to return the front-panel LEDs to the standard targets when you are done using the **TAR** or **TAR F** command for testing.

## TEST DB

Access Levels B, 2

Use the **TEST DB *name 01* [*name02…name10*][*s*]** command in relays equipped with Ethernet communications to pulse as many as 10 binaries (Relay Word bits), where *name01…name10* are the Device Word bits that are to be pulsed and *s* is the number of seconds to pulse the binaries. The range for *s* is 1 to 30 seconds, with a default of one second. If the binary is a logical 0, the command will pulse it to one. If the binary is a logical 1, the command will pulse it to zero. This command affects both SER and IEC 61850 communications.

## TFE (Through-Fault Event Report)

The **TFE** command displays the following data for each individually recorded through-fault event:

- Date and time of the through fault
- Duration (seconds) of the through fault
- Maximum current (amperes primary) for each monitored current input

The following cumulative values (updated for each new through-fault event) are also displayed:

- Through-fault count
- Simple $I^2t$ calculation for each monitored current input

There are various choices for the **TFE** command, listed briefly below. Refer to *Section 5: Metering and Monitoring* for a complete description of the through-fault event reports:

| | |
|---|---|
| **TFE** | Displays cumulative and individual through-fault event data. The 20 most recent individual events are displayed. |
| **TFE A** | Displays cumulative and individual through-fault event data. All the most recent individual events are displayed (as many as 1200). |
| **TFE C** | Clears/resets cumulative and individual through-fault event data. |
| **TFE *n*** | Displays cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 1200. |
| **TFE P** | Preloads cumulative through-fault event data. |
| **TFE R** | Clears/resets cumulative and individual through-fault event data. |

## TIM (Time)

Access Levels 1, B, 2

The **TIM** command displays or sets the time stored by the internal clock. The time is set or displayed on a 24-hour clock basis, not a.m./p.m. View the current time with **TIM <Enter>**. To set the clock, type **TIM *t1* <Enter>** where *t1* is the new time in hours:minutes:seconds; the seconds are optional. Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes. The following example sets the clock to 23:30:00.

```
=>>TIM 23:30:00 <Enter>
23:30:00
=>>
```

**NOTE:** After setting the time, allow at least 60 seconds before powering down the relay or the new setting may be lost.

A quartz crystal oscillator provides the time base for the internal clock. You can also set the time clock automatically through the relay time-code input using a source of demodulated IRIG-B time code.

### TRI (Trigger an Event)

Access Levels 1, B, 2

The **TRI** command generates an event record. The command is a convenient way to record all inputs and outputs from the relay any time you want (e.g., testing or commissioning). The event type is recorded as TRIG any time the **TRI** command is issued.

```
=>>TRI <Enter>
Triggered

=>>

XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

Event: TRIG
Targets:
Winding 1 Currents (A Sec), ABC:   123.1   123.1   123.1
Winding 2 Currents (A Sec), ABC:   123.1   123.1   123.1
Winding 3 Currents (A Sec), ABC:   123.1   123.1   123.1
Winding X Voltages (V Sec), ABC:   123.1   123.1   123.1
Volts/Hertz Percent:   123.1
=>>
```

### VER (Version)

Access Levels 1, B, 2

The **VER** command provides relay configuration and information such as firmware version and relay hardware configuration.

## Ethernet Port Command Explanations

The following commands are available through Telnet-to-card (Ethernet port) communications.

### 2AC

Access Levels 1, 2

Enter **2AC** over Telnet on an optional Ethernet port to move to Access Level 2 on that port. Ethernet ports do not support the password jumper.

### ACC

Access Levels 0, 1, 2

Enter **ACC** over Telnet on an optional Ethernet port to move to Access Level 1 on that port. Ethernet ports do not support the password jumper.

### EXIT

Access Levels 0, 1, 2

Use the **EXIT** command to properly terminate a Telnet session, which includes setting the port access level to zero and setting the target row to zero.

## GOOSE

Access Levels 1, B, 2

Use the **GOOSE** command to display transmit and receive GOOSE messaging information, which can be used for troubleshooting. The **GOOSE** command variants and options are shown below.

| | |
|---|---|
| **GOOSE** | Display GOOSE information |
| **GOOSE *count*** | Display GOOSE information *count* times |

The information displayed for each GOOSE IED is described below.

| | |
|---|---|
| **Transmit GOOSE Control Reference** | This field represents GOOSE control reference information that includes the IED name, ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and GSEControl name (GSE Control Block Name)<br>(e.g., SEL_387E_1CFG/LLN0$GO$GooseDSet13) |
| **Receive GOOSE Control Reference** | This field represents the goCbRef (GOOSE Control Block Reference) information that includes the iedName (IED name), ldInst (Logical Device Instance), LN01 lnClass (Logical Node Class), and cbName (GSE Control Block Name)<br>(e.g., SEL_387E_1CFG/LLN0$GO$GooseDSet13) |
| **MultiCastAddr (Multicast Address)** | This hexadecimal field represents the GOOSE multicast address. |
| **Ptag** | This three-bit decimal field represents the priority tag value, where spaces are used if the priority tag is unknown. |
| **Vlan** | This twelve-bit decimal field represents the virtual LAN (Local Area Network) value, where spaces are used if the virtual LAN is unknown. |
| **StNum (State Number)** | This hexadecimal field represents the state number that increments with each state change. |
| **SqNum (Sequence Number)** | This hexadecimal field represents the sequence number that increments with each GOOSE message. |
| **TTL (Time to Live)** | This field contains the time (in ms) before the next message is expected. |
| **Code** | This text field contains warning or error condition text when appropriate that is abbreviated as follows: |

| **Code Abbreviation** | **Explanation** |
|---|---|
| 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 | Optional code for when the host is disabled or becomes unresponsive after the GOO command has been issued |

| | |
|---|---|
| **Transmit Data Set Reference** | This field represents the DataSetReference (Data Set Reference) that includes the IED name, LN0lnClass (logical Node Class), and GSEControl datSet (Data Set Name)<br>(e.g., SEL_387E_1/LLN0$Dset13) |
| **Receive Data Set Reference** | This field represents the datSetRef (Data Set Reference) that includes the iedName (IED Name), ldInst (Logical Device Instance), LN0 lnClass (Logical Node Class), and datSet (Data Set Name)<br>(e.g., SEL_387E_1CFG/LLN0$Dset13) |

An example response to the **GOOSE** command is shown in *Figure 7.7*.

```
#>>GOO <Enter>
GOOSE Transmit Status
-----------------------------------------------------------------------------
SEL-387E_Line/LLN0$GO$GooseDSet13
                      2:5     1256       347        6
   Data Set: SEL-387E_Line/LLN0$GooseDSet13

GOOSE Receive Status

   MultiCastAddr   Ptag:Vlan  StNum      SqNum      TTL    Code
-----------------------------------------------------------------------------
SEL-311L_Line_DifferentialCFG/LLN0$GO$GooseDSet13
   01-03-A7-00-00-01  3:1     1253758689 4786543985 123456
   Data Set: SEL-311L_Line_Differential/LLN0$GooseDSet13

SEL-387E_Current_DifferentialCFG/LLN0$GO$GooseDSet13
   01-03-A7-00-00-01  3:23    12568945   34         0
   Data Set: SEL-387E_1_CFG_Current_Differential/LLN0$GooseDSet13

SEL-421_DistanceCFG/LLN0$GO$GooseDSet13
   01-03-A7-00-00-01  3:343   1945       34456      456
   Data Set: SEL-421_Distance/LLN0$GooseDSet13

SEL-487B_Bus_DifferentialCFG/LLN0$GO$GooseDSet13
   01-03-A7-00-00-01  3:5     12568945   34783456   123456
   Data Set: SEL-487B_Bus_Differential/LLN0$GooseDSet13

#>>
```

**Figure 7.7 GOOSE Command Response**

## HELP

Access Levels 1, 2

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 that command.

## ID

Access Levels 0, 1, 2

Enter **ID** over Telnet on an optional Ethernet port to obtain Ethernet port identification and configuration information.

Each line of the **ID** command report contains an identification code and a line checksum. The SEL-387E presents these codes in the following order, but the optional iedName, type, and configVersion codes will only be displayed if IEC 61850 is enabled (E61850 = Y). The optional codes are taken from the IED element in the CID file and can be used to verify that the document has the expected CID file.

- FID: the Firmware Identification string
- BFID: the Boot Firmware Identification string

- CID: the checksum of the firmware
- iedName: the IED name (e.g., SEL_387E_OtterTail)
- type: the IED type (e.g., SEL_387E)
- configVersion: the CID file configuration version (e.g., ICD-387E-R100-V0-Z001001-D20060512)

## MAC

Access Level 1, 2

Use the **MAC** command to display the MAC address of PORT 5 and PORT 6, as shown below.

```
Port 5 MAC Address:  00-30-A7-00-00-00
Port 6 MAC Address:  00-30-A7-23-23-23
```

## QUI

Access Levels 0, 1, 2

Enter **QUIT** over Telnet on an optional Ethernet port to return the relay to Access Level 0 on that port.

## STA

Access Level 1, 2

Enter **STA** over Telnet on an optional Ethernet port to obtain a status report for the Ethernet port. Items in the STA report are the header, failures, warnings, Ethernet link status, and communications card operational status.

The self-test status fields shown below are the same as those shown at the bottom of a STA report obtained using a serial port, with the exceptions of CR_RAM and NON_VOL. The CR_RAM and NON_VOL fields are combined with the ROM field in the serial port STA report. When CR_RAM is FAIL then there is a failure in the nonvolatile Ethernet card configuration. When NON_VOL is FAIL then there is a failure with the nonvolatile CID file. The other fields are defined in *Relay Command Explanations on page 7.18*.

```
Date:  04/24/2006     Time:  16:54:22

FID = SEL-E3-R100-V0-Z001001-D20060616                CID = 78E5

HOST   PORT 5   PORT 6   RAM     ROM     FPGA    DPRAM   CR_RAM   NON_VOL   PS
OK     LINK     NOLINK   OK      OK      OK      OK      OK       OK        OK

Device Enabled
```

### STA C and STA R

Access Level 2

The optional Ethernet ports latch all self-test warnings and failures to capture transient out-of-tolerance conditions. Enter **STA C** or **STA R** over Telnet on an optional Ethernet port to reboot the Ethernet ports and reset their self-test status. The following example shows the steps required to reset the relay self-test status.

## Alarm Conditions

The SEL-387E asserts the ALARM output while the relay turns on until all self-tests pass and whenever a diagnostic test fails. In addition to these, the ALARM output pulses for one second with the commands and conditions shown in *Table 7.9*.

**Table 7.9 Commands With Alarm Conditions**

| Command | Condition |
|---|---|
| **2AC** | Entering Access Level 2 or<br>Three wrong password attempts into Access Level 2 |
| **ACC** | Three wrong password attempts into Access Level 1 |
| **BAC** | Entering Breaker Access Level or<br>Three wrong password attempts into Breaker Access Level |
| **COP *m n*** | Copying a setting group to the active setting group |
| **GRO *n*** | Changing the active setting group |
| **PAS *n* newpas** | Any password is changed |
| **SET** commands | Changing the SET G settings, the SET R settings, or the active group SET settings (SET P does not alarm) |

## Main Board Jumpers

Installing and removing certain main board jumpers affects execution of some commands. *Table 7.10* lists all jumpers you should be concerned with and their effects.

**Table 7.10 Main Board Jumpers**

| Jumper | Comment |
|---|---|
| JMP6A | Disables password protection when installed |
| JMP6B | Enables **CLO**, **OPE**, and **PUL** commands when installed |

# Section 8

# Front-Panel Operation

## Front-Panel Operation

A close-up view of the user interface portion of the SEL 387E Relay front panel is shown in *Figure 8.1*. It includes a two-line, 16-character LCD; 16 LED target indicators; and eight pushbuttons for local communication.

**Figure 8.1 SEL-387E Relay Front-Panel User Interface**

The LCD shows event, metering, setting, and relay self-test status information. The display is controlled with the eight multifunction pushbuttons. The target LEDs display relay target information as described by the legend. The bottom row can be remapped to display a Relay Word row of bits, in response to the **TAR F** serial port command.

### Time-Out

If no buttons are pressed on the front panel, the relay waits for a period specified in the SET G setting FP_TO (Front-Panel Time-Out) and then takes the following actions:

- The front-panel LCD resets to the default display.
- The front-panel access level reverts to Access Level 1.
- The LCD backlighting is turned off.
- Any routine being executed via a front-panel command is interrupted.
- The target LEDs (lower row) revert to the default targets.

FP_TO is factory set to 15 minutes and can be set from 1 to 99 minutes.

### Displays

The LCD is controlled by the pushbuttons, automatic messages the relay generates, and user-programmed Display Points. These Display Points are discussed at the end of this section in more detail. The default display is a scroll through any active, nonblank Display Points. If none are active, the relay scrolls through four two-line displays of the A-, B-, and C-phase currents and voltages in primary quantities. If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the display as set. Each

display remains for two seconds, before scrolling continues. Any message generated by the relay due to an alarm condition takes precedence over the normal default display. The **EXIT** button returns the display to the default display, if some other front-panel function is being performed.

Error messages such as self-test failures are displayed on the LCD in place of the default display when they occur. Do not turn off the relay if this happens, but refer to *Section 10: Testing and Troubleshooting* for further instructions.

While the relay turns on, the LCD displays `Initializing`. It will then scroll through the winding current and voltage displays until the relay is again enabled. When the **EN** LED indicates the relay is enabled, the active Display Points will be scrolled.

Menu choices on the LCD are listed horizontally on the second line. The first character of the menu choice is underlined. The left and right arrow buttons move the underline to the adjacent menu selection. Once the underline indicates your selection, use the **SELECT** button to proceed.

## Target LEDs

The target LEDs are an indication of what the relay has detected on the power system and how the relay has reacted. The front-panel legend gives a brief description of each target. *Section 4: Control Logic* describes each target LED in detail.

The only times the target LEDs do not illuminate according to their labels are when (1) the user has reprogrammed LEDA, LEDB, or LEDC to respond to a SELOGIC® control equation, or (2) the **TAR F** command is issued through one of the serial ports. The **TAR F** command remaps the second row of LEDs to follow a particular row in the Relay Word bits, such that assertion of a Relay Word bit will light the corresponding LED position. Refer to *TAR F n (Show Relay Word Targets on Front-Panel LEDs) on page 7.36* for a complete description of the **TAR F** command.

The states of the 12 dedicated LEDs (all but **EN**, **A**, **B**, **C**) are stored in nonvolatile memory. If the power is lost to the relay, these 12 targets will be restored to their last state when power is restored. **EN** responds only to internal self-test routines, while **A**, **B**, and **C** respond to the present state of their GLOBAL settings, which are SELOGIC control equations.

## Password Access

Commands that are at Access Level 2 (**2AC**) or the Breaker Access Level (**BAC**) are password protected from the front panel. *Access Level 1* commands have no password protection. The front panel normally is active at Access Level 1. If you issue a command from the front panel that requires a Level B or Level 2 password, the relay prompts you for a password. After you enter the password for the higher access level, you remain at that access level only until the front panel times out from inactivity or you **EXIT** from the specific command. When you **EXIT** the command, the front panel returns to Access Level 1.

If the password jumper, **JMP6A**, is installed, there is no password protection, and you will not be prompted for a password. If a particular level password has been disabled with serial port command **PAS *n* DISABLE <Enter>**, you will not be prompted for a password.

When prompted for a password, enter the BAC or 2AC password, depending on the requirements of the command. All commands are available using the 2AC password. The front-panel request for password shows a display of 12 characters. Use the up/down arrow keys to scroll and set the first character of the password. Passwords are case sensitive; be sure you use upper- or lowercase letters as needed. Use the right arrow key to move to the second

character, and adjust it using the up/down arrows as before. Continue this process until *all 12* characters are filled. If the password has fewer than 12 characters, fill the remaining slots with a "blank," found between the numeral 9 and the lowercase "a" in the character scroll. When the password is complete, push SELECT to enter it. If the password is correct, the relay will change to the higher level and permit you to perform the commands of that level. If it is incorrect, the relay will declare an invalid password and allow another attempt. After three incorrect attempts, the relay will pulse the ALARM contact for one second and the front panel will exit the command you are trying to access.

# Pushbuttons

Eight multifunction pushbuttons control the front-panel display. The button legend defines the primary function in the top row and the secondary function in the bottom row. The primary functions are for command selection, while the secondary functions are for cursor movements and specific commands within dialogs. The eight pushbutton primary functions will be discussed in the order in which they appear from left to right on the front panel.

## Primary Function Review

### TARGET RESET/LAMP TEST

The left-most button is dedicated to the TARGET RESET function. Except while viewing or editing settings, pressing TARGET RESET causes the front-panel LEDs to illuminate for a two-second lamp test and then clear all target LEDs except for the EN LED, which is illuminated if the relay is enabled. While viewing or editing settings, the TARGET RESET button acts as a Help function, showing specific information about the displayed setting.

### METER

The METER button performs all of the **MET** serial port commands, via a multilevel menu structure. The METER display is updated every two seconds.

While within the METER menu structure, the CANCEL button will take the user back up to the previous menu. The EXIT button will take the user out of METER and back to the default display.

While METER information is being scrolled every two seconds, the scroll can be stopped by pushing SELECT. The user may then manually scroll through the displays with the up/down arrow keys. This facilitates writing down the displayed information by hand, for example. Pushing SELECT again will resume the scroll.

*Figure 8.5*, at the end of this section, shows the full METER menu and display structure.

When METER is pushed, the seven dual-function buttons revert to their secondary functions. The first METER menu prompts the user to select the **W1**, **W2**, **W3**, **V**, **CMBO**, **DIF**, **DC**, **F**, **PWR**, or **ENG** metering display. W1 to W3 are winding displays, V is the voltage input display, CMBO is W1 and W2 combined current, DIF is the differential element display, DC is the

battery monitor display, F is the measured system frequency, PWR is the calculated power display, and ENG is the energy metering display. Use any arrow button to highlight the choice. Then push **SELECT**.

## Windings (W1, W2, W3)

If a winding has been selected, a second menu prompts the user to select the type of metering to display. The choices are INSTantaneous, DEMand, PKD peak demand, or SECondary. Use the right/left arrows to choose, then push **SELECT**.

**NOTE:** The harmonic spectrum metering function, the **MET H** serial port command, is not available from the front panel.

If INST or SEC is selected, the relay scrolls through the primary current magnitudes, or secondary current magnitudes and angles, for the selected winding. If DEM or PKD is selected, a third menu appears, prompting the user to select either to **DISPLAY** the demand information or to **RESET** the demand accumulators.

**NOTE:** RESET of the DEM or PKD is a Level 1 function and is not password-protected from the front panel.

Use the right/left arrows and **SELECT** to choose. If RESET is chosen, the relay will prompt for a Yes/No verification of the choice. Use the right/left arrows and **SELECT** to choose. If DISPLAY is chosen, the relay will scroll through the demand values. Three-phase real and reactive power demand and peak demand values are displayed in the power (PWR) menu.

## Voltage (V)

If V is selected, a second menu prompts the user to select the type of metering to display. The choices are INSTantaneous, or SECondary. Use the right/left arrows to choose, then push **SELECT**.

**NOTE:** The harmonic spectrum metering function, the **MET H** serial port command, is not available from the front panel.

If INST or SEC is selected, the relay scrolls through the primary voltage magnitudes, or secondary voltage magnitudes and angles, for the selected voltage. Use the right/left arrows and **SELECT** to choose.

If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the displays as set.

## Differential Element (DIF)

If DIF is selected, the relay scrolls through the instantaneous multiple of tap values for Operate, Restraint, and harmonic quantities.

## Battery Monitor (DC)

If DC is selected, the relay displays `Station Battery` and `VDC= nnn.n`.

## Frequency (F)

If F is selected, the relay displays `System Frequency` and `FREQ = xx.xx`.

## Power (PWR)

If PWR is selected, a submenu showing a selection of **INST DEM PKD** is displayed. This represents choices for instantaneous, demand, and peak demand power metering. If INST (instantaneous) is selected, the relay scrolls through real (MW), reactive (MVAR), and apparent (MVA) power values. If the current and voltage transformers are wye-connected (DELTA_Y = Y, W*n*CT = Y) along with all three phase voltages connected to the relay (TPVI = Y), all phase quantities are displayed. Otherwise, only total power

values appear, assuming balanced load conditions. If **DEM**(demand) is selected, three-phase MW and MVAR are displayed. If **PKD**(peak demand) is selected, the peak demand values for three-phase MW and MVAR are displayed.

### Energy (ENG)

If ENG is selected, a second screen giving the user a choice of Energy DISPLAY or RESET appears. If DISPLAY is chosen, the relay scrolls through real (MWh) and reactive (MVARh) quantities.

## EVENTS

Push the **EVENTS** button to display short event summaries, comparable to the **HIS** serial port command.

If no EVENT records exist, the display states `No Fault Data` and terminates the command.

If there are records to view, use the right/left arrows to review data within an event record and the up/down arrows to move between event records. The information displayed for a given event is: event number, date/time, active setting group, fault targets, and the winding secondary current magnitudes (IA, IB, IC). The currents only appear if the entire event report still resides in relay memory. The Analog Input Label names are not used in this display. Current information is simply listed, for example, as **W1** followed by **A B C** and the magnitudes. There may be as many as 99 event summaries in the history buffer, but a much smaller number of full event reports. The **EVENTS** command will display everything but the currents for the older, incomplete history summaries. Use **CANCEL** or **EXIT** to return to the default display.

*Figure 8.8*, at the end of this section, shows the EVENTS display structure.

## STATUS

The **STATUS** button displays the relay status information, in similar fashion to the serial port **STA** command. When **STATUS** is pushed, the initial display shows:

`STATUS:  [OK/WARN/FAIL]`

`FID=SEL-387E-R10` (e.g., the first 12 characters of the FID string)

The STATUS line shows the worst state of the several parameters examined. The right/left arrow keys can be used to view the rest of the FID string.

The up/down arrow keys are then used to manually scroll through the diagnostic fields, showing the analog channel offsets, power supply voltages, internal temperature, RAM (OK/FAIL), etc. The display remains in this scroll sequence until either **CANCEL** or **EXIT** is pushed.

## OTHER

The **OTHER** button is used to access several miscellaneous functions; it mimics the corresponding serial port commands for these functions. Pushing **OTHER** provides a menu that prompts the user to select DATE, TIME, TARget, BKR (breaker), RESET51, or LCD. These perform the same functions as the serial port commands **DAT**, **TIM**, **TAR**, **BRE**, and **RES**. Use any arrow key and **SELECT** to choose the function. These OTHER subfunctions are discussed below in alphabetical order.

## BKR

This function displays the breaker monitor accumulator values for internal and external trips, the accumulated interrupted currents by pole, the percent contact wear, and the time/date of last reset, for the selected breaker.

When BKR is selected, a second menu appears to prompt the user to select Bk1, Bk2, or Bk3. Use the right/left arrow keys and **SELECT** to choose. Another menu appears, asking whether DISPLAY or RESET is desired. Use the right/left arrow keys and **SELECT** to choose.

If DISPLAY is selected, the display scrolls automatically, showing the internal and external trip counters for the breaker chosen, the phase currents accumulated for each type of trip, and the percent contact wear, by breaker pole. The first two-line display shows P1, the second P2, and the third P3. The fourth display shows `% wear` for each of the three poles, in integer values of 100 or less. The fifth display shows `Last Reset From` and the date/time of last reset. Pushing **SELECT** will toggle between stop-scroll and resume-scroll to facilitate hand recording of data values.

Push **CANCEL** to return to the OTHER main menu. Push **EXIT** to return to the default display.

*Figure 8.9*, at the end of this section, shows the full OTHER/BKR menu and display structure.

## DATE

The DATE function is used to change the date stored in the relay. It is identical to the serial port **DATE** command.

**NOTE:** After setting the date, allow at least 60 seconds before powering down the relay or the new setting may be lost.

When selected, a two-line display appears, with the current date on the first line and a prompt to Set or Cancel on the second. Use the right/left arrows and **SELECT** to choose. The date display will follow whichever format was selected by the DATE_F setting, either MDY or YMD. If Set is selected, a second display prompts the user to change the date. Because this is a Level 1 command, it is not password protected from the front panel. Use the right/left arrows to move between the MM/DD/YY fields and the up/down arrows to scroll to the number selected for the field. When the date is shown correctly, push **SELECT** to enter it. Push **CANCEL** to return to the OTHER main menu. Push **EXIT** to return to the default display.

## LCD

The rotating default display can be locked on a single screen. Access the scroll lock control with the **OTHER** pushbutton.

```
DATE TIME TAR
BKR RESET51 LCD
```

Select `LCD` for Scroll Lock Control mode. The rotating display will then appear, and the scroll mode reminder screen will appear every eight seconds for one second as a reminder that the display is in Scroll Lock Control mode.

```
Scroll lock OFF
SELECT to Lock
```

**Stop Scrolling (Lock).** When in the Scroll Lock Control mode, press the **SELECT** key to stop display rotation. Scrolling can be stopped on any of the display point screens. While rotation is stopped, the active display is updated continuously so that the display point changes can be seen. If no button is pressed for eight seconds, the reminder message will appear for one second, followed by the active screen.

```
Scroll lock ON
SELECT to Unlock
```

**Restart Scrolling (Unlock).** The **SELECT** key unlocks the modified rotating display.

## RESET51

This command equates exactly to the **RES** serial port command. RESET51 clears all time accumulators of all the inverse-time overcurrent elements, both for separate windings and for the combined overcurrent elements. RESET51 may be useful for saving time in testing the relay overcurrent elements, but is not likely to be used while the relay actually is in service.

If RESET51 is selected, a password screen will appear if password protection is in force. Next, a `Reset 51? Yes No` screen appears. Use the right/left arrows to underscore **Yes** or **No**, then push **SELECT**. Yes will reset the accumulators and exit the command. No will abort the command and return to the OTHER main menu; or, simply push **CANCEL** to return to the OTHER main menu. Push **EXIT** to return to the default display.

## TAR

This command is roughly equivalent to the **TAR F** serial port command. When TAR is selected in the OTHER main menu, the display shows `TAR 0`, the first row of the Relay Word bits, with `EN` shown in the second row (relay enabled). The up/down arrow keys may be used to scroll through the remaining rows of the Relay Word bits. For these rows, the asserted Relay Word bit names will be listed in the second row of the display, and the corresponding LED positions will be lit in the target area above the display. If more bits are asserted than will fit in the display, the right/left arrow keys may be used to see the off-screen names.

Push **CANCEL** to return to the OTHER main menu. Push **EXIT** to return to the default display.

## TIME

This command works like the **DATE** command above and is equivalent to the **TIME** serial port command.

**NOTE:** After setting the time, allow at least 60 seconds before powering down the relay or the new setting may be lost.

When selected, a two-line display appears, with the current time on the first line and a prompt to Set or Cancel on the second. Use the right/left arrows and **SELECT** to choose. Because this is a Level 1 command, it is not password protected from the front panel. If Set is selected, a second display appears, prompting the user to change the time. Use the right/left arrows to move

between the HH:MM:SS fields, and the up/down arrows to scroll to the number selected for the field. When the time is shown correctly, push **SELECT** to enter it. Push **CANCEL** to return to the OTHER main menu. Push **EXIT** to return to the default display.

## SET

The SET function has the most elaborate menu and display structure of all the pushbutton functions. Only numeric value settings, or settings having fixed character string values, can be displayed or changed on the display. Settings that are SELOGIC control equations cannot be displayed or changed.

To show or set relay settings, press the **SET** button. There are four set/show options: **GROUP**, **GLOBAL**, **PORT**, and **PASS**. Use the right/left arrow keys and **SELECT** to choose. These will be discussed in alphabetical order.

*Figure 8.10*, at the end of this section, shows the essential menu and display structure for the **SET** button. It does not show anything below the setting section (subgroup) level, because this would be too cumbersome.

### GLOBAL

This command is roughly equivalent to the **SHO G** and **SET G** serial port commands. When GLOBAL is selected, a menu appears for selecting whether to Set or Show the settings. If Set, a password entry screen appears, if password protection is in force.

The next screen is either the **Set GLOBAL** or **Show GLOBAL** display, in which a message scrolls across the second line, reminding the user to `Press TARGET RESET for help during set/show routine`. This special use for the **TARGET RESET** button provides the user with a short description of the setting and the range of values, should the user not recognize the setting by its character string name.

The next menus to appear are to allow the user to enter a specific section of the GLOBAL settings, rather than having to scroll through all GLOBAL settings. The sections are **RELAY SETTINGS**, **BATTERY MONITOR**, **BKR*n* MONITOR**, **ANALOG INPUT LABELS**, **SETTING GROUP SElection**, and **FRONT PANEL**. Use any arrow key to move to the section you want, then push **SELECT** to enter that section.

For example, if we select RELAY SETTINGS, the first setting `LER=15` appears in the second line of the display. If you do not recognize this setting, push the **TARGET RESET** button, and a single scroll across the first line will indicate that this is the `Length of Event Report (15, 29, 60 Cycles)` setting.

If we are in the Show mode, we can only observe the value. The **SELECT** button acts like a down arrow to move to the next setting. The up/down arrows themselves can be used to move within the list of settings.

If in the Set mode, we can choose to change the value by pushing **SELECT**. An underscore will appear under the first character of the value. If it has discrete values, like LER, the up/down arrows can be used to scroll through the available choices. If it is a numerical variable, the digits are changed one at a time, using the right/left arrows to move to the digit, and the up/down arrows to select the number to insert. When the setting is displayed at the new value, push **SELECT** to enter the change.

When the complete list of settings has been shown or set, the display returns to the level at which the user selects which section to Set or Show. **CANCEL** may also be used to move to this level from within the section of settings. **EXIT**, in the Set mode, brings the display to a `Save Changes? Y/N` selection point. In the Show mode, **EXIT** returns you to the default display.

## GROUP

This command is roughly equivalent to the **SHO** and **SET** serial port commands. When GROUP is selected, a menu appears for selecting which of the six setting groups to Show or Set. Use the right/left arrow keys and **SELECT** to choose. The next screen asks whether the user intends to Set or Show the settings. If Set, a password entry screen appears, if password protection is in force.

The next screen is either the **Set GROUP *n*** or **Show GROUP *n*** display (*n* = the group number), in which a message scrolls across the second line to remind the user to `Press TARGET RESET for help during set/show routine`. This special use for the **TARGET RESET** button provides the user with a short description of the setting and the range of values, should the user not recognize the setting by its Character string name.

The next menus to appear are to allow the user to enter a specific section of the GROUP settings, rather than having to scroll through all GROUP settings. The sections are **CONFIG**. **SETTINGS**, **GENERAL DATA**, **DIFF ELEMS**, **WINDING *n* ELEMS**, **COMBINED ELEMS**, **24 ELEMS**, **27 ELEMS**, **59 ELEMS**, **81 ELEMS**, and **MISC. TIMERS**. Four additional section titles appear after MISC. TIMERS. These are **TRIP LOGIC**, **CLOSE LOGIC**, **EVENT TRIGGER**, and **OUTPUT CONTACT LOGIC**. These sections are entirely SELOGIC control equations; they cannot be viewed or changed from the front panel. Use an arrow key to scroll past these latter sections. Use any arrow key to move to the section you want, then push **SELECT** to enter that section.

For example, if we select CONFIG. SETTINGS, the first setting `E87W1=Y` appears in the second line of the display. If users do not recognize this setting, they can push the **TARGET RESET** button, and a single scroll across the first line will inform them that this is the `Enable Wdg1 in Differential Element (Y, N)` setting.

If we are in the Show mode, we can only observe the value. The **SELECT** button acts like a down arrow to move to the next setting. The up/down arrows themselves can be used to move within the list of settings.

If in the Set mode, we can choose to change the value by pushing **SELECT**. An underscore will appear under the first character of the value. If changing a discrete values, such as E87W1, the up/down arrows can be used to scroll through the available choices. If changing a numerical variable, the digits change one at a time, using the right/left arrows to move to the digit and the up/down arrows to select the number to insert. When the setting is displayed at its new value, push **SELECT** to enter the change.

When the complete list of settings has been shown or set, the display returns to the menu level at which the user selects which section to Set or Show. **CANCEL** may also be used to move to this level from within the section of settings. **EXIT**, in the Set mode, brings the display to a `Save Changes? Y/N` selection point. In the Show mode, **EXIT** returns you to the default display.

## 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.

This command is like the password setting feature of the **PAS** serial port command. You cannot view the list of passwords from the front panel; you can only enter existing passwords where required, or change them to some other value with this front-panel command.

If PASSWORD is selected, the first display requires you to enter the existing Level 2 password, if password protection is in force.

The next display asks the level of access for which you are changing the password. These are **ACC**, **BAC**, and **2AC**, corresponding to the Level 1, Level B, and Level 2 serial port access request commands. Use the right/left arrow keys and **SELECT** to choose.

The third display permits setting of the new password for the level selected. This is done in the same manner as for normal entering of the password. To set a new password, push **SELECT** when the new password is displayed fully.

**CANCEL** may be used to return to an earlier menu. **EXIT** will abort the **PASSWORD** command and return to the default display.

## PORT

This command is roughly equivalent to the **SET P** and **SHO P** serial port commands. When PORT is selected, a menu appears for selecting which of the four-port setting groups to Show or Set. Use the right/left arrow keys and **SELECT** to choose. The next screen asks whether the user intends to Set or Show the settings. If Set, a password entry screen appears, if password protection is in force.

The next screen is either the **Set PORT *n*** or **Show PORT *n*** display (*n* = the port number), in which a message scrolls across the second line to remind the user to `Press TARGET RESET for help during set/show routine`. This special use for the **TARGET RESET** button provides the user with a short description of the setting and the range of values, should the user not recognize the setting by its character string name. After the scroll, the first setting for the selected port appears in the second line of the display.

For example, the first setting `PROTO=SEL` appears. If users do not recognize this setting, they can push the **TARGET RESET** button, and a single scroll across the first line will inform them that this is the `Protocol (SEL, LMD, DNP)` setting.

If we are in the Show mode, we can only observe the value. The **SELECT** button acts like a down arrow to move to the next setting. The up/down arrows themselves can be used to move within the list of settings.

If in the Set mode, we can choose to change the value by pushing **SELECT**. An underscore will appear under the first character of the value. If changing a discrete value, such as PROTO, the up/down arrows can be used to scroll through the available choices. If changing a numerical variable, change the digits one at a time, using the right/left arrows to move to the digit and the up/down arrows to select the number to insert. When the setting is displayed at the new value, push **SELECT** to enter the change.

When the complete list of settings has been shown or set, the display prompts for a `Save Changes? Y/N` choice. After the choice, it exits the **PORT** command and returns to the default display. **CANCEL** may be used to return to an earlier menu. **EXIT** will abort the **PORT** command and return to the default display.

## CNTRL

Use local control to enable/disable schemes, trip/close breakers, and so on, via the front panel.

### Local Bits

In more specific terms, local control asserts (sets to logical 1) or deasserts (sets to logical 0) what are called local bits LB1 through LB16. These local bits are available as Relay Word bits and are used in SELOGIC control equations.

Local control can emulate the following switch types in *Figure 8.2* through *Figure 8.4*.

**Figure 8.2 Local Control Switch Configured as an ON/OFF Switch**

**Figure 8.3 Local Control Switch Configured as an OFF/MOMENTARY Switch**

**Figure 8.4 Local Control Switch Configured as an ON/OFF/MOMENTARY Switch**

Local control switches are created by making corresponding switch position label settings. These text label settings are set with the **SET** command or viewed with the **SHO** command via the serial port. Refer to *SHO P (Show Port Settings) on page 7.33*.

**Table 8.1 Correspondence Between Local Control Switch Positions and Label Settings**

| Switch Position | Label Setting | Setting Definition | Logic State |
|---|---|---|---|
| not applicable | NLB*n* | Name of Local Control Switch | not applicable |
| ON | SLB*n* | Set Local bit LB*n* | logical 1 |
| OFF | CLB*n* | Clear Local bit LB*n* | logical 0 |
| MOMENTARY | PLB*n* | Pulse Local bit LB*n* | logical 1 for one processing interval |

Note that the first setting in *Table 8.1* (NLB*n*) is the overall switch name setting.

**Table 8.2 Correspondence Between Local Control Switch Types and Required Label Settings**

| Local Switch Type | Label NLBn | Label CLBn | Label SLBn | Label PLBn |
|---|---|---|---|---|
| ON/OFF | X | X | X | |
| OFF/MOMENTARY | X | X | | X |
| ON/OFF/MOMENTARY | X | X | X | X |

Disable local control switches by "nulling out" all the label settings for that switch. The local bit associated with this disabled local control switch is then fixed at logical 0.

## Factory Settings Examples

Local bits LB3 and LB4 are used in a few of the factory SELOGIC control equation settings for manual trip and close functions. Their corresponding local control switch position labels are set to configure the switches as OFF/MOMENTARY switches:

| Local Bit | Label Settings | Function |
|---|---|---|
| LB3 | NLB3 = MANUAL TRIP 1 | trips breaker and drives reclosing relay to lockout |
| | CLB3 = RETURN | OFF position (return from MOMENTARY position) |
| | SLB3 = | ON position—not used (left blank) |
| | PLB3 = TRIP | MOMENTARY position |
| LB4 | NLB4 = MANUAL CLOSE 1 | closes breaker, separate from automatic reclosing |
| | CLB4 = RETURN | OFF position (return from MOMENTARY position) |
| | SLB4 = | ON position—not used (left blank) |
| | PLB3 = CLOSE | MOMENTARY position |

## View Local Control (With Factory Settings)

Access local control via the **CNTRL** pushbutton. If local control switches exist (i.e., corresponding switch position label settings were made), the following message displays with the rotating default display messages.

```
Press CNTRL for
Local Control
```

Press the **CNTRL** pushbutton, and the first set local control switch displays (shown here with factory default settings).

Press the right arrow pushbutton and scroll to the next set local control switch.

The MANUAL TRIP 1: RETURN/TRIP and MANUAL CLOSE 1: RETURN/CLOSE switches are both OFF/MOMENTARY switches (see *Figure 8.4*).

There are no more local control switches in the factory default settings. Press the right arrow pushbutton and scroll to the "output contact testing" function.

This front-panel function provides the same function as the serial port **PUL** command.

## Operate Local Control (With Factory Settings)

Press the right arrow pushbutton, and scroll back to the first set local control switch in the factory default settings.

Press the **SELECT** pushbutton, and the operate option for the displayed local control switch displays.

Scroll left with the left arrow button and then select `Yes`. The display then shows the new local control switch position.

Because this is an OFF/MOMENTARY type switch, the MANUAL TRIP 1 switch returns to the RETURN position after momentarily being in the TRIP position. Technically, the MANUAL TRIP 1 switch (being an OFF/MOMENTARY type switch) is in the TRIP position for one processing interval (1/4 cycle; long enough to assert the corresponding local bit LB3 to logical 1) and then returns to the RETURN position (local bit LB3 deasserts to logical 0 again).

On the display, the MANUAL TRIP 1 switch is shown to be in the TRIP position for two seconds (long enough to be seen), and then it returns to the RETURN position.

The MANUAL CLOSE 1 switch is an OFF/MOMENTARY type switch, like the MANUAL TRIP 1 switch, and operates similarly.

## Local Control State Retained When Relay De-Energized

Local bit states are stored in nonvolatile memory, so when power to the relay is turned off, the local bit states are retained.

For example, suppose the local control switch with local bit output LB1 is configured as an ON/OFF type switch (as shown below).

If power to the relay is turned off and then turned on again, local bit LB1 remains at logical 1. This is similar to a traditional panel, where enabling/disabling of other functions is accomplished by panel-mounted switches. If dc control voltage to the panel is lost and then restored again, the switch positions are still in place. If the switch is in the enable position (switch closed) before the power outage, it will be in the same position after the outage when power is restored.

## Pulse Output Contacts

Use the control button **Ctrl** to mimic the **PULse**, **OPEn**, and **CLOse** serial port commands. This is useful during relay checkout, to verify that output contacts actually function in response to a command.

Under the CTRL menu, use local bit pushbutton functions to select whether to PULSE, CLOSE, or OPEN individual local bits. The screen will prompt for `Pulse  Close  Open`. Use the right/left arrow keys and **SELECT** to choose.

If Pulse is selected, the next screen will prompt for the output to be pulsed. These are OUT101 to OUT107 and ALARM. Use the up/down arrow keys and **SELECT** to choose. The display will follow with a Yes/No verification request. Again, use the up/down arrow keys and **SELECT** to choose.

The relay will pulse the output contact for one second, then return to the contact selection screen, in case there are more contacts to test. **CANCEL** will return to the main CNTRL menu. **EXIT** will abort the command and return to the default display.

**NOTE:** The CNTRL function, while useful during testing, should not be used while the relay is actually in service. During the one-second interval while contact OUT10X is being pulsed, all other OUT10Y contacts are frozen in their existing state and are not permitted to change. This could prevent a trip or other vital output from being issued during the pulse interval.

If Close is selected, the next screen prompts for the breaker (Bk1 to Bk4) to be closed. Use the right/left arrow keys and **SELECT** to choose, for example, Bk1. The relay then asks `Close Bkr 1?  Yes  No`. Use the right/left arrow keys and **SELECT** to choose. If Yes, the relay asserts the CC1 Relay Word bit. If CC1 has been assigned to the CL1 Close Logic setting, the breaker will close. If No is selected, the relay returns to the Close menu.

If Open is selected, a sequence exactly like the one for Close takes place. If Yes is selected, the relay asserts Relay Word bit OC1 for Bkr 1, and if this bit has been assigned to the TR1 Trip Logic setting, the breaker will open. The TRIP front-panel LED will also light. It can be turned off by pushing the TARGET RESET button or by the **TAR R** serial port command.

Because all three CNTRL functions are legitimate event types, an Event Report will be triggered whenever any is activated. An automatic message will be sent to any port set to receive messages. If the output contacts are listed as SER triggers, the contact assertion and deassertion will appear in the SER report, with time tags. Contact operate timing can thus be easily analyzed.

### GROUP

The GROUP function is identical to the **GRO** and **GRO *n*** (*n* = 1 to 6) serial port commands.

When you select the GROUP button, the relay display shows `Active Group 1` (for example), and inquires whether you want to Change or Exit. Use the right/left arrow keys and SELECT to choose.

If Change is selected, the display shows `Change to Group` in the first line and the present group number in the second line. Use the up/down arrows and SELECT to choose another group. The relay will ask for a Yes/No verification of the change. Use the right/left arrow keys and SELECT to choose. The change will be made and the ALARM contact pulsed for one second if Yes is chosen, and if SS1 through SS6 are not asserted or assigned. These group selection settings always take precedence over the **GROUP** command function.

CANCEL may be used to return to an earlier menu. EXIT will abort the command and return to the default display.

## Secondary Function Review

The secondary button functions come into effect as soon as one of the buttons for the above primary functions has been pushed. These secondary functions remain in effect until a primary function has been completed, aborted or exited, and the display has returned to the default display. They will be discussed in the left to right order in which they appear on the front panel, below the horizontal line. The first button, TARGET RESET/LAMP TEST, has no secondary function except as a HELP key, explained earlier under the SET primary function.

### CANCEL

The CANCEL button returns the display to the previous menu, within a primary function. Use the CANCEL button to go back after issuing a SELECT. If there is no previous menu, the default display is shown. If the CANCEL button is pushed while in the default display mode, the relay interprets the button as the METER button.

### SELECT

The SELECT button is used within primary function dialogs to select a menu choice. Once the choice has been identified with the arrow buttons, use the SELECT button to select that choice. If the SELECT button is pushed while in the default display mode, the relay interprets the button as the EVENTS button.

### Arrows

The arrow buttons are used throughout the front-panel primary function displays for scrolling through lists of items, identifying menu choices by moving the cursor, and scrolling to the left or right for more information. If one of the arrow buttons is pushed while in the default display mode, the relay interprets the button according to the primary function. That is:

"left" = STATUS, "right" = OTHER, "up" = SET, and "down" = CNTRL.

### EXIT

If you push the EXIT button at any time within one of the dialogs, the procedure is aborted, and the display reverts to the default display. If the EXIT button is pushed while in the default display mode, the relay interprets the button as the GROUP button.

## Pushbutton/Serial Port Equivalents

*Table 8.3* summarizes the pushbutton functions and their approximate equivalents in serial port commands.

**Table 8.3 Front-Panel Button Serial Port Equivalents**

| Button | Similar SEL-387E Serial Port Commands |
|---|---|
| TARGET RESET/LAMP TEST | **TAR R** |
| METER | **MET**, **MET** (**D**, **DIF**, **P**, **SEC**, **RD**, **RP**) |
| EVENTS | **HIS** |
| STATUS | **STA** |
| OTHER | **DAT**, **TIM**, **TAR F**, **BRE**, **BRE R**, **RES** |
| SET | **SET**, **SET G**, **SET P**, **SHO**, **SHO G**, **SHO P**, **PAS** |
| CNTRL | **PUL**, **CLO**, **OPE** |
| GROUP | **GRO**, **GRO *n*** |

# Programmable LEDA, LEDB, LEDC

Three of the LEDs in the second row may be programmed by the user through use of SELOGIC control equations. These settings appear under the FRONT PANEL section of the GLOBAL settings, accessible by the **SHO G** and **SET G** serial port commands. These settings can neither be seen nor changed from the front panel itself.

The factory default settings are as follows:

**LEDA** = OCA + 87E1 **LEDB** = OCB + 87E2 **LEDC** = OCC + 87E3

The Relay Word bits OCA, OCB, and OCC indicate selection of Phase A, B or C by the overcurrent elements for those respective phases. The Relay Word bits 87E1, 87E2, and 87E3 indicate trips initiated by differential elements 1, 2, or 3, respectively. These correspond, essentially, to Phases A, B, and C. Thus, LEDA, LEDB, and LEDC are factory set to indicate either an overcurrent or differential selection of their respective phases as the ones involved in a fault. They are therefore labeled as FAULT TYPE LEDs.

It is probably best to leave these settings in place when the relay is in service. Otherwise, observers of the front-panel labels might be confused by seeing the LEDs lit for apparently no reason; determining why the LEDs are lit would be impossible without a serial port connection to the relay. For testing or other purposes, however, these programmable LEDs may be very helpful for identifying conditions, defined by SELOGIC control equations that are of interest to the user.

# Programmable Default Display Points

Rotating default displays on the relay front panel replace indicating panel lights. Traditional indicating panel lights are turned on and off by circuit breaker auxiliary contacts, front-panel switches, SCADA contacts, etc. They indicate such conditions as circuit breaker open/closed.

## Traditional Indicating Panel Lights Replaced With Rotating Default Display

The indicating panel lights are not needed if the rotating default display feature in the SEL-387E is used.

There are 16 of these default displays available in the SEL-387E. Referred to as Display Points, each default display has available two complementary screens (e.g., `BREAKER CLOSED` and `BREAKER OPEN`). The settings for these Display Points are located in the FRONT PANEL area of the GLOBAL settings. They are viewable and settable from the serial ports, via the **SHO G** or **SET G** commands. Because they include SEL-387E control equations and variable text, they cannot be accessed from the front panel.

## General Operation of Rotating Default Display Settings

SELOGIC control equations display point setting DP*n* (*n* = 1 through 16) controls the display of corresponding, complementary text settings:

DP*n*_1 (displayed when DP*n* = logical 1)

DP*n*_0 (displayed when DP*n* = logical 0)

Make each text setting through the serial port using the command **SET G**. View these text settings using the serial port command **SHO G**. These text settings are displayed in pairs on the SEL-387E front-panel display on a two-second rotation. They must not be longer than 16 characters. Any active Display Points take precedence as the default display over the standard scroll through the winding current values. Relay-generated messages, however, take precedence over the Display Points.

Below are some examples of how the Display Points may be used.

### Circuit Breaker Status Indication Example

Make SELOGIC control equations display point setting DP2:

DP2 = IN102  (IN102 is assigned to the 52A2 function for Breaker 2)

Make corresponding, complementary text settings:

DP2_1 = BREAKER 2 CLOSED

DP2_0 = BREAKER 2 OPEN

Display point setting DP2 controls the display of the text settings.

### Circuit Breaker Closed

The optoisolated input IN102 is energized when the 52a circuit breaker auxiliary contact is closed, resulting in:

DP2 = IN102 = logical 1

This results in the display of corresponding text setting DP2_1 on the front-panel display:

```
BREAKER 2 CLOSED
```

### Circuit Breaker Open

The optoisolated input IN1 is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

DP2 = IN102 = logical 0

This results in the display of corresponding text setting DP2_0 on the front-panel display:

```
BREAKER 2 OPEN
```

## Display Only One Message Example

To display just one screen, but not its complement, set only one of the text settings. For example, to display just the "breaker closed" condition, but not the "breaker open" condition, make the following settings:

| | |
|---|---|
| DP2 = IN102 | (52a circuit breaker auxiliary contact connected to input IN102) |
| DP2_1 = BREAKER 2 CLOSED | (displays when DP2 = logical 1) |
| DP2_0 = | (blank) |

### Circuit Breaker Closed

The optoisolated input IN102 is energized when the 52a circuit breaker auxiliary contact is closed, resulting in:

DP2 = IN102 = logical 1

This results in the display of corresponding text setting DP2_1 on the front-panel display:

```
BREAKER 2 CLOSED
```

### Circuit Breaker Open

The optoisolated input IN102 is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

DP2 = IN102 = logical 0

Corresponding text setting DP2_0 is not set (it is blank), so no message is displayed on the front-panel display.

# Figures of Selected Front-Panel Menu Structures

**Figure 8.5 METER Menu and Display Structure**

**Figure 8.6 METER Menu and Display Structure (continued)**

**Figure 8.7 METER Menu and Display Structure (continued)**

Where n = event number
m = group number

Note: If secondary currents > 99.9, drop the decimal place.

**Figure 8.8 EVENTS Display Structure**

**Figure 8.9 OTHER/BKR Menu and Display Structure**

**Figure 8.10 SET Menu and Display Structure**

# Section 9

# Analyzing Events

## Introduction

The SEL-387E Relay offers two styles of event reports:

- Standard 15-, 29-, or 60-cycle event reports
- Sequential Events Recorder (SER) report

These event reports contain date, time, current, relay element, optoisolated input, and output contact information.

The relay generates (triggers) standard 15-, 29-, or 60-cycle event reports by fixed and programmable conditions. These reports show information for 15, 29, or 60 continuous cycles depending on the Global setting LER. The length of the pre-fault data contained in the event report is determined by the Global setting PRE. This setting allows for 1 to (LER-1) cycles of pre-fault data in each event report. The number of event reports stored in nonvolatile memory depends on the LER setting as follows:

| LER | Number of Event Reports Saved |
|---|---|
| 15 | 18–21 |
| 29 | 12–14 |
| 60 | 7 |

The number of events saved will be fewer if mixed lengths (e.g., LER = 60 for three event reports and then changed to LER = 29) are stored together or if the relay is subjected to frequent turn-off/turn-on cycles.

If the relay nonvolatile memory is full and another event is triggered, the latest event report will overwrite the oldest event report, and the oldest event report will be lost. See *Figure 9.2* for an example standard 15-cycle event report.

The relay adds lines in the Sequential Events Recorder (SER) report by programmable conditions only. The SER lists date and time-stamped lines of information each time a programmed condition changes state. The relay stores the latest 512 lines of the SER report in nonvolatile memory. If the report fills up, newer rows overwrite the oldest rows in the report. See *Figure 9.8* for an example SER report.

# Standard 15-, 29-, or 60-Cycle Event Reports

## Event Report Length (Settings LER and PRE)

The SEL-387E provides user-programmable event report length and pre-fault length. Event report length is set at 15, 29, or 60 cycles, using the Global setting LER. Pre-fault length ranges from 1 to (LER-1) cycles. Set the pre-fault length with the Global setting PRE. The LER and PRE settings are accessible via either the **SET G** serial port command or the **SET/GLOBAL** front-panel pushbuttons.

Changing the LER and/or PRE settings has no effect on previously stored nonvolatile reports.

## Standard Event Report Triggering

The relay triggers (generates) a standard 15-, 29-, or 60-cycle event report when any of the following occurs:

- Relay Word bits TRIP1 through TRIP4 assert
- Relay Word bits CLS1 through CLS3 assert
- Programmable SELOGIC® control equation setting ER asserts to logical 1
- **PULSE** serial port/front-panel command executed for output contacts
- **TRIGGER** serial port command executed

### Relay Word Bits TRIP1–TRIP4, CLS1–CLS3

Relay Word bits TRIP*n* (*n* = 1, 2, 3, or 4) would usually be assigned to an output contact for tripping a circuit breaker (e.g., setting OUT101 = TRIP1). SELOGIC control equation settings TR*n* initiate the Trip Logic and control the assertion of Relay Word bits TRIP*n* (see *Figure 5.7*). The Relay Word bit OC*m* (*m* = 1, 2, 3), initiated by the "Open breaker *m*" serial port command **OPE *m*** or the front-panel CNTRL/Open command, would normally be assigned to TR*m*.

Similarly, Relay Word bits CLS*m* (*m* = 1, 2, 3) would be assigned to an output contact for closing a circuit breaker (e.g., setting OUT105 = CLS1). SELOGIC control equation settings CL*m* initiate the Close Logic and control the assertion of Relay Word bits CLS*m* (see *Figure 5.8*). The Relay Word bit CC*m*, initiated by the "Close breaker *m*" serial port command CLO *m* or the front-panel CNTRL/Close command, would normally be assigned to CL*m*.

Any condition that is set to trip in setting TR*n*, or to close in setting CL*m*, does not have to be entered in SELOGIC control equation setting ER. The assertion of Relay Word bit TRIP*n* or CLS*m* automatically triggers a standard 15-, 29-, or 60-cycle event report.

### Programmable SELOGIC Control Equation Setting ER

The SELOGIC control equation setting ER is set to trigger standard 15-, 29-, or 60-cycle event reports for conditions other than tripping or closing conditions already listed in settings TR*n* or CL*m*. When setting ER sees a logical 0 to logical 1 transition, it generates an event report (if it is not already generating a report that encompasses the new transition). The factory setting is:

ER = /50P11 + /51P1 + /51Q1 + /51P2 + /51Q2 + /51P3

ER is factory set with definite-time and inverse-time overcurrent element pickups for phase- and negative-sequence quantities on Windings 1, 2, and 3. Thus, at the inception of a fault, whichever pickup asserts first will trigger a standard 15-, 29-, or 60-cycle event report.

Note the rising-edge operator symbol (/) in front of each of these elements. See *Section 4: Control Logic* for more information on rising-edge operators and SELOGIC control equations in general.

Rising-edge operators are especially useful in generating an event report at fault inception, then generating another event report later if a breaker trips on some time-delayed element.

### PULSE and TRIGGER Commands

The **PUL** serial port/front-panel command is used to assert the output contacts for testing purposes or for remote control. If an output contact is asserted with the **PUL** command, a standard 15-, 29-, or 60-cycle event report is also generated. Because the **PUL** command generates an event report, precautions should be taken to retrieve and store any existing event reports of interest that presently may be in the relay, before testing the output contacts with the **PUL** command. Failure to do so may result in some or all of the existing reports being overwritten when **PUL** commands are issued.

The sole function of the **TRI** serial port command is to generate standard 15-, 29-, or 60-cycle event reports, primarily for testing purposes. Simply type **TRI <Enter>**, to execute the command.

See *Section 7: Communications* for more information on the serial port commands **TRI** and **PUL**.

## Standard Event Report Summary

Each time the relay generates a standard 15-, 29-, or 60-cycle event report, it also generates a corresponding event summary (see *Figure 9.1*). Event summaries contain the following information:

- Relay and terminal identifiers (settings RID and TID)
- Date and time when the event was triggered
- Event type
- Front-panel targets at the time of trip
- Phase (IA, IB, IC) currents for the three (3) current winding inputs
- Phase (VA, VB, VC) voltage inputs
- Percent volts/hertz

This event summary information is also contained in the corresponding standard 15-, 29-, or 60-cycle event report. The identifiers, date, and time information is at the top of the standard 15-, 29-, or 60-cycle event report, and the other information follows at the end. See *Figure 9.2*.

The example event summary in *Figure 9.1* corresponds to the full-length standard 15-cycle event report in *Figure 9.2*.

```
XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
Event: TRIG
Targets:
Winding 1 Currents (A Sec), ABC:   123.1   123.1   123.1
Winding 2 Currents (A Sec), ABC:   123.1   123.1   123.1
Winding 3 Currents (A Sec), ABC:   123.1   123.1   123.1
Winding X Voltages (V Sec), ABC:   123.1   123.1   123.1
Volts/Hertz Percent:   123.1
=>>
```

**Figure 9.1 Example Event Summary**

**NOTE:** The relay sends event summaries to all serial ports with setting AUTO = Y each time an event triggers.

The latest 99 event summaries are stored in nonvolatile memory and are accessed by the **HIS** command. The **HIS C** command clears the event summaries and corresponding full-length standard event reports from nonvolatile memory. See *HIS (History of Events) on page 7.22* and *HIS C (Clear History and Events) on page 7.23* for more information.

## Event Type

The "Event:" field shows the event type. The possible event types and their descriptions are shown in *Table 9.1*. Note the correspondence to the preceding event report triggering conditions (see *Standard Event Report Triggering on page 9.2*).

**Table 9.1 Event Types**

| Event | Event Triggered by: |
|---|---|
| TRIP1 | Assertion of Relay Word bit TRIP1 |
| TRIP2 | Assertion of Relay Word bit TRIP2 |
| TRIP3 | Assertion of Relay Word bit TRIP3 |
| TRIP4 | Assertion of Relay Word bit TRIP4 |
| CLS1 | Assertion of Relay Word bit CLS1 |
| CLS2 | Assertion of Relay Word bit CLS2 |
| CLS3 | Assertion of Relay Word bit CLS3 |
| ER | SELOGIC control equation setting ER |
| PULSE | Execution of **PUL** serial port command |
| TRIG | Execution of **TRI** serial port command |

The order of precedence for listing the event type in the summary is: TRIP, CLOSE, ER, PULSE, TRIG (as implied by the table). If more than one type of report trigger occurs within the same report period, the type of highest precedence will be shown in the "Event:" field of the report summary.

## Targets

The target field shows all front-panel targets that were illuminated at the end of the triggered event report. The targets include: TRIP, INST, 87-1, 87-2, 87-3, 24, 50/51, 81, A, B, C, N, W1, W2, and W3.

### Winding Currents

The "Winding *n* Currents (A Sec), ABC:" (*n* = 1, 2, or 3) field shows each winding input current present in the event report row containing the maximum secondary phase current. The standard 15-, 29-, or 60-cycle event report will mark the reference row used in the summary report with an asterisk. The listed currents for each of the three (3) winding inputs are:

Phase (A = channel IA, B = channel IB, C = channel IC)

### Voltages

The "Winding *n* Voltages (V Sec), ABC:" (*n* = 1, 2, or 3) field shows each winding input voltage present in the event report row containing the maximum secondary phase current. The standard 15-, 29-, or 60-cycle event report will mark the reference row used in the summary report with an asterisk. The listed voltages for each of the three (3) winding inputs are:

Phase (A = channel VA, B = channel VB, C = channel VC)

Percent Volts/Hertz

## Retrieving Full-Length Standard Event Reports

Any given event report has four different ways it can be displayed, depending on the particular serial port command issued to the relay. The command choices are shown below.

| Serial Port Command | Format |
|---|---|
| **EVENT** | Winding event report |
| **EVENT C** | Compressed ASCII event report |
| **EVENT D** | Digital event report |
| **EVENT DIF** | Differential event report |
| **EVENT R** | Raw (unfiltered) winding event report |

### Event (Winding Event Report)

The winding event report contains secondary phase currents for each of the three current winding inputs and secondary phase voltages for the voltage winding inputs, as well as the status of the eight digital outputs and six optoisolated inputs.

Use the **EVE** command to retrieve winding event reports. There are several options for customizing the report format. The general command format is:

**EVE [*n*, S*x*, L*y*[-[*w*]]]** (parameters in [ ] are optional)

where:

| | |
|---|---|
| *n* | Event number; defaults to 1 if not listed, where 1 is the most recent event. |
| S*x* | Display *x* samples per cycle (4 or 8); defaults to 4 if not listed. |
| L*y* | Display *y* cycles of data (1 to LER); defaults to LER if not listed. |
| L*y*- | Display from cycle *y* to end of report. |
| L*y*-*w* | Display from cycle *y* to cycle *w*. |

Refer to *Figure 9.2* for an example winding event report. This example event report displays rows of information each quarter-cycle; it was retrieved with the **EVE <Enter>** command.

```
=>>EVE <Enter>
XFMR 1                                  Date: MM/DD/YY  Time: HH:MM:SS.SSS
STATION A

FID=SEL-387E-R700-V0-Z101003-D20060616

Winding 1         Winding 2         Winding 3        Winding X           OUT  IN
    Amps Sec          Amps Sec          Amps Sec         Volts Sec        1357 135
 IAW1  IBW1  ICW1  IAW2  IBW2  ICW2  IAW3  IBW3  ICW3  VAWX  VBWX  VCWX  246A 246
 [1]
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
 [2]
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
   .
   .
   .
 [15]
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...

Event: TRIP1 TRIP2 TRIP3 TRIP4
Targets: TRIP INST 87-1 87-2 87-3 24 81 A B C N W1 W2 W3 50/51
Winding 1 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding 2 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding 3 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding X Voltages (V Sec), ABC:  123.1   123.1   123.1
Volts/Hertz Percent:  123.1
=>>
```

**Figure 9.2 Example Winding Event Report**

The trigger row includes a ‘>’ character following immediately after the last analog column to indicate the trigger point. A ‘*’ character following immediately after the last analog column denotes that the designated row was used for the Event Summary currents. The ‘*’ character takes precedence over the ‘>’ character when both conditions occur for the same row.

*Table 9.2* summarizes the event report current columns. The column headings shown are the default headings, corresponding to the designations on terminals Z01 to Z21. If the Analog Input Labels settings have been changed within the Global setting area, these will appear in the report as set.

**Table 9.2 Winding Event Report Current Columns**

| Column Heading | Definition |
|---|---|
| IAW1 | Current measured by Winding 1 input channel IA (amperes, secondary) |
| IBW1 | Current measured by Winding 1 input channel IB (amperes, secondary) |
| ICW1 | Current measured by Winding 1 input channel IC (amperes, secondary) |
| IAW2 | Current measured by Winding 2 input channel IA (amperes, secondary) |
| IBW2 | Current measured by Winding 2 input channel IB (amperes, secondary) |
| ICW2 | Current measured by Winding 2 input channel IC (amperes, secondary) |
| IAW3 | Current measured by Winding 3 input channel IA (amperes, secondary) |
| IBW3 | Current measured by Winding 3 input channel IB (amperes, secondary) |
| ICW3 | Current measured by Winding 3 input channel IC (amperes, secondary) |
| VAWX | Voltage measured by Winding x input channel VA (volts, secondary) |
| VBWX | Voltage measured by Winding x input channel VB (volts, secondary) |
| VCWX | Voltage measured by Winding x input channel VC (volts, secondary) |

*Table 9.3* summarizes the winding event report output and input columns.

**Table 9.3 Winding Event Report Output and Input Columns**

| Column Heading | Symbol | Definition |
|---|---|---|
| All | . | All indication deasserted |
| OUT 12 | 1 | Output contact OUT101 asserted |
| | 2 | Output contact OUT102 asserted |
| | b | Both OUT101 and OUT102 asserted |
| OUT 34 | 3 | Output contact OUT103 asserted |
| | 4 | Output contact OUT104 asserted |
| | b | Both OUT103 and OUT104 asserted |
| OUT 56 | 5 | Output contact OUT105 asserted |
| | 6 | Output contact OUT106 asserted |
| | b | Both OUT105 and OUT106 asserted |
| OUT 7A | 7 | Output contact OUT107 asserted |
| | A | Output contact ALARM asserted |
| | b | Both OUT107 and ALARM asserted |
| IN 12 | 1 | Optoisolated input IN101 asserted |
| | 2 | Optoisolated input IN102 asserted |
| | b | Both IN101 and IN102 asserted |
| IN 34 | 3 | Optoisolated input IN103 asserted |
| | 4 | Optoisolated input IN104 asserted |
| | b | Both IN103 and IN104 asserted |
| IN 56 | 5 | Optoisolated input IN105 asserted |
| | 6 | Optoisolated input IN106 asserted |
| | b | Both IN105 and IN106 asserted |

## Event D (Digital Event Report)

The digital event report contains the status of the overcurrent elements (instantaneous, definite-time and inverse-time overcurrent phase, single-phase, calculated residual, and negative-sequence overcurrent elements), combined current overcurrent elements, voltage and frequency elements, dc battery monitor, and the demand current thresholds (phase, calculated residual, and negative-sequence for each of the three winding inputs). The status of the Relay Word bits TRIP*n* (*n* = 1, 2, 3, and 4), as well as the status of the eight digital outputs and six optoisolated inputs, is also included.

Use the **EVE D** command to retrieve digital event reports. There are several options for customizing the report format. The general command format is:

**EVE D [*n*, S*x*, L*y*[-[*w*]]]** (parameters in [ ] are optional)

where:

*n* Event number; defaults to 1 if not listed, where 1 is the most recent event.

S*x* Display *x* samples per cycle (4 or 8); defaults to 4 if not listed.

L*y* Display *y* cycles of data (1 to LER); defaults to LER if not listed.

L*y*- Display from cycle *y* to end of report.

L*y*-*w* Display from cycle *y* to cycle *w*.

Refer to *Figure 9.3* for an example digital event report. This example event report displays rows of information each quarter-cycle; it was retrieved with the **EVE D <Enter>** command.

```
=>>EVE D <Enter>
XFMR 1                                  Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

FID=SEL-387E-R700-V0-Z101003-D20060616

     Overcurrent Elements                Voltage/Freq
Winding 1    Winding 2    Winding 3       Elements             D
5        5   5        5   5        5   5  2  2  5    8   T     E      O
0        1   0        1   0        1   1  4  7  9    1   R  D  M      U    I
PPABCNNQQPNQ PPABCNNQQPNQ PPABCNNQQPNQ PN DC PVPPVPGQ    P  C  PPNNQQ T    N
123331212    123331212    123331212    CC 12  1P 1P  135 13 13 131313 1357 135
  444          444          444        11            246 24 24 2 2 2  246A 246
[1]
............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...
[2]
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............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...*
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[15]
............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...
............ ............ ............ .. .. ........... .. .. ...... .... ...

Event: TRIP1 TRIP2 TRIP3 TRIP4

Targets: TRIP INST 87-1 87-2 87-3 24 81 A B C N W1 W2 W3 50/51
Winding 1 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding 2 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding 3 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding X Voltages (V Sec), ABC:  123.1   123.1   123.1
Volts/Hertz Percent: 123.1
=>>
```

**Figure 9.3 Example Digital Event Report**

The trigger row includes a ‘>’ character following immediately after the last digital column to indicate the trigger point. A ‘*’ character following immediately after the last digital column denotes that the designated row was used for the Event Summary currents. The ‘*’ character takes precedence over the ‘>’ character when both conditions occur for the same row.

The following table summarizes the digital event report columns.

**Table 9.4 Digital Event Report Column Description** (Sheet 1 of 4)

| Column Heading | Symbol | Definition |
|---|---|---|
| All | . | All indication deasserted |
| Wdg 1<br>50P1 | 1<br>T | 50P11 asserted<br>50P11T asserted |
| Wdg 1<br>50P2 | 2 | 50P12 asserted |
| Wdg 1<br>50A34 | 3<br>4<br>b | 50A13 asserted<br>50A14 asserted<br>50A13 and 50A14 asserted |

**Table 9.4 Digital Event Report Column Description** (Sheet 2 of 4)

| Column Heading | Symbol | Definition |
|---|---|---|
| Wdg 1 50B34 | 3 | 50B13 asserted |
| | 4 | 50B14 asserted |
| | b | 50B13 and 50B14 asserted |
| Wdg 1 50C34 | 3 | 50C13 asserted |
| | 4 | 50C14 asserted |
| | b | 50C13 and 50C14 asserted |
| Wdg 1 50N1 | 1 | 50N11 asserted |
| | T | 50N11T asserted |
| Wdg 1 50N2 | 2 | 50N12 asserted |
| Wdg 1 50Q1 | 1 | 50Q11 asserted |
| | T | 50Q11T asserted |
| Wdg 1 50Q2 | 2 | 50Q12 asserted |
| Wdg 1 51P | p | 51P1 asserted |
| | T | 51P1T asserted |
| | r | Timing to reset (51P1RS = Y) |
| | 1 | Timing to reset after 51P1T assertion (51P1RS = N) |
| | . | 51P1R asserted |
| Wdg 1 51N | p | 51N1 asserted |
| | T | 51N1T asserted |
| | r | Timing to reset (51N1RS=Y) |
| | 1 | Timing to reset after 51N1T assertion (51N1RS=N) |
| | . | 51N1R asserted |
| Wdg 1 51Q | p | 51Q1 asserted |
| | T | 51Q1T asserted |
| | r | Timing to reset (51Q1RS = Y) |
| | 1 | Timing to reset after 51Q1T assertion (51Q1RS = N) |
| | . | 51Q1R asserted |
| Use same logic for overcurrent elements in Wdg 2 and Wdg 3. | | |
| 51PC1 | p | 51PC1 asserted |
| | T | 51PC1T asserted |
| | r | Timing to reset (51PC1RS=Y) |
| | 1 | Timing to reset after 51PC1T assertion (51PC1RS=N) |
| | . | 51PC1R asserted |
| 51NC1 | p | 51NC1 asserted |
| | T | 51NC1T asserted |
| | r | Timing to reset (51NC1RS=Y) |
| | 1 | Timing to reset after 51NC1T assertion (51NC1RS=N) |
| | . | 51NC1R asserted |
| 24D1 | 1 | 24D1 element picked up |
| | D | 24D1 element picked up; timer timed out on pickup time; timer output 24D1T asserted |
| 24C2 | 2 | 24C2 element picked up and timing |
| | C | 24C2 element timed out |
| | r | 24C2 element fully reset |

**Table 9.4 Digital Event Report Column Description** (Sheet 3 of 4)

| Column Heading | Symbol | Definition |
|---|---|---|
| 27P | 1 | L 1 instantaneous phase undervoltage element picked up |
| | 2 | L 2 instantaneous phase undervoltage element picked up |
| | b | Both Level 1 and Level 2 phase undervoltage elements picked up |
| 27V1 | V | 27V1 positive-sequence undervoltage element picked up |
| 27PP | 1 | Level 1 phase-to-phase undervoltage element picked up |
| | 2 | Level 2 phase-to-phase undervoltage element picked up |
| | b | Both Level 1 and Level 2 phase-to-phase undervoltage elements picked up |
| 59P | 1 | L 1 instantaneous phase overvoltage element picked up |
| | 2 | L 2 instantaneous phase overvoltage element picked up |
| | b | Both Level 1 and Level 2 phase overvoltage elements picked up |
| 59V1 | V | Positive-sequence instantaneous overvoltage element 59V1 picked up |
| 59PP | 1 | Level 1 phase-to-phase instantaneous overvoltage element picked up |
| | 2 | Level 2 phase-to-phase instantaneous overvoltage element picked up |
| | b | Both phase-to-phase instantaneous overvoltage elements picked up |
| 59G | 1 | Level 1 instantaneous residual overvoltage element picked up |
| | 2 | Level 2 instantaneous residual overvoltage element picked up |
| | b | Both Level 1 and Level 2 residual overvoltage elements picked up |
| 59Q | Q | Negative-sequence instantaneous overvoltage element 59Q picked up |
| 81D 12 | 1 | Frequency element 81D1 asserted |
| | 2 | Frequency element 81D2 asserted |
| | b | Both frequency elements asserted |
| 81D 34 | 3 | Frequency element 81D3 asserted |
| | 4 | Frequency element 81D4 asserted |
| | b | Both frequency elements asserted |
| 81D 56 | 5 | Frequency element 81D5 asserted |
| | 6 | Frequency element 81D6 asserted |
| | b | Both frequency elements asserted |
| TRP 12 | 1 | TRIP1 asserted |
| | 2 | TRIP2 asserted |
| | b | TRIP1 and TRIP2 asserted |
| TRP 34 | 3 | TRIP3 asserted |
| | 4 | TRIP4 asserted |
| | b | TRIP3 and TRIP4 asserted |
| DC 12 | 1 | DC1 asserted |
| | 2 | DC2 asserted |
| | b | DC1 and DC2 asserted |
| DC34 | 3 | DC3 asserted |
| | 4 | DC4 asserted |
| | b | DC3 and DC4 asserted |

**Table 9.4 Digital Event Report Column Description** (Sheet 4 of 4)

| Column Heading | Symbol | Definition |
|---|---|---|
| DEM P12 | 1 | PDEM1 asserted |
| | 2 | PDEM2 asserted |
| | b | PDEM1 and PDEM2 asserted |
| DEM P3 | 3 | PDEM3 asserted |
| DEM N12 | 1 | NDEM1 asserted |
| | 2 | NDEM2 asserted |
| | b | NDEM1 and NDEM2 asserted |
| DEM N3 | 3 | NDEM3 asserted |
| DEM Q12 | 1 | QDEM1 asserted |
| | 2 | QDEM2 asserted |
| | b | QDEM1 and QDEM2 asserted |
| DEM Q3 | 3 | QDEM3 asserted |
| OUT 12 | 1 | Output contact OUT101 asserted |
| | 2 | Output contact OUT102 asserted |
| | b | Both OUT101 and OUT102 asserted |
| OUT 34 | 3 | Output contact OUT103 asserted |
| | 4 | Output contact OUT104 asserted |
| | b | Both OUT103 and OUT104 asserted |
| OUT 56 | 5 | Output contact OUT105 asserted |
| | 6 | Output contact OUT106 asserted |
| | b | Both OUT105 and OUT106 asserted |
| OUT 7A | 7 | Output contact OUT107 asserted |
| | A | Output contact ALARM asserted |
| | b | Both OUT107 and ALARM asserted |
| IN 12 | 1 | Optoisolated input IN101 asserted |
| | 2 | Optoisolated input IN102 asserted |
| | b | Both IN101 and IN102 asserted |
| IN 34 | 3 | Optoisolated input IN103 asserted |
| | 4 | Optoisolated input IN104 asserted |
| | b | Both IN103 and IN104 asserted |
| IN 56 | 5 | Optoisolated input IN105 asserted |
| | 6 | Optoisolated input IN106 asserted |
| | b | Both IN105 and IN106 asserted |

## Event DIF (Differential Event Report)

The differential event report contains the operate and restraint currents in a given differential element along with the second- and fifth-harmonic content of the current. The status of the restrained and unrestrained differential elements, the fifth-harmonic alarm, the restricted earth fault function, the Relay Word bits TRIP*n* (*n* = 1, 2, 3, and 4), the SELOGIC control equation Timed Variables and Latch Bits, eight of the 16 Remote Bits, the eight digital outputs, and the six optoisolated inputs are shown.

Use the **EVE DIF** command to retrieve differential event reports. There are several options to customize the report format. The general command format is:

**EVE DIF*z* [*n*, S*x*, L*y*[-[*w*]]]** (parameters in [ ] are optional)

where:

| | |
|---|---|
| *z* | Display results for differential element *z* (*z* = 1, 2, or 3). |
| *n* | Event number; defaults to 1 if not listed, where 1 is the most recent event. |
| S*x* | Display *x* samples per cycle (4 or 8); defaults to 4 if not listed. |
| L*y* | Display *y* cycles of data (1 to LER); defaults to LER if not listed. |
| L*y*- | Display from cycle *y* to end of report. |
| L*y*-*w* | Display from cycle *y* to cycle *w*. |

Refer to *Figure 9.4* for an example differential event report. This example event report displays rows of information each quarter-cycle; it was retrieved with the **EVE DIF1 <Enter>** command.

```
=>>EVE DIF1 <Enter>
XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A
FID=SEL-387E-R700-V0-Z101003-D20060616
                             Differential       Set 1  Set 2  Set 3
    Differential Quantities  87   87B HB  TR TRP    LT     LT          OUT  IN
       Multiples of TAP      R            HE 13 VVVV13 VVVV13 VVVVVVVV 1357 135
   IOP1   IRT1   I1F2   I1F5 U123 123 123 5F 24 123424 123424 12345678 246A 246
[1]
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
[2]
 123.12 123.12 123.12 123.12>.... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12*.... ... ... .. .. ...... ...... ........ .... ...
    .
    .
    .
[15]
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
 123.12 123.12 123.12 123.12 .... ... ... .. .. ...... ...... ........ .... ...
Event: TRIP1 TRIP2 TRIP3 TRIP4
Targets: TRIP INST 87-1 87-2 87-3 24 81 A B C N W1 W2 W3 50/51
Winding 1 Currents (A Sec), ABC: 123.1 123.1 123.1
Winding 2 Currents (A Sec), ABC: 123.1 123.1 123.1
Winding 3 Currents (A Sec), ABC: 123.1 123.1 123.1
Winding X Voltages (V Sec), ABC: 123.1 123.1 123.1
Volts/Hertz Percent: 123.1
=>>
```

**Figure 9.4 Example Differential Event Report**

The trigger row includes a ‘>’ character following immediately after the last analog column to indicate the trigger point. A ‘*’ character following immediately after the last analog column denotes that the designated row was used for the Event Summary currents. The ‘*’ character takes precedence over the ‘>’ character when both conditions occur for the same row.

*Table 9.5* summarizes the event report current columns.

**Table 9.5 Differential Event Report Current Columns**

| Column Heading | Definition |
|---|---|
| IOP1 | Operate current for differential element 1 (multiples of tap) |
| IRT1 | Restraint current for differential element 1 (multiples of tap) |
| I1F2 | Second-harmonic current for differential element 1 (multiples of tap) |
| I1F5 | Fifth-harmonic current for differential element 1 (multiples of tap) |

*Table 9.6* summarizes the digital event report columns.

**Table 9.6 Differential Event Report Element Columns** (Sheet 1 of 2)

| Column | Symbol | Definition |
|---|---|---|
| All | . | All indication deasserted |
| Dif El | R | 87R asserted |
| 87RU | U | 87U asserted |
| | b | 87R and 87U asserted |
| Dif El | R | 87R1 asserted |
| 87 1 | U | 87U1 asserted |
| | b | 87R1 and 87U1 asserted |
| Dif El | R | 87R2 asserted |
| 87 2 | U | 87U2 asserted |
| | b | 87R2 and 87U2 asserted |
| Dif El | R | 87R3 asserted |
| 87 3 | U | 87U3 asserted |
| | b | 87R3 and 87U3 asserted |
| Dif El | 1 | 87BL1 asserted |
| 87B 1 | . | 87BL1 not asserted |
| Dif El | 1 | 87BL2 asserted |
| 87B 2 | . | 87BL2 not asserted |
| Dif El | 1 | 87BL3 asserted |
| 87B 3 | . | 87BL3 not asserted |
| Dif El | 2 | 2HB1 asserted |
| HB 1 | 5 | 5HB1 asserted |
| | b | 2HB1 and 5HB1 asserted |
| Dif El | 2 | 2HB2 asserted |
| HB 2 | 5 | 5HB2 asserted |
| | b | 2HB2 and 5HB2 asserted |
| Dif El | 2 | 2HB3 asserted |
| HB 3 | 5 | 5HB3 asserted |
| | b | 2HB3 and 5HB3 asserted |
| TH5 | p | TH5 asserted |
| | T | TH5 asserted longer than TH5D |
| REF | P | 32IF*50G4*!REFP asserted (timing to trip) |
| | T | 32IF*50G4*REFP asserted (timed out) |
| | 1 . | Timing 1 cycle to reset after REFP assertion Reset |
| TRP 12 | 1 | TRIP1 asserted |
| | 2 | TRIP2 asserted |
| | b | TRIP1 and TRIP2 asserted |
| TRP 34 | 3 | TRIP3 asserted |
| | 4 | TRIP4 asserted |
| | b | TRIP3 and TRIP4 asserted |
| Set 1 | | |
| V1 | p | S1V*n* asserted (timing to output) |
| V2 | T | S1V*n*T asserted (timed out); S1V*n* asserted |
| V3 | d | S1V*n*T asserted, S1V*n* deasserted (timing to reset) |
| V4 | | |
| Set 1 | 1 | Latch Bit 1 Latched |
| LT 12 | 2 | Latch Bit 2 Latched |
| | b | Latch Bit 1 and Latch Bit 2 Latched |

**Table 9.6 Differential Event Report Element Columns** (Sheet 2 of 2)

| Column | Symbol | Definition |
|---|---|---|
| Set 1 | 3 | Latch Bit 3 Latched |
| LT 34 | 4 | Latch Bit 4 Latched |
| | b | Latch Bit 3 and Latch Bit 4 Latched |
| Set 2 | | |
| V1 | p | S2V*n* asserted (timing to output) |
| V2 | T | S2V*n*T asserted (timed out); S2V*n* asserted |
| V3 | d | S2V*n*T asserted, S2V*n* deasserted (timing to reset) |
| V4 | | |
| Set 2 | 1 | Latch Bit 1 Latched |
| LT 12 | 2 | Latch Bit 2 Latched |
| | b | Latch Bit 1 and Latch Bit 2 Latched |
| Set 2 | 3 | Latch Bit 3 Latched |
| LT 34 | 4 | Latch Bit 4 Latched |
| | b | Latch Bit 3 and Latch Bit 4 Latched |
| Set 3 | | |
| V1 | p | S3V*n* asserted (timing to output) |
| V2 | T | S3V*n*T asserted (timed out); S3V*n* asserted |
| V3 | d | S3V*n*T asserted, S3V*n* deasserted (timing to reset) |
| V4 | | |
| V5 | | |
| V6 | | |
| V7 | | |
| V8 | | |
| OUT 12 | 1 | OUT101 asserted |
| | 2 | OUT102 asserted |
| | b | OUT101 and OUT102 asserted |
| OUT 34 | 3 | OUT103 asserted |
| | 4 | OUT104 asserted |
| | b | OUT103 and OUT104 asserted |
| OUT 56 | 5 | OUT105 asserted |
| | 6 | OUT106 asserted |
| | b | OUT105 and OUT106 asserted |
| OUT 7A | 7 | OUT107 asserted |
| | A | ALARM asserted |
| | b | OUT107 and ALARM asserted |
| IN 12 | 1 | IN101 asserted |
| | 2 | IN102 asserted |
| | b | IN101 and IN102 asserted |
| IN 34 | 3 | IN103 asserted |
| | 4 | IN104 asserted |
| | b | IN103 and IN104 asserted |
| IN 56 | 5 | IN105 asserted |
| | 6 | IN106 asserted |
| | b | IN105 and IN106 asserted |

## Event R (Raw Winding Event Report)

The raw winding event report contains secondary phase currents for each of the three winding inputs, secondary phase voltages for one of the three windings, as well as the status of the eight digital outputs and six optoisolated inputs. The SEL-387E samples the analog ac input currents 64 times per

power system cycle. The relay filters the samples to remove transient signals. The relay operates on the filtered values and reports them in most event reports. The raw or unfiltered event report allows viewing of the samples before digital filtering occurs.

Use the **EVE R** command to retrieve raw winding event reports. There are several options for customizing the report format. The general command format is:

**EVE R [*n*, S*x*, L*y*[-[*w*]]]** (parameters in [ ] are optional)

where:

| | |
|---|---|
| *n* | Event number; defaults to 1 if not listed, where 1 is the most recent event. |
| S*x* | Display *x* samples per cycle (4, 8, 16, 32, or 64); defaults to 16 if not listed. |
| L*y* | Display *y* cycles of data (1 to LER); defaults to LER if not listed. |
| L*y*- | Display from cycle *y* to end of report. |
| L*y*-*w* | Display from cycle *y* to cycle *w*. |

Refer to *Figure 9.5* for an example raw winding event report. This example event report displays rows of information each quarter-cycle; it was retrieved with the **EVE R S4 <Enter>** command. The raw event report always shows 1.5 cycles of pretrigger data, in this case six samples instead of four.

```
=>>EVE R S4 <Enter>
XFMR 1                                  Date: MM/DD/YY  Time: HH:MM:SS.SSS
STATION A
FID=SEL-387E-R700-V0-Z101003-D20060616
Winding 1         Winding 2         Winding 3        Winding X           OUT  IN
    Amps Sec          Amps Sec          Amps Sec         Volts Sec       1357 135
 IAW1  IBW1  ICW1  IAW2  IBW2  ICW2  IAW3  IBW3  ICW3  VAWX  VBWX  VCWX  246A 246
 [0]
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
 [1]
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
[2]
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 >.... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 *.... ...
   .
   .
   .
[15]
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
+1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234 +1234  .... ...
Event: TRIP1 TRIP2 TRIP3 TRIP4
Targets: TRIP INST 87-1 87-2 87-3 24 81 50/51 A B C N W1 W2 W3
Winding 1 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding 2 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding 3 Currents (A Sec), ABC:  123.1   123.1   123.1
Winding X Voltages (V Sec), ABC:  123.1   123.1   123.1
Volts/Hertz Percent: 123.1
=>>
```

**Figure 9.5 Example Raw Winding Event Report**

The trigger row includes a '>' character following immediately after the last analog column to indicate the trigger point. A '*' character following immediately after the last analog column denotes that the designated row was used for the Event Summary currents. The '*' character takes precedence over the '>' character when both conditions occur for the same row.

The following table summarizes the raw event report current columns. The column headings shown are the default headings, corresponding to the designations on terminals Z01 to Z21. If the Analog Input Labels settings have been changed within the Global setting area, these will appear in the report as set.

**Table 9.7 Raw Winding Event Report Current Columns**

| Column Heading | Definition |
|---|---|
| IAW1 | Current measured by Winding 1 input channel IA (amperes, secondary) |
| IBW1 | Current measured by Winding 1 input channel IB (amperes, secondary) |
| ICW1 | Current measured by Winding 1 input channel IC (amperes, secondary) |
| IAW2 | Current measured by Winding 2 input channel IA (amperes, secondary) |
| IBW2 | Current measured by Winding 2 input channel IB (amperes, secondary) |
| ICW2 | Current measured by Winding 2 input channel IC (amperes, secondary) |
| IAW3 | Current measured by Winding 3 input channel IA (amperes, secondary) |
| IBW3 | Current measured by Winding 3 input channel IB (amperes, secondary) |
| ICW3 | Current measured by Winding 3 input channel IC (amperes, secondary) |
| VAWX | Voltage measured by Winding x input channel VA (volts, secondary) |
| VBWX | Voltage measured by Winding x input channel VB (volts, secondary) |
| VCWX | Voltage measured by Winding x input channel VC (volts, secondary) |

The following table summarizes the raw winding event report output and input columns.

**Table 9.8 Raw Winding Event Report Outputs and Inputs** (Sheet 1 of 2)

| Column Heading | Symbol | Definition |
|---|---|---|
| All | . | All indication deasserted |
| OUT 12 | 1 | Output contact OUT101 asserted |
| | 2 | Output contact OUT102 asserted |
| | b | Both OUT101 and OUT102 asserted |
| OUT 34 | 3 | Output contact OUT103 asserted |
| | 4 | Output contact OUT104 asserted |
| | b | Both OUT103 and OUT104 asserted |
| OUT 56 | 5 | Output contact OUT105 asserted |
| | 6 | Output contact OUT106 asserted |
| | b | Both OUT105 and OUT106 asserted |
| OUT 7A | 7 | Output contact OUT107 asserted |
| | A | Output contact ALARM asserted |
| | b | Both OUT107 and ALARM asserted |
| IN 12 | 1 | Optoisolated input IN101 asserted |
| | 2 | Optoisolated input IN102 asserted |
| | b | Both IN101 and IN102 asserted |

**Table 9.8 Raw Winding Event Report Outputs and Inputs** (Sheet 2 of 2)

| Column Heading | Symbol | Definition |
|---|---|---|
| IN 34 | 3 | Optoisolated input IN103 asserted |
| | 4 | Optoisolated input IN104 asserted |
| | b | Both IN103 and IN104 asserted |
| IN 56 | 5 | Optoisolated input IN105 asserted |
| | 6 | Optoisolated input IN106 asserted |
| | b | Both IN105 and IN106 asserted |

## Compressed ASCII Event Reports

The SEL-387E provides Compressed ASCII event reports to facilitate event report storage and display. The SEL-2032, the SEL-2030, or the SEL-2020 Communications Processor and the SEL-5601-2 SYNCHROWAVE® Event Software take advantage of the Compressed ASCII format. Use the **EVE C** command or the **CEVENT** command to display Compressed ASCII event reports. See *CEVENT Command on page E.5* for further information.

## Extracting RMS Phasor Data from Filtered Event Reports

*Figure 9.6* and *Figure 9.7* look in detail at one cycle of A-phase current (channel IA) from a typical filtered Event Report. *Figure 9.6* shows how the event report ac current column data relate to the actual sampled waveform and RMS magnitude values. *Figure 9.7* shows how the event report current column data can be converted to phasor RMS values.

**Figure 9.6 Derivation of Event Report Current Values and RMS Current Values From Sampled Current Waveform**

In *Figure 9.6* note that any two rows of current data from the event report that are one quarter-cycle apart can be used to calculate RMS current values. One quarter-cycle represents 90 electrical degrees; therefore, the two samples are effectively perpendicular to each other and can be treated as rectangular components of the phasor quantity. By using the normal method of taking the square root of the sum of the squares of the samples, the magnitude of the phasor can be extracted. Because the actual sample values have been divided by $\sqrt{2}$ (multiplied by $1/\sqrt{2}$ in the drawing) before being entered into the report column, no further adjustment is needed after doing the magnitude calculation. In the example in *Figure 9.6*, successive pairs of samples result in magnitude calculations very close to the true value of 2748 A, RMS. The true RMS value is shown as $IA_{peak}$ times $1/\sqrt{2}$ = 3887 • 0.707 = 2748 A.

**Figure 9.7 Derivation of Phasor RMS Current Values From Event Report Current Values**

In *Figure 9.7* note that two rows of current data one quarter-cycle apart can be used to calculate phasor RMS current values. At the time of interest, the present sample is used as the Real Axis, or "X" component, while the value from one quarter-cycle before is used as the Imaginary Axis, or "Y" component. Plotting the components as shown, and noting that the angle of the phasor is Arctan (Y/X), the complete phasor quantity can be derived and compared with other current phasors calculated from other current pairs selected from the same two rows of the Event Report. In *Figure 9.7*, at the present sample, the phasor RMS current value is:

$$IA = 2749\ A\ \angle{-30.0°}$$

The present sample (IA = 2380 A) is a real RMS current value that relates to the phasor RMS current value:

$$2749\ A \bullet \cos(-30.0°) = 2380\ A$$

A calculation of the phasor using the previous pair, X = –1375 and Y = –2376, yields a calculation of:

$$IA = 2745\ A\ \angle{-120.0°}$$

Thus, the phasor rotates in a counterclockwise direction in 90-degree increments, as expected, when successive pairs of samples are used for making the calculation.

# Sequential Events Recorder (SER) Event Report

*Figure 9.8* demonstrates an example SER event report.

```
=>>SER 2/26/97 2/27/97 <Enter>

XFMR 1                                    Date: MM/DD/YY    Time: HH:MM:SS.SSS
STATION A

FID=SEL-387E-R700-V0-Z101003-D20060616
#      DATE         TIME       ELEMENT          STATE

4     2/26/97   10:33:54.873   TRIP3           Asserted
3     2/26/97   10:33:55.373   TRIP3           Deasserted
2     2/27/97   10:34:06.872   CLS3            Asserted
1     2/27/97   10:34:07.372   CLS3            Deasserted

=>>
```

**Figure 9.8 Example SER Event Report**

## SER Event Report Row Triggering and ALIAS Settings

The relay triggers (generates) a row in the SER event report for any change of state in any one of the elements listed in the SER1, SER2, SER3, or SER4 trigger settings. Use port command **SHO R** to view the settings, or **SET R** to set them. The factory default settings are:

SER1 = **IN101,IN102,IN103,IN104,IN105,IN106**

SER2 = **OUT101,OUT102,OUT103,OUT104,OUT105,OUT106,OUT107**

SER3 = **0**

SER4 = **0**

The elements are Relay Word bits from *Table 4.8*. Each element is looked at individually to see if it asserts or deasserts. Any assertion or deassertion of a listed element triggers a row in the SER event report. For example, setting SER1 contains all six of the optoisolated inputs. Any time dc voltage is applied to, or removed from, one of these inputs, a row is triggered in the SER event report.

In the SER settings are 20 settings by which the user can redefine the names of Relay Word bits in the SER report, to make the entries more readily identifiable to the user. The settings are ALIAS1 to ALIAS20. If they are not set, they are listed as, for example, ALIAS1 = NA.

**NOTE:** Alias names can only consist of letters (capital or lowercase), numbers, and the underscore character; they cannot contain spaces or any other type of character.

To rename a Relay Word bit with an ALIAS*n* setting, use **SET R** to access the settings. For each "ALIAS*n* =" setting, list the bit name, then a space, then the desired name, which can contain any combination of 15 letters, numbers, and underscores. For example, one setting might be ALIAS2 = CLS1 BKR1CLOSE. In the report, instead of CLS1 being listed, the name BKR1CLOSE will appear, indicating a breaker 1 close operation was performed.

In addition to the SER*n* trigger settings, if the relay is newly powered up or a settings change is made, a row is triggered in the SER event report with the message:

```
Relay newly powered up or settings changed
```

Each entry in the SER includes SER row number, date, time, element name, and element state. Generally, the rows are listed from top to bottom in chronological order, oldest first, to facilitate analyzing the sequence. The newest records have the lowest row numbers, the oldest records the highest row numbers.

## Making SER Event Report Trigger Settings

Each SER trigger setting (SER1, SER2, SER3, or SER4) can be set with as many as 24 elements (Relay Word bits from *Table 4.8*). Thus, as many as 96 total elements can be monitored for SER event report row triggering.

You can make SER settings using spaces or commas as delimiters between elements. For example, if setting SER1 is made as follows:

SER1 = **IN101,IN102  IN103,,IN104  ,  IN105,  , IN106**

The relay displays the settings as:

SER1 = **IN101,IN102,IN103,IN104,IN105,IN106**

## Retrieving SER Event Report Rows

The latest 512 rows of the SER event report are stored in nonvolatile memory. Row 1 is the most recently triggered row, and row 512 is the oldest. These lines are accessed with the **SER** command in the following different ways:

| Example SER Serial Port Commands | Format |
|---|---|
| **SER** | If **SER** is entered with no numbers following it, all available rows are displayed (up to row number 512). They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number. |
| **SER 17** | If **SER** is entered with a single number following it (17 in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number. |
| **SER 10 33** | If **SER** is entered with two numbers following it (10 and 33 in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number. |
| **SER 47 22** | If **SER** is entered with two numbers following it (47 and 22 in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number. |
| **SER 3/30/96** | If **SER** is entered with one date following it (date 3/30/96 in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number. |
| **SER 2/17/96 3/23/96** | If **SER** is entered with two dates following it (date 2/17/96 chronologically *precedes* date 3/23/96 in this example), all the rows between (and including) dates 2/17/96 and 3/23/96 are displayed, if they exist. They display with the oldest row (date 2/17/96) at the beginning (top) of the report and the latest row (date 3/23/96) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number. |
| **SER 3/16/96 1/5/96** | If **SER** is entered with two dates following it (date 3/16/96 chronologically *follows* date 1/5/96 in this example), all the rows between (and including) dates 1/5/96 and 3/16/96 are displayed, if they exist. They display with the latest row (date 3/16/96) at the beginning (top) of the report and the oldest row (date 1/5/96) at the end (bottom) of the report. *Reverse* chronological progression through the report is down the page and in ascending row number. |

The date entries in the above example **SER** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

If the requested SER event report rows do not exist, the relay responds:

```
Invalid Record
```

If there are no rows in the SER event report buffer, the relay responds:

```
No SER data
```

## Clearing SER Event Report Buffer

If the **SER C** command is entered, the relay prompts the operator for confirmation:

```
Clear SER Buffer
Are you sure (Y/N)?
```

If "Y" is entered, the relay clears the SER event reports from nonvolatile memory. If "N" is entered, no reports are cleared, and the relay responds:

```
Canceled
```

The process of clearing SER event reports may take as long as 30 seconds under normal operation or longer if the relay is busy processing a fault or protection logic.

### Note: Clear the SER Buffer With Care

Automated clearing of the SER buffer should be limited to reduce the possibility of wearing out the nonvolatile memory. Limit automated **SER C** commands to once per week or less.

# Section 10

# Testing and Troubleshooting

## Introduction

Use this section for determining and establishing test routines for the SEL-387E Relay. This section includes discussions on testing philosophies, methods, and tools. It also shows example test procedures for metering, overcurrent elements, differential elements, and harmonic blocking functions. Relay troubleshooting procedures are at the end of the section.

Protective relay testing may be divided into three categories: acceptance, commissioning, and maintenance testing. The categories are differentiated by when they take place in the life cycle of the relay, as well as by the complexities of the tests.

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**, **TARGET F** Command | Use the **TARGET *n*** 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 (SER1, SER2, SER3, or SER4) 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. Refer to the **SET** command. |

For more information on these features and commands, see *Section 7: Communications*.

## Low-Level Test Interface

The SEL-387E has a low-level test interface between the calibrated input module and the separately calibrated processing module. 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. Access the test interface by removing the relay front panel.

*Figure 10.1* shows the low-level interface connections. 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. *Figure 10.1* shows the signal scaling factors.

**⚠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 10.1 Low-Level Test Interface**

## Test Methods

Test the pickup and dropout of relay elements using one of three methods: front-panel target LCD/LED indication, output contact operation, and the Sequential Events Recorder (SER).

### Target LED Illumination

During testing use target LED illumination to determine relay element status. Using the **TAR F** command, set the front-panel targets to display the element under test. Monitor element pickup and dropout by observing the target LEDs.

For example, the Winding 1 phase definite-time overcurrent element 50P11 appears in Relay Word Row 2. When you type the command **TAR F 50P11 <Enter>**, the terminal displays the labels and status for each bit in the Relay Word row (2) and the LEDs display their status. Thus, with these new targets displayed, if the Winding 1 phase definite-time overcurrent element (50P11) asserts, the far left LED illuminates. See *Section 4: Control Logic* for a list of all Relay Word elements.

Be sure to reset the front-panel targets to the default targets after testing before returning the relay to service. Reset these targets by pressing the front-panel TARGET RESET button, or by issuing the **TAR R** command from the serial port.

### Output Contact Operation

To test using this method, set one programmable output contact to assert when the element under test picks up. With the **SET *n*** command, enter the Relay Word bit name of the element under test.

For an "a" contact, when the condition asserts, the output contact closes. When the condition deasserts, the output contact opens.

For a "b" contact, when the condition asserts, the output contact opens. When the condition deasserts, the output contact closes.

Programmable contacts can be changed to "a" or "b" contacts with a solder jumper. Refer to *Section 2: Installation* for jumper locations. Using contact operation as an indicator, you can measure element operating characteristics, stop timers, etc.

Tests in this section assume an "a" output contact.

### Sequential Events Recorder (SER)

To test using this method, set the SER to trigger for the element under test. With the **SET R** command, put the element name in the SER1, SER2, SER3, or SER4 setting.

Whenever an element asserts or deasserts, a time stamp is recorded. View the SER report with the **SER** command. The SER report will list the actual element name (Relay Word bit) unless this bit has been renamed using one of the ALIAS*n* settings, in which case the ALIAS will appear in the report. Clear the SER report with the **SER C** command.

## Acceptance Testing

When: When qualifying a relay model to be used on the utility system.

Goal:

1. Ensure relay meets published critical performance specifications such as operating speed and element accuracy.
2. Ensure that the relay meets the requirements of the intended application.
3. Gain familiarity with relay settings and capabilities.

What to test: All protection elements and logic functions critical to the intended application.

SEL performs detailed acceptance testing on all new relay models and versions. We are certain that the relays we ship meet their published specifications. It is important for you to perform acceptance testing on a relay if you are unfamiliar with its operating theory, protection scheme logic, or settings. This helps ensure the accuracy and correctness of the relay settings when you issue them.

## Equipment Required

The following equipment is necessary to perform all of the acceptance tests:

- A terminal or computer with terminal emulation with EIA-232 serial interface
- Interconnecting data cable between terminal and relay
- Source of relay control power
- Source of two currents at nominal frequency
- Source of one current at two times and/or five times nominal frequency
- Source of variable three-phase voltage adjustable from 40 to 70 Hz
- Ohmmeter or contact opening/closing sensing device

## Initial Checkout

Step 1. Purpose: Be sure you received the relay in satisfactory condition.

Method: Inspect the instrument for physical damage such as dents or rattles.

Step 2. Purpose: Verify requirements for relay logic inputs, control power voltage level, and voltage and current inputs.

Method: Refer to the information sticker on the rear panel of the relay. *Figure 10.2* provides an example. Check the information on this sticker before applying power to the relay or starting tests. Be sure your dc supply is correctly adjusted for the control and logic input requirements.

**Figure 10.2 Relay Part Number and Hardware Identification Sticker**

## Power Supply

Step 1. Purpose: Establish control power connections.

Method: Connect a frame ground to terminal marked **GND** on the rear panel and connect rated control power to terminals marked **+** and **–**. Relays supplied with 125 or 250 V power supplies may be powered from a 115 Vac wall receptacle for testing. Other power supplies require dc voltage and are polarity sensitive.

Step 2. Purpose: Verify that +5 Vdc is presented on Ports 2 and 3. This voltage is sometimes required by external devices that include a dc powered modem.

Method:

a. Execute the **STATUS** command from the serial port or front panel, and inspect the voltage readings for the power supply.

b. Verify that JMP1 is installed for Serial Port 3 and JMP2 is installed for Serial Port 2. Refer to *Section 2: Installation* for further information about the jumpers.

c. Use a voltmeter to read the +5 V output. Pin 1 of each port should have +5 Vdc on it when the jumpers mentioned above are installed.

d. Compare the +5 V readings from the status report and voltmeter. The voltage difference should be less than 50 mV (0.05 V), and both readings should be within ±0.15 V of 5 V.

## Serial Communications

Step 1. Purpose: Verify the communications interface setup.

Method: Connect a computer terminal to Ports 2, 3, or 4 of the relay.

Communication Parameters: 2400 Baud, 8 Data Bits, 1 Stop Bit, N Parity

Cables: SEL-C234A for 9-pin male computer connections

SEL-C227A for 25-pin male computer connections

Step 2. Purpose: Apply control voltage to the relay, and start Access Level 0 communications.

Method: Apply control voltage to the relay. The enable target (EN) LED should illuminate. If not, be sure that power is present. Type **<Enter>** from your terminal to get the Access Level 0 response from the relay. The = prompt should appear, indicating that you have established communications at Access Level 0.

The ALARM relay should pull in, holding its "b" contacts open.

**NOTE:** If you are using a battery simulator, be sure the simulator voltage level is stabilized before turning the relay on.

If the relays pull in but your terminal does not respond with the equal sign, check the terminal configuration. If neither occurs, turn off the power and refer to *Relay Troubleshooting on page 10.38*.

The = prompt indicates that communications with the relay are at Access Level 0, the first of four possible levels. The only command accepted at this level is **ACC <Enter>**, which opens communications on Access Level 1.

Step 3. Purpose: Establish Access Level 1 communications.

Method: Type **ACC <Enter>**. At the prompt, enter the Access Level 1 password and press **<Enter>** (see *PAS (Passwords) on page 7.26* for a table of factory default passwords). The => prompt should appear, indicating that you have established communications at Access Level 1.

Step 4. Purpose: Verify relay self-test status.

Method: Type **STA <Enter>**. A display similar to the screen capture following should appear on the terminal:

**NOTE:** The current input names shown are the default values; any inputs renamed in the Analog Input Labels settings will appear as set.

To view a relay status report, see the example following the discussion of *Status Monitor Report Function (STATUS Command) on page 5.19*.

Step 5. Purpose: View factory settings entered before shipment.

Method: The relay is shipped with factory settings; type **SHO <Enter>** to view the settings. *Section 6: Settings* includes a complete description of the settings.

## Outputs

Step 1. Purpose: Verify that output contacts operate when you execute the **PULSE** command.

Method:

a. Isolate all circuitry connected to the output contacts.

b. Set the target LEDs to display the output contacts, by typing **TAR F OUT101 <Enter>**. The front-panel LEDs should now follow Row 41 of the Relay Word where OUT101 is listed.

c. Execute the **PULSE *n*** command for each output contact. Verify that the corresponding target LED illuminates and the output contact closes for approximately one second. For example, type **PUL OUT101 <Enter>** to test output contact OUT101.

d. Repeat this step for each output. Use the **TARGET F** (**TAR F**) command to display the appropriate output elements.

Step 2. Purpose: Verify that externally connected circuitry is operational.

Method:

a. Isolate all circuitry connected to the output contacts except the circuit under test.

b. Set the target LEDs to display the output contacts by typing **TAR F OUT101 <Enter>**. The bottom row of the front-panel LEDs will follow Row 41 of the Relay Word where OUT101 is listed.

c. Execute the **PULSE *n*** command for each output contact. Verify that the corresponding target LED illuminates and output contact closes for approximately one second. For example, type **PUL OUT101 <Enter>** to test output contact 101.

d. Repeat this step for each output. Use the **TARGET F** (**TAR F**) command to display the appropriate output elements. Verify that the connected circuitry operates as expected.

## Inputs

Purpose: Verify that logic inputs assert when control voltage is applied across the respective terminal pair.

Method:

a. Set the target LEDs to display the level-sensitive inputs by typing **TAR F IN101 <Enter>**. The bottom row of the front-panel LEDs will follow logic inputs IN101 through IN106, which is Relay Word Row 27.

b. Apply the appropriate control voltage to each input and make sure that the corresponding target LED turns on.

c. Repeat this step for each input. Use the **TARGET F** (**TAR F**) command to display the appropriate output elements.

# Metering

## Current Metering

Step 1. Purpose: Connect simulated power system secondary current sources to the relay.

Method: Turn relay power off and connect current sources. If three current sources are available, connect them to the relay in a full three-phase connection, as shown in *Figure 10.3*. If only two current sources are available, connect the sources as shown in *Figure 10.4* to generate balanced positive-sequence currents:

a. Connect the A-phase and B-phase current sources to the dotted A and B current input terminals.

b. Connect both undotted A and B current input terminals to the undotted C current input terminal.

c. Connect the dotted C current input terminal to both the A and B current source returns.

Set the current sources to deliver one ampere with A-phase at 0 degrees, B-phase lagging A-phase by 120 degrees, and C-phase leading A-phase by 120 degrees.

Step 2. Purpose: Verify correct current levels.

Method: Turn relay power on, and use the **METER** command to measure the currents applied in *Step 1*. With applied currents of one ampere per phase and a current transformer ratio of 120:1 (**SHO CTR1 <Enter>** displays the CT ratios for each winding, **<Ctrl + X>** cancels scrolling), the displayed line currents should be the applied current, 120 amperes ±3%, ±12 amperes.

Step 3. Purpose: Verify phase rotation.

Method: Verify that residual (IR) and negative-sequence (3I2) quantities are approximately zero. If IR equals three times the applied current, then all three phases have the same angle. If 3I2 equals three times the applied current, then the phase rotation is reversed. Turn the current sources off.

**Figure 10.3 Test Connections for Balanced Load With Three-Phase Current Sources**

**Figure 10.4 Test Connections for Balanced Load With Two-Phase Current Sources**

## Voltage Metering

Step 1. Purpose: Connect simulated power system secondary voltage sources to the relay.

Method: Connect a source of variable three-phase voltage to the relay as shown in *Figure 10.5*. Set the voltage sources to deliver 67 Volts with A-phase at 0 degrees, B-phase lagging A-phase by 120 degrees, and C-phase leading A-phase by 120 degrees.

**Figure 10.5 Voltage Test Connection**

Step 2. Purpose: Verify correct voltage levels.

Method: Turn relay power on, and use the **METER** command to measure the voltages applied in Step 1. With applied voltages of 67 Volts per phase and a voltage transformer ratio of 2000:1 (**SHO PTR <Enter>** displays the PT ratios, **<Ctrl + X>** cancels scrolling), the displayed line voltages should be the applied voltage, 134 kV ±2 kV and ±5% of applied voltage times PTR.

Step 3. Purpose: Verify phase rotation.

Method: Verify that residual (VRW*x*) and negative-sequence (3V2W*x*) quantities are approximately zero. If VRW*x* equals three times the applied voltage, then all three phases have the same angle. If 3V2W*x* equals three times the applied voltage, then the phase rotation is reversed.

## Frequency Metering

Purpose: Verify frequency metering.

Method: Use the **METER** command to measure the frequency applied in *Step 1 on page 10.8*. The displayed frequency should equal the applied frequency ±0.01 Hz.

## Volts/Hertz Metering

Purpose: Verify volts/hertz metering

Method: Use the **METER** command to measure the volts/hertz applied in *Step 1 on page 10.8*. The displayed volts/hertz should equal the following ±1%:

$$\text{Volts/Hertz} = \frac{\sqrt{3} \bullet V_{sec} \bullet PTR \bullet NFREQ}{10 \bullet freq \bullet V_{nom}}$$

$V_{sec}$ = Secondary Voltage (applied)

PTR = Potential transformer ratio (Setting)

Freq = Frequency (applied)

NFREQ = Nominal Frequency (Setting)

$V_{nom}$ = Nominal Voltage in kV (Setting)

## Winding Overcurrent

Each winding overcurrent element that is to be tested must be enabled. Enable the overcurrent elements for a particular winding with the EOC1, EOC2, and EOC3 settings for Windings 1, 2, and 3, respectively. Setting these to "Y" enables the overcurrent elements for the corresponding winding. The pickup settings for each overcurrent element must also be set to a pickup value. If they are not set to a value, but are set to "OFF," that particular overcurrent element is disabled.

### Instantaneous Overcurrent Elements

**NOTE:** This example tests the Winding 1 50P11 phase overcurrent element. Use the same procedure to test all instantaneous overcurrent elements for each winding.

Step 1. Purpose: Determine the expected instantaneous overcurrent element pickup value.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 50P11P <Enter>**).

Step 2. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 50P11 <Enter>**). The SEL-387E now displays the state of several Winding 1 overcurrent elements on the bottom row of front-panel LEDs.

Step 3. Purpose: Connect and apply a single-current test source until the appropriate LED illuminates.

Method: Connect a single-current test source (i.e., Source 1) as shown in *Figure 10.6*. Turn on the current test source for the winding under test, and slowly increase the magnitude of current applied until the appropriate element asserts (i.e., 50P11), causing the LED to illuminate (i.e., left-most). Note the magnitude of the current applied. It should equal the 50P1P setting ±5% of the setting ±0.02 $I_{nom}$ (negative-sequence elements are ±6% of the setting ±0.02 $I_{nom}$).

Step 4. Purpose: Repeat test for each instantaneous overcurrent element for each winding.

Method: Repeat *Step 1* through *Step 3* for each instantaneous overcurrent element listed in *Table 10.1* for each winding. Remember to view the appropriate TARGET and apply current to the appropriate winding. The computer terminal will display the LED labels from left to right when the **TAR F** command is issued.

**Figure 10.6 Test Connections for Two Single-Current Test Sources**

**Table 10.1 Instantaneous Overcurrent Elements and Corresponding Settings**

| | Winding 1 | | Winding 2 | | Winding 3 | |
|---|---|---|---|---|---|---|
| | **Bit** | **Setting** | **Bit** | **Setting** | **Bit** | **Setting** |
| Phase Level 1 | 50P11 | 50P11P | 50P21 | 50P21P | 50P31 | 50P31P |
| Phase Level 2 | 50P12 | 50P12P | 50P22 | 50P22P | 50P32 | 50P32P |
| Phase Inverse-Time | 51P1 | 51P1P | 51P2 | 51P2P | 51P3 | 51P3P |
| A-Phase Level 3 | 50A13 | 50P13P | 50A23 | 50P23P | 50A33 | 50P33P |
| B-Phase Level 3 | 50B13 | | 50B23 | | 50B33 | |
| C-Phase Level 3 | 50C13 | | 50C23 | | 50C33 | |
| Phase Level 3 | 50P13 | | 50P23 | | 50P33 | |
| A-Phase Level 4 | 50A14 | 50P14P | 50A24 | 50P24P | 50A34 | 50P34P |
| B-Phase Level 4 | 50B14 | | 50B24 | | 50B34 | |
| C-Phase Level 4 | 50C14 | | 50C24 | | 50C34 | |
| Phase Level 4 | 50P14 | | 50P24 | | 50P34 | |
| Residual Level 1 | 50N11 | 50N11P | 50N21 | 50N21P | 50N31 | 50N31P |
| Residual Level 2 | 50N12 | 50N12P | 50N22 | 50N22P | 50N32 | 50N32P |
| Residual Inverse-Time | 51N1 | 51N1P | 51N2 | 51N2P | 51N3 | 51N3P |
| Neg-Seq Level 1 | 50Q11 | 50Q11P | 50Q21 | 50Q21P | 50Q31 | 50Q31P |
| Neg-Seq Level 2 | 50Q12 | 50Q12P | 50Q22 | 50Q22P | 50Q32 | 50Q32P |
| Neg-Seq Inverse-Time | 51Q1 | 51Q1P | 51Q2 | 51Q2P | 51Q3 | 51Q3P |

## Definite-Time and Inverse-Time Overcurrent Elements

**NOTE:** This example tests the Winding 1 51P1 phase inverse-time overcurrent element. Use the same procedure to test all definite-time and inverse-time overcurrent elements for each winding.

Step 1. Purpose: Determine the expected time delay for the overcurrent element.

Method:

a. Execute the **SHOWSET** command via the relay front panel or serial port and verify the time delay settings (i.e., **SHO 51P1 <Enter>**). The delay settings will follow the pickup settings when they are displayed.

b. Calculate the time delay to pickup (tp). Definite-time elements will be equal to the delay setting (i.e., 50P11D setting for the 50P11 element). Inverse-time elements are calculated using three element settings and the

operating time equations shown in *Section 3: Protection Functions*. TD is the time-dial setting (i.e., 51P1TD), and M is the applied multiple of pickup current.

For example, if 51P1P = 2.2 A, 51P1C = U3, and 51P1TD = 4.0, we can use the equation below to calculate the expected operating time for M = 3 (applied current equals M • 51P1P = 6.6 A):

$$tp = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$$

tp = 2.33 seconds

Step 2. Purpose: Set the Sequential Events Recorder to record the element timing.

Method: Use **SET R SER1 <Enter>** to set SER1 equal to the element pickup and time-out Relay Word bits (i.e., 51P1, 51P1T). When prompted, set SER2, SER3, and SER4 to NA. Save the settings.

Step 3. Purpose: Connect and apply a single-current test source at a level that is M times greater than the pickup (i.e., 2.2 • M = 6.6 A for this example).

Method: Connect a single-current test source as shown in *Figure 10.6*. Turn on the single-current test source for the winding under test at the desired level.

Step 4. Purpose: Verify the operation times.

Method: Type **SER <Enter>** to view the sequential events records. The assertion and deassertion of each element listed in the SER1, 2, 3, and 4 settings is recorded. Subtract the time from the assertion of the pickup (i.e., 51P1) to the assertion of the time-delayed element (i.e., 51P1T). **SER C** clears the sequential events records.

**NOTE:** If the time-overcurrent element induction-disk reset emulation is enabled (i.e., 51P1RS = Y), the element under test may take some time to reset fully. If the element is not fully reset when you run a second test, the time to trip will be lower than expected. To reset all time-overcurrent elements before running additional tests, enter the **RESET <Enter>** command from the relay serial port.

Step 5. Purpose: Repeat the test for each definite-time and inverse-time overcurrent element, for each winding.

Method: Repeat *Step 1* through *Step 4* for each time element listed in *Table 10.2* for each winding. Remember to set the SER for the appropriate elements and apply current to the appropriate winding.

**Table 10.2 Time-Delayed Overcurrent Elements and Corresponding Settings**

| | Winding 1 | | Winding 2 | | Winding 3 | |
|---|---|---|---|---|---|---|
| | **Bit** | **Setting** | **Bit** | **Setting** | **Bit** | **Setting** |
| Phase Level 1 | 50P11 | 50P11P | 50P21 | 50P21P | 50P31 | 50P31P |
| Definite-Time | 50P11T | 50P11D | 50P21T | 50P21D | 50P31T | 50P31D |
| Phase Inverse-Time | 51P1 | 51P1P | 51P2 | 51P2P | 51P3 | 51P3P |
| Curve | | 51P1C | | 51P2C | | 51P3C |
| Time-Dial | | 51P1TD | | 51P2TD | | 51P3TD |
| Time-Out | 51P1T | | 51P2T | | 51P3T | |
| Residual Level 1 | 50N11 | 50N11P | 50N21 | 50N21P | 50N31 | 50N31P |
| Definite-Time | 50N11T | 50N11D | 50N21T | 50N21D | 50N31T | 50N31D |
| Residual Inverse-Time | 51N1 | 51N1P | 51N2 | 51N2P | 51N3 | 51N3P |
| Curve | | 51N1C | | 51N2C | | 51N3C |
| Time-Dial | | 51N1TD | | 51N2TD | | 51N3TD |
| Time-Out | 51N1T | | 51N2T | | 51N3T | |
| Neg-seq Level 1 | 50Q11 | 50Q11P | 50Q21 | 50Q21P | 50Q31 | 50Q31P |
| Definite-Time | 50Q11T | 50Q11D | 50Q21T | 50Q21D | 50Q31T | 50Q31D |
| Neg-seq Inv-Time | 51Q1 | 51Q1P | 51Q2 | 51Q2P | 51Q3 | 51Q3P |
| Curve | | 51Q1C | | 51Q2C | | 51Q3C |
| Time-Dial | | 51Q1TD | | 51Q2TD | | 51Q3TD |
| Time-Out | 51Q1T | | 51Q2T | | 51Q3T | |

## Phase Overcurrent Elements

The SEL-387E has many phase overcurrent elements. They all operate based on a comparison between the phase current directly applied to the winding inputs and the phase overcurrent setting. The elements that have a P as the third character of the element name operate when any one of the three-phase currents exceeds the phase current setting threshold. The elements that have an A, B, or C as the third character in the element name operate based on that phase current.

Test the instantaneous and time-delayed phase overcurrent elements by applying current to the inputs and comparing relay operation to the phase overcurrent settings. These tests were outlined earlier in this section.

## Negative-Sequence Overcurrent Elements

The SEL-387E has 12 negative-sequence overcurrent elements. They all operate based on a comparison between a negative-sequence calculation of the three-phase inputs and the negative-sequence overcurrent setting. The negative-sequence calculation that is performed on the three-phase inputs is as follows:

3I2 = (A-phase + B-phase (shifted by –120) + C-phase (shifted by 120))

This means that if balanced positive-sequence currents are applied to the relay, the relay reads:

3I2 = 0 (load conditions)

For testing purposes, apply a single-phase current to the relay and the negative-sequence overcurrent elements will operate. For example, assume one ampere on A-phase and zero on B- and C-phases:

3I2 = (1 + 0 (shifted –120) + 0 (shifted 120)) = 1 (simulated ground fault condition)

Test the instantaneous and time-delayed negative-sequence overcurrent elements by applying current to the inputs and comparing relay operation to the negative-sequence overcurrent settings. These tests were outlined earlier in this section.

## Residual Overcurrent Elements

The SEL-387E has many residual overcurrent elements. They all operate based on a comparison between a residual calculation of the three-phase inputs and the residual overcurrent setting. The residual calculation that is performed on the three-phase inputs is as follows:

IR = (A-phase + B-phase + C-phase) (all angles are considered as well)

This means that if balanced positive-sequence currents are applied to the relay, the relay reads IR = 0 (load conditions) because the currents cancel one another.

For testing purposes, apply a single-phase current to the relay and the residual overcurrent elements will operate. For example, assume one ampere on A-phase and zero on B- and C-phases:

IR = (1 + 0 (shifted 120) + 0 (shifted –120)) = 1 (simulated ground fault condition)

Test the instantaneous and time-delayed residual overcurrent elements by applying current to the inputs and comparing relay operation to the residual overcurrent settings. These tests were outlined earlier in this section.

## Torque-Control

SELOGIC® control equations are provided for various overcurrent elements (i.e., 51P1TC) that provide a torque-control (required to be true for element operation). Test the torque-control equations.

Step 1. Purpose: Set the torque-control equation for the desired condition.

Method: Execute the **SET** command via the relay serial port and set the desired torque-control equation to the desired condition. For a test example, a digital input is used. Enter **SET 51P1TC <Enter>**. When prompted, set 51P1TC to IN101. For an alternate way of testing, use the relay serial port to set the 51P1TC to 1 (always asserted) or 0 (always deasserted), instead of asserting an input.

Step 2. Purpose: Assert the torque-control equation.

Method: Apply the appropriate conditions to assert the torque-control equation. For this test example, apply control voltage to IN101.

Step 3. Purpose: Display the appropriate Relay Word bit to verify the torque-control equation.

Method: Execute the **TARGET** command (i.e., **TAR F IN101 <Enter>**). The SEL-387E now displays the state of the six input elements in the second row of the front-panel LEDs. If multiple elements are used in the torque-control equation, several **TARGET** commands must be issued to view the individual elements.

Step 4. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs for the desired overcurrent element.

Method: Execute the **TARGET** command (i.e., **TAR F 51P1 <Enter>**). The SEL-387E now displays the state of several overcurrent elements in the second row of the front-panel LEDs. The 51P1 bit is the fourth LED from the left.

Step 5. Purpose: Execute and verify an overcurrent test.

Method: Referring to the overcurrent tests previously outlined in this section, execute an overcurrent test and verify its operation.

Step 6. Purpose: Verify that the torque-control equation disables the overcurrent element when deasserted.

Method: Remove the torque-control conditions to deassert the torque-control equation. For this test example, remove control voltage from IN101. Re-execute the same overcurrent test and verify that it does not operate.

## Combined Overcurrent Elements

The SEL-387E has one set of combined overcurrent elements. Set EOCC = Y to enable this set, which uses the sum of currents from Windings 1 and 2. The set has a phase-overcurrent and a residual-overcurrent element, both of which are inverse-time elements using the same curves as the similar Winding 51 elements. This set consists of units 51PC1 and 51NC1.

The test for the combined overcurrent elements is intended to simulate the application for these elements, namely a ring-bus or breaker-and-a-half scheme where two sets of CT inputs from two breakers are brought to the relay. These two inputs are for the same physical winding, whose current is the phasor sum of the two inputs.

The test configuration is that shown in *Figure 10.6*, with two sources delivering current to the same phase of Windings 1 and 2.

The test below is for element 51PC1, using Windings 1 and 2 inputs. Set the pickup, curve, and time-dial values for this element as desired. The pickup should be set fairly low, at about one or two amperes. Disable the complementary 51NC1 element by setting 51NC1P to OFF.

Step 1. Purpose: Determine the expected time delay for the overcurrent element.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the element settings (i.e., **SHO 51PC1P <Enter>**). The pickup is 51PC1P, the curve type is 51PC1C, and the time-dial is 51PC1TD.

Calculate the time delay to pickup (tp). Inverse-time elements are calculated using three element settings and the operating time equations shown in *Section 3: Protection Functions*. TD is the time-dial setting (i.e., 51PC1TD), and M is the applied multiple of pickup current.

For example, if 51PC1P = 2.2 A, 51PC1C = U3, and 51PC1TD = 4.0, we can use the equation below to calculate the expected operating time for M = 3 (applied current equals M • 51PC1P = 6.6 A):

$$tp = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$$

tp = 2.33 seconds

Step 2. Purpose: Set the Sequential Events Recorder to record the element timing.

Method: Use **SET R SER1 <Enter>** to set SER1 equal to the element pickup and time-out Relay Word bits (i.e., 51PC1, 51PC1T). When prompted, set SER2, SER3, and SER4 to NA. Save the settings.

Step 3. Purpose: Connect and apply two single-current test sources to create sufficient current to operate the 51PC1 element.

Method: Connect two single-current test sources as shown in *Figure 10.6*. Set the IAW1 current at some fixed value, such as 10 A at angle zero degrees. Set the IAW2 current at 10 A at 180 degrees. Because the phasor sum is zero, nothing will happen.

Execute the **TAR F 22** command. Relay Word bits 51PC1 and 51PC1T will appear in the second row of LEDs, in the A and B positions, during the tests. Before the test, LED **C** should be lit, representing bit 51PC1R (reset).

Slowly reduce IAW2 until the unit picks up, indicated by LED **A**. This should happen when IAW2 equals 10 – 51PC1P. After verifying pickup, increase IAW2 back to 10 A. LED **A** will extinguish. Wait for LED **C** to reappear, indicating reset. Or, issue command **RES** to force a reset.

Suddenly reduce the current IAW2 to a value equal to 10 – M • 51PC1P, where M is the desired multiple of pickup. Allow the unit to proceed to time-out, indicated by the lighting of LED **B**. (LED **A** will also be lit.)

Step 4. Purpose: Verify the operation time.

Method: Type **SER <Enter>** to view the sequential events records. The assertion and deassertion of each element listed in the SER1, 2, 3, and 4 settings are recorded. Subtract the time of the assertion of the pickup (i.e., 51PC1) from the assertion time of the time-out bit (i.e., 51PC1T). This is the operate time. **SER C** clears the sequential events records.

Step 5. Purpose: Repeat the test for 51NC1.

Method: Repeat *Step 1* through *Step 4* for the other elements. Remember to set the SER for the appropriate elements and apply current to the appropriate winding. Also remember to disable the pickup of the complementary element in each set, so that only the phase or residual element is being tested at one time.

## Restricted Earth Fault (REF) Function

The test for the REF function is similar to that for the combined overcurrent element using two current sources to inject current into two different windings. Small currents are used to demonstrate the sensitivity of the element to internal ground faults. The test assumes a 5 A relay is being used.

The settings for the REF function are these:

E32I = Enabling SELOGIC control equations. Set E32I = 1.

32IOP = Winding(s) for obtaining the Operate quantity. Set 32IOP = 1.

a0 = Positive-sequence restraint factor. Use default setting, a0 = 0.1.

50GP = Residual current sensitivity level. Use default setting, 50GP = 0.5 A.

**NOTE:** To use the setting 50GP = 0.5, be sure that the ratio CTRmax/CTR3 is not more than 2.0, where CTRmax is the larger of CTR1 and CTR3. Using the default CT ratio settings, CTRmax = CTR3, so the ratio CTRmax/CTR3 = 1. Therefore, the 50GP setting can remain at 0.5A.

If the ratio CTRmax/CTR3 is greater than 2.0, set 50GP equal to 0.25 A times the actual ratio of CTRmax/CTR3.

Recall that the default CT ratio settings are: CTR1 = 120, and CTR3 = 400.

Step 1. Purpose: Determine the expected time delay for the restricted earth fault function.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the element settings (i.e., **SHO E321 <Enter>**).

Calculate the time delay to pickup (tp). Inverse-time elements are calculated using three element settings and the operating time equations shown in *Section 3: Protection Functions*. TD is the time-dial setting, and M is the applied multiple of pickup current.

For example, 50GP = 0.5 A. The REF curve is type U4, extremely inverse. The time dial is fixed at 0.5. Only the IRW3 current is used for the time curve calculation. Setting IRW3 at 1 A represents a multiple of pickup of M = 2.0. We can use the equation below to calculate the expected operating time for curve U4 at M = 2, TD = 0.5:

$$tp = TD \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$$

tp = 0.963 seconds

Step 2. Purpose: Set the Sequential Events Recorder to record the element timing.

Method: Use **SET R SER1 <Enter>** to set SER1 equal to the element pickup and time-out Relay Word bits (i.e., 50G3, 32IF, and REFP). When prompted, set SER2, SER3, and SER4 to NA. Save the settings.

Step 3. Purpose: Connect and apply two single-current test sources to test the REF element.

Method: Connect two single-current test sources as shown in *Figure 10.6*, but with Source Current 2 connected to one of the Winding 3 inputs (e.g., IAW3). Set the IAW1 current magnitude to:

$$IAW1 \geq 2 \bullet 50GP \bullet \frac{CTR3}{CTR1}$$

Using the default CT ratios, IAW1 should be set to at least 2 • 0.5 A • 400/120, or 3.33 A. Set the magnitude of IAW1 to 4 A; set the angle of IAW1 to 180 degrees.

Set the IAW3 current at 1 A at zero degrees. Because the currents are opposite in phase, nothing should happen. Verify this as follows:

Execute the **TAR 38** command. Relay Word bits 50G3, 32IR, 32IF, and REFP are all in this row. With the currents applied as above, 50G3 should be 1, and REFP should remain at 0. Bit 32IR should be 1, indicating an external (reverse) fault. Bit 32IF should be 0.

Change the angle of IAW1 to zero degrees, or any value within about ±80 degrees of IAW3. The REF element should function. Verify this as follows:

Execute the **TAR 38** command again. 50G3 should still be 1, REFP should be 1 (indicating time-out), 32IR should be 0, and 32IF should be 1 (indicating an internal, or forward, fault).

Step 4. Purpose: Verify the operation time.

Method: Type **SER <Enter>** to view the SER records. The assertion and deassertion of each element listed in the SER1, 2, 3, and 4 settings is recorded. Subtract the time of assertion of the directional element (32IF) from the assertion time of the time-out bit (REFP). This is the operate time, which should be about one second, as calculated above. (50G3 will have remained asserted from earlier in the test because no change was made to the IAW3 current.) **SER C** clears the SER records.

Step 5. Purpose: Verify relay operation for faults with high neutral current but a small difference in phase current.

Method: Clear the SER by typing **SER C <Enter>**. Connect a single current source to phase IAW3. Set both current magnitude and phase angle to zero. Type **TAR 32IE 9999** and confirm that the status of the 32IE Relay Word bit is logical 0. Inject 0.7 A into the relay and confirm that Relay Word bit 32IE asserts to logical 1. Type **TAR 50GC 10** and verify that

Relay Word bit 50GC is logical 0. Stop the injection and use the **SER** command to confirm the assertion of Relay Word bit 32IF in approximately 1.5 cycles after the assertion of Relay Word bit 32IE. Repeat the test injecting first in phase IBW3 and then in phase ICW3.

## Differential

The SEL-387E has several components to its differential element. *Figure 10.7* gives a representation of the differential characteristic and the plot of each test. Each test only uses Winding 1 and 2 inputs. Any combination of two winding inputs may be used for the test. The differential elements for each winding must be enabled for each winding under test with the E87W1, E87W2, and E87W3 settings. Set each setting equal to "Y" to enable the corresponding differential element.

**Figure 10.7 Percentage Restraint Differential Characteristic**

### U87P Unrestrained Differential Element

Step 1. Purpose: Verify the expected unrestrained differential element pickup setting.

**NOTE:** This value is in per unit of tap.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO U87P <Enter>**).

Step 2. Purpose: Calculate the required current to pick up the unrestrained differential element.

**CAUTION**
The continuous rating of the current inputs is 3 • $I_{nom}$. For this test, you may want to choose low values of U87P and TAPn to limit the required test current to a safe value.

Method: Calculate the expected pickup for the 87U element by multiplying the U87P setting by the TAP1, TAP2, or TAP3 setting and the compensation constant A shown in *Table 10.3*. The CT connection compensation settings W1CTC, W2CTC, and W3CTC determine the A constant for the calculations. Use the corresponding TAP*n* and W*n*CTC settings for the winding under test.

Step 3. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 87U <Enter>**). The SEL-387E now displays the state of several differential elements in the second row of the front-panel LEDs. The 87U bit is the fourth from the left.

Step 4. Purpose: Connect and ramp a single-current test source until the appropriate LED illuminates.

Method: Connect a single-current test source as shown in *Figure 10.6*. Turn on the current test source for the winding under test, and slowly increase the magnitude of current applied until the 87U element asserts. Note the magnitude of the current applied. It should equal the value calculated in *Step 2*, ±5% ±0.02 $I_{nom}$.

Step 5. Purpose: Repeat the test for each phase for each winding if desired.

Method: Repeat *Step 1* through *Step 4* for each phase. Remember to view the appropriate TARGET and apply current to the appropriate winding. The computer terminal will display the LED labels from left to right when the **TAR F** command is issued.

**Table 10.3 Connection Compensation Factor**

| WnCTC Setting | A |
|---|---|
| 0 | 1 |
| Odd: 1, 3, 5, 7, 9, 11 | $\sqrt{3}$ |
| Even: 2, 4, 8, 10 | 3.0 |
| Even: 6, 12 | 1.5 |

## O87P Differential Element Pickup

Step 1. Purpose: Verify the expected restrained differential element minimum pickup setting.

**NOTE:** This value is in per unit of tap.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO O87P <Enter>**).

Step 2. Purpose: Calculate the required current to pick up the restrained differential element.

Method: Calculate the expected pickup for the 87R element by multiplying the O87P setting by the TAP1, TAP2, or TAP3 setting and the compensation constant A shown in *Table 10.3*. The CT connection compensation settings W1CTC, W2CTC, and W3CTC determine the A constant for the calculations. Use the corresponding TAP*n* and W*n*CTC settings for the winding under test.

Step 3. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 87R <Enter>**). The SEL-387E now displays the state of several differential elements in the second row of the front-panel LEDs. The 87R bit is the right-most LED.

Step 4. Purpose: Connect and ramp a single-current test source until the appropriate LED illuminates.

Method: Connect a single-current test source as shown in *Figure 10.6*. Turn on the current test source for the winding under test, and slowly increase the magnitude of current applied until the 87R element asserts. Note the magnitude of the current applied. It should equal the value calculated in step 2, ±5% ±0.02 $I_{nom}$.

Step 5. Purpose: Repeat the test for each phase for each winding if desired.

Method: Repeat *Step 1* through *Step 4* for each phase. Remember to view the appropriate TARGET and apply current to the appropriate winding. The computer terminal will display the LED labels from left to right when the **TAR F** command is issued.

## SLP1 Restrained Differential Threshold

Step 1. Purpose: Verify the differential characteristic settings and set winding compensation.

Method: Execute the **SHO TAP1 <Enter>** command via the relay front panel or serial port and verify the (TAP*n*) settings, the restraint slope 1 percentage (SLP1) setting, the restraint slope 2 percentage (SLP2) setting, the restraint current slope 1 limit (IRS1) setting, and the O87P minimum pickup setting.

Execute the **SET W1CTC <Enter>** command and set the W*n*CTC settings for the two windings to be used to the same value (0, 1, …, 12). Save the settings.

Step 2. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 87R <Enter>**). The SEL-387E now displays the state of several differential elements in the second row of the front-panel LEDs. The 87R bit is the right-most LED.

Step 3. Purpose: Select a test point on the percentage differential curve in *Figure 10.7*.

Method: Decide where you want to cross the differential characteristic by picking a restraint value IRT, which is a vertical line on the graph. Because this test is for the SLP1 threshold, select a point greater than the O87P intersection point and below IRS1. If SLP2 = OFF, IRS1 and SLP2 are not functional.

$$O87P \bullet \frac{100}{SLP1} < IRT < IRS1$$

The value of IOP corresponding to the selected IRT equals the following:

$$IOP = \frac{SLP1}{100} \bullet IRT$$

Both IRT and IOP are in multiples of tap.

Step 4. Purpose: Calculate the expected current for Windings 1 and 2 at the restrained differential element SLP1 threshold for the test point selected above.

Method: Calculate the Winding 1 current for the test using the following formula:

$$IAW1 = IRT \bullet \left(1 + \frac{SLP1}{200}\right) \bullet TAP1 \bullet A$$

Calculate the Winding 2 current for the test using the following formula:

$$IAW2 = IRT \bullet \left(1 - \frac{SLP1}{200}\right) \bullet TAP2 \bullet A$$

**⚠CAUTION**
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.

The A connection compensation constant is based on *Table 10.3*. Because the windings have the same W*n*CTC setting, the A constant will be the same for both windings. The A constant must be used to achieve the exact curve point on which we have based the calculations. The TAP*n* settings can be different for the two windings.

Step 5. Purpose: Calculate the initial current for Winding 2 for this test.

Method: Calculate the Winding 2 initial current for the test using the following formula:

$$IAW2 = IAW1 \bullet \frac{TAP2}{TAP1}$$

This formula determines the current necessary for IOP = 0 given the IAW1 calculated above.

Step 6. Purpose: Connect a single-current test source to A-phase of Winding 1 and a single-current test source to A-phase of Winding 2. Ramp down Winding 2 current until the appropriate LED illuminates.

Method: Connect the two current test sources as shown in *Figure 10.6*. Turn on the current test source for A-phase of Winding 1 (IAW1) at the value calculated above, *and set the phase angle at zero degrees*. Turn on the current test source for A-phase of Winding 2 (IAW2) at the calculated initial current *and set the phase angle at 180 degrees*. Slowly decrease the magnitude of IAW2 until the 87R element asserts. Note the magnitude of the current applied. It should equal the value calculated in *Step 4* ±5% ±0.02 $I_{nom}$.

Step 7. Purpose: Repeat the test for each phase for each winding if desired.

**NOTE:** IRS1 must be greater than 100/SLP1 • 087P if SLP2 is not set to OFF.

Method: Repeat *Step 1* through *Step 6* for each phase. Remember to view the appropriate TARGET and apply currents to the appropriate windings. The computer terminal will display the LED labels from left to right when the **TAR F** command is issued.

## SLP2 Restrained Differential Threshold

**NOTE:** For this test, use only WnCTC = 0 or WnCTC = an odd numbered setting (1, 3, 5, 7, 9, 11). Depending on the value of IRT selected in Step 3, the even-numbered settings may produce 87R outputs from 87R-2 and 87R-3 before the calculated slope 2 current (below) reaches the curve value for 87R-1. This could lead to erroneous conclusions about the accuracy of the 87R elements.

Step 1. Purpose: Verify the differential characteristic settings and set winding compensation.

Method: Execute the **SHO TAP1 <Enter>** command via the relay front panel or serial port and verify the (TAP*n*) settings, the Restraint Slope 1 Percentage (SLP1) setting, the Restraint Slope 2 Percentage (SLP2) setting, and the restraint current slope 1 limit (IRS1) setting.

Execute the **SET W1CTC <Enter>** command and set the W*n*CTC settings for the two windings to be used to the same value. Save the settings.

Step 2. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 87R <Enter>**). The SEL-387E now displays the state of several differential elements in the second row of the front-panel LEDs. The 87R bit is the right-most LED.

Step 3. Purpose: Select a test point on the percentage differential curve in *Figure 10.7*.

Method: Decide where you want to cross the differential characteristic by picking a restraint value IRT, which is a vertical line on the graph. Because this test is for the SLP2 threshold, select a point greater than the IRS1 setting.

**IRT** > IRS1

The value of IOP that corresponds to the selected IRT is as follows:

$$\mathrm{IOP} = \frac{\mathrm{SLP2}}{100} \bullet \mathrm{IRT} + \mathrm{IRS1} \bullet \left(\frac{\mathrm{SLP1} - \mathrm{SLP2}}{100}\right)$$

Both IRT and IOP are in multiples of tap.

Step 4. Purpose: Calculate the expected current for Winding 1 and 2 at the restrained differential element SLP2 threshold for the test point selected above.

Method: Calculate the Winding 1 current for the test using the following formula:

$$\mathrm{IAW1} = \left(\mathrm{IRT} \bullet \left(1 + \frac{\mathrm{SLP2}}{200}\right) + \mathrm{IRS1} \bullet \left(\frac{\mathrm{SLP1} - \mathrm{SLP2}}{200}\right)\right) \bullet \mathrm{TAP1} \bullet \mathrm{A}$$

**⚠CAUTION**
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.

Calculate the Winding 2 current for the test using the following formula:

$$\mathrm{IAW2} = \left(\mathrm{IRT} \bullet \left(1 - \frac{\mathrm{SLP2}}{200}\right) - \mathrm{IRS1} \bullet \left(\frac{\mathrm{SLP1} - \mathrm{SLP2}}{200}\right)\right) \bullet \mathrm{TAP2} \bullet \mathrm{A}$$

The A connection compensation constant is based on *Table 10.3*. Because the windings have the same W*n*CTC setting, the A constant will be the same for both windings. The A constant must be used to achieve the exact curve point on which we have based the calculations. The TAP*n* settings can be different for the two windings.

Step 5. Purpose: Calculate the initial current for Winding 2 for this test.

Method: Calculate the Winding 2 initial current by multiplying the Winding 2 expected current calculated above by 110 percent.

IAW2 (initial) = 1.1 • IAW2 (from *Step 4*)

Step 6. Purpose: Connect a single-current test source to A-phase of Winding 1 and a single-current test source to A-phase of Winding 2. Ramp down Winding 2 current until the appropriate LED illuminates.

Method: Connect the two current test sources as shown in *Figure 10.6*. Turn on the current test source for A-phase of Winding 1 (IAW1) at the value calculated above *and set the phase angle to zero degrees*. Turn on the current test source for A-phase of Winding 2 (IAW2) at the calculated starting current *and set the phase angle at 180 degrees*. Slowly decrease the magnitude of current IAW2 until the 87R element asserts. Note the magnitude of the current applied. It should equal the value calculated in step 4 ±5% ±0.02 $I_{nom}$.

Step 7. Purpose: Repeat the test for each phase for each winding combination if desired.

Method: Repeat *Step 1* through *Step 6* for each phase. Remember to view the appropriate TARGET and apply current to the appropriate winding. The computer terminal will display the LED labels from left to right when the **TAR F** command is issued.

## Second-Harmonic Blocking

**NOTE:** This test requires a current source capable of generating second-harmonic current. This example tests the second-harmonic blocking function.

Step 1. Purpose: Verify the second-harmonic restraint percentage.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the percentage of fundamental current that the magnitude of second-harmonic current must exceed for differential restraint. Enter **SHO PCT2 <Enter>**.

Step 2. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 87R <Enter>**). The SEL-387E now displays the state of several differential elements in the second row of the front-panel LEDs. The 87R bit is the right-most LED.

Step 3. Purpose: Connect two current test sources to one phase of one winding input.

Method: Connect a current source to the IAW1 input. Connect a second current source in parallel with the first source to the IAW1 input as shown in *Figure 10.8*.

Step 4. Purpose: Apply fundamental current to pick up the 87R element.

Method: Turn on the first current test source connected to the Winding 1 input (IAW1) equal to the TAP1 setting multiplied by the connection constant A shown in *Table 10.3*. The 87R LED will illuminate once current is applied to the relay.

Step 5. Purpose: Apply and ramp second-harmonic current to drop out the 87R element.

Method: Turn on the second current source for second-harmonic current (120 Hz for NFREQ = 60 and 100 Hz for NFREQ = 50). Starting at zero current, slowly increase the magnitude of this second current source until the 87R element deasserts, causing the 87R LED to completely extinguish. Note the value of the applied current from the second test source. The current from the second-harmonic source should equal the PCT2 setting divided by 100, multiplied by the magnitude of the fundamental current source, ±5% and ±0.02 $I_{nom}$.

$$\text{IAW1 (second harmonic)} = \frac{\text{PCT2}}{100} \bullet \text{IAW1 (fundamental)}$$

$$\pm 5\% \ \pm 0.02\ I_{nom}$$

**Figure 10.8 Test Connections for Parallel Current Sources**

## Fifth-Harmonic Blocking

**NOTE:** This test requires a current source capable of generating fifth-harmonic current. This example tests the fifth-harmonic blocking function.

Step 1. Purpose: Verify the fifth-harmonic restraint percentage.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the percentage of fundamental current that the magnitude of fifth-harmonic current must exceed for differential restraint. Enter **SHO PCT5 <Enter>**.

Step 2. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 87R <Enter>**). The SEL-387E now displays the state of several differential elements in the second row of the front-panel LEDs. The 87R bit is the right-most LED.

Step 3. Purpose: Connect two current test sources to one phase of one winding input.

Method: Connect a current source to the IAW1 input. Connect a second current source in parallel with the first source to the IAW1 input as shown in *Figure 10.8*.

Step 4. Purpose: Apply fundamental current to pick up the 87R element.

Method: Turn on the first current test source connected to the Winding 1 input (IAW1) equal to the TAP1 setting multiplied by the connection constant A shown in *Table 10.3*. The 87R LED will illuminate once current is applied to the relay.

Step 5. Purpose: Apply and ramp fifth-harmonic current to drop out the 87R element.

Method: Turn on the second current source for fifth-harmonic current (300 Hz for NFREQ = 60 and 250 Hz for NFREQ = 50). Starting at zero current, slowly increase the magnitude of this second current source until the 87R element deasserts, causing the 87R LED to completely extinguish. Note the value of the applied current from the second test source. The current from the fifth-harmonic source should equal the PCT5 setting divided by 100, and multiplied by the magnitude of the fundamental current source, ±5% and ±0.02 $I_{nom}$.

$$\text{IAW1 (fifth harmonic)} = \frac{\text{PCT5}}{100} \bullet \text{IAW1 (fundamental)}, \pm 5\%, \pm 0.02\ I_{nom}$$

## Harmonic Restraint

**NOTE:** This test requires a current source capable of generating second- and fourth-harmonic current. This example tests the second-harmonic restraint function. Test the fourth-harmonic restraint function in a similar way.

Step 1. Purpose: Verify the second-harmonic restraint percentage.

Method: Execute the **SHOW** command via the relay front panel or serial port and verify the percentage of fundamental current that the magnitude of second-harmonic current must exceed for differential restraint. Enter **SHO PCT2 <Enter>**.

Step 2. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 87R <Enter>**). The SEL-387E now displays the state of several differential elements in the second row of the front-panel LEDs. The 87R bit is the right-most LED.

Step 3. Purpose: Connect two current test sources to one phase of one winding input.

Method: Connect a current source to the IAW1 input. Connect a second current source in parallel with the first source to the IAW1 input as shown in *Figure 10.8*.

Step 4. Purpose: Apply fundamental current to pick up the 87R element.

Method: Turn on the first current test source connected to the Winding 1 input (IAW1) equal to the TAP1 setting multiplied by the connection constant A shown in *Table 10.3*. The 87R LED will illuminate once current is applied to the relay.

The following test applies to a single-harmonic injection at a time, i.e., only the second or the fourth harmonic, not both. Set E87W1 = E87W2 = Y1, and HRSTR = Y. Set the second current source for second-harmonic current (120 Hz for NFREQ = 60 and 100 Hz for NFREQ = 50). Turn on the second current test source connected to the Winding 1 input (IAW1). Starting at zero current, slowly increase the magnitude

of applied current until the 87R element deasserts, causing the 87R LED to extinguish completely. Note the value of the applied current from the second test source. The general equation to calculate the percentage of harmonic content for a single slope is: (±5% ±0.10 A [5 A relay] or ±5% ±0.02 A [1 A relay]):

$$I1F2 = (IOP1 - IRT1 \bullet f(SLP)) \bullet \frac{PCT2}{100}$$

and

$$\%\ \text{harmonics} = \frac{I1F2}{IOP1} \bullet 100\ \text{(percent)}$$

For inrush conditions, current normally is applied to one side of the transformer, and the equation simplifies to the following:

$$\%\ \text{harmonic} = PCT2\left(1 - \frac{SLP1}{200}\right)$$

where:

PCT2 = second-harmonic setting in percent

SLP1 = slope 1 setting

For example

SLP1 = 50 percent

PCT2 = 20 percent

$$\%\ \text{harmonic} = 20\left(1 - \frac{50}{200}\right) = 15\ \text{percent}$$

For values on the second slope, use the following equation:

$$\%\ \text{harmonic} = \left(\frac{PCT2}{200}\right) \bullet \left(200 - SLP2 - \frac{IRS1}{IRT}(SLP1 - SLP2)\right)$$

where:

PCT2 = second-harmonic setting in percent

SLP1 = slope 1 setting

SLP2 = slope 2 setting

IRS1 = intersection where SLP2 begins

IRT = restraint quantity at which the calculation is carried out

**NOTE:** The second and fourth harmonics are combined to form the restraint quantity.

For example:

Slope 1 = 25 percent

Slope 2 = 60 percent

PCT2 = 20 percent

IRS1 = 3, and choose IRT = 6

$$\%\ \text{harmonic} = \left(\frac{20}{200}\right) \bullet \left(200 - 60 - \frac{3}{6}(25 - 60)\right) = 15.75\ \text{percent}$$

## Over-/Undervoltage Elements

Purpose: Verify the operation of over- and undervoltage elements.

Verify the operation of overvoltage elements.

Step 1. Connect a source of variable three-phase voltage to the relay as shown in *Figure 10.5*.

Step 2. Purpose: Verify the expected phase overvoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 59P1P <Enter>**).

Step 3. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 59P1 <Enter>**). The SEL-387E now displays the state of the overvoltage elements on the bottom row of front-panel LEDs.

Step 4. Purpose: Apply balanced three-phase voltage below the setting and raise one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*, adjusted to a value below the 59P1P setting. Raise one phase voltage until the 59P1 LED illuminates. The voltage should equal the 59P1P setting ±2 V and ±5% of setting. Repeat the test for the other two phases.

Step 5. Purpose: Repeat the test for each phase overvoltage element.

Method: Repeat *Step 1–Step 4* for the 59P2 overvoltage element.

Step 6. Purpose: Verify the expected phase-to-phase overvoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 59PP1 <Enter>**).

Step 7. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 59PP1 <Enter>**). The SEL-387E now displays the state of the overvoltage elements on the bottom row of front-panel LEDs.

Step 8. Purpose: Apply balanced three-phase voltage greater than the setting and raise one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*, adjusted to a value below the 59PP1 setting. Raise one phase voltage until the 59PP1 LED illuminates. The phase-to-phase voltage should equal the 59PP1 setting ±2 V and ±5% of setting. Repeat the test for the other two phase-to-phase voltages.

Step 9. Purpose: Repeat the test for each phase-to-phase overvoltage element.

Method: Repeat *Step 6–Step 8* for each 59PP2 overvoltage element.

Step 10. Purpose: Verify the expected positive-sequence overvoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 59V1P <Enter>**).

Step 11. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 59V1 <Enter>**). The SEL-387E now displays the state of the overvoltage elements on the bottom row of front-panel LEDs.

Step 12. Purpose: Apply balanced three-phase voltage below the setting and raise one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Raise one phase voltage until the 59V1 LED illuminates. The positive-sequence voltage, V1, may be calculated as (VA + VB +VC)/3 if the voltages are 120 degrees apart in proper phase rotation.

Step 13. Purpose: Verify the expected negative-sequence overvoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 59QP <Enter>**).

Step 14. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 59Q <Enter>**). The SEL-387E now displays the state of the overvoltage elements on the bottom row of front-panel LEDs.

Step 15. Purpose: Apply balanced three-phase voltage below the setting and raise one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Raise one phase voltage until the 59Q LED illuminates. The negative-sequence voltage, V2, should equal the 59QP setting ±2 V and ±5% of setting. The negative-sequence voltage may be calculated as $(VA + a^2VB + aVC)/3$ where $a = 1 \angle 120$.

Step 16. Purpose: Verify the expected residual overvoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 59G1P <Enter>**).

Step 17. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 59G1 <Enter>**). The SEL-387E now displays the state of the overvoltage elements on the bottom row of front-panel LEDs.

Step 18. Purpose: Apply balanced three-phase voltage below the setting and raise one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Raise one phase voltage until the 59G1 LED illuminates. The residual voltage, 3V0, should equal the 59G1P setting ±2 V and ±5% of setting. The residual voltage may be calculated as the vector sum (VA + VB +VC).

Step 19. Purpose: Repeat the test for each residual overvoltage element.

Method: Repeat *Step 16–Step 18* for the 59G2 overvoltage element.

Verify the operation of undervoltage elements.

Step 1. Connect a source of variable three-phase voltage to the relay as shown in *Figure 10.5*.

Step 2. Purpose: Verify the expected phase undervoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 27P1P <Enter>**).

Step 3. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 27P1 <Enter>**). The SEL-387E now displays the state of the undervoltage elements on the bottom row of front-panel LEDs.

Step 4. Purpose: Apply balanced three-phase voltage greater than the setting and reduce one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*, adjusted to a value greater than the 27P1P setting. Reduce one phase voltage until the 27P1 LED illuminates. The voltage should equal the 27P1P setting ±2 V and ±5% of setting. Repeat the test for the other two phases.

Step 5. Purpose: Repeat the test for each phase undervoltage element.

Method: Repeat *Step 1–Step 4* for the 27P2 undervoltage element.

Step 6. Purpose: Verify the expected phase-to-phase undervoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 27PP1 <Enter>**).

Step 7. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 27PP1 <Enter>**). The SEL-387E now displays the state of the undervoltage elements on the bottom row of front-panel LEDs.

Step 8. Purpose: Apply balanced three-phase voltage greater than the setting and reduce one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*, adjusted to a value greater than the 27PP1 setting. Reduce one phase voltage until the 27PP1 LED illuminates. The phase-to-phase voltage should equal the 27PP1 setting ±2 V and ±5% of setting. Repeat the test for the other two phase-to-phase voltages.

Step 9. Purpose: Repeat the test for each phase-to-phase undervoltage element.

Method: Repeat *Step 6–Step 8* for the 27PP2 undervoltage element.

Step 10. Purpose: Verify the expected positive-sequence undervoltage pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 27V1P <Enter>**).

Step 11. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 27V1 <Enter>**). The SEL-387E now displays the state of the undervoltage elements on the bottom row of front-panel LEDs.

Step 12. Purpose: Apply balanced three-phase voltage greater than the setting and reduce one phase voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*, adjusted to a value greater than the 27V1P setting. Reduce one phase voltage until the 27V1 LED illuminates. The positive-sequence voltage should equal the 27V1P setting ±2 V and ±5% of setting. The positive-sequence voltage, V1, may be calculated as (VA + VB + VC)/3 if the voltages are 120 degrees apart in proper phase rotation.

## Frequency Elements

Purpose: Verify the operation of frequency elements.

Step 1. Connect a source of variable three-phase voltage and frequency to the relay as shown in *Figure 10.5*.

Step 2. Purpose: Verify the expected frequency pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 81D1P <Enter>**).

Step 3. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 81D1 <Enter>**). The SEL-387E now displays the state of the frequency elements on the bottom row of front-panel LEDs.

Step 4. Purpose: Apply balanced three-phase voltage and change the frequency until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the frequency to a value greater (or less) than the 81D1P setting until the 81D1 LED illuminates. The frequency should equal the 81D1P setting ±0.01 Hz.

Step 5. Purpose: Repeat the test for each frequency element.

Method: Repeat *Step 1–Step 4* for 81D2P through 81D6P elements.

Step 6. Purpose: Verify the expected frequency time delay setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 81D1D <Enter>**).

Step 7. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 81D1T <Enter>**). The SEL-387E now displays the state of the frequency time-delayed elements on the bottom row of front-panel LEDs.

Step 8. Purpose: Apply balanced three-phase voltage and change the frequency until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the frequency to a value greater (or less) than the 81D1P setting. The 81D1T LED should illuminate 81D1D seconds later, within ±0.0042 seconds and ±0.1% of setting.

Step 9. Purpose: Repeat the test for each frequency element.

Method: Repeat *Step 6–Step 8* for the 81D2D through 81D6D frequency time-delayed element.

## Volts/Hertz Elements

Purpose: Verify the operation of volts/hertz elements.

Step 1. Connect a source of variable three-phase voltage and frequency to the relay as shown in *Figure 10.5*.

Step 2. Purpose: Verify the Level 1 volts/hertz pickup setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24D1P <Enter>**).

Step 3. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24D1 <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 4. Purpose: Apply balanced three-phase voltage and change the voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24D1P setting until the 24D1 LED illuminates. The 24D1 pickup should be ±1% of setting. Calculate pickup voltage as:

**NOTE:** When TPVI = N, the relay assumes the voltage applied to the A-phase terminal is a line-to-neutral voltage. Therefore, if a phase-to-phase voltage is applied to the A-phase terminal, the volts/hertz element calculation does not result in the expected value.

$$V_{sec} = \frac{10 \bullet 24D1P \bullet freq \bullet V_{nom}}{\sqrt{3} \bullet PTR \bullet NFREQ}$$

| | | |
|---|---|---|
| $V_{sec}$ | = | Secondary Voltage (applied) |
| PTR | = | Potential transformer ratio (Setting) |
| freq | = | Frequency (applied) |
| NFREQ | = | Nominal Frequency (Setting) |
| $V_{nom}$ | = | Nominal Voltage in kV (Setting) |

Step 5. Purpose: Verify the Level 1 volts/hertz delay setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24D1D <Enter>**).

Step 6. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24D1T <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 7. Purpose: Apply balanced three-phase voltage and change the voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24D1P setting. The 24D1T LED should illuminate 24D1D seconds later, ±0.1% of setting ±4.2 ms (at 60 Hz).

Step 8. Purpose: Verify the Level 2 volts/hertz pickup setting, 24D2P1.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24D2P1 <Enter>**).

Step 9. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24C2 <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 10. Purpose: Apply balanced three-phase voltage and change the voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24D2P1 setting until the 24C2 LED illuminates. The 24C2 pickup should be ±1% of setting. Calculate pickup voltage as:

$$V_{sec} = \frac{10 \bullet 24D2P1 \bullet freq \bullet V_{nom}}{\sqrt{3} \bullet PTR \bullet NFREQ}$$

| | | |
|---|---|---|
| $V_{sec}$ | = | Secondary Voltage (applied) |
| PTR | = | Potential transformer ratio (Setting) |
| freq | = | Frequency (applied) |
| NFREQ | = | Nominal Frequency (Setting) |
| $V_{nom}$ | = | Nominal Voltage in kV (Setting) |

Step 11. Purpose: Verify the Level 2 Volts/Hertz delay setting, when 24CCS = DD and 24D2D1 < 24D2D2.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24CCS <Enter>**, **SHO 24D2D1 <Enter>**). 24CCS should be set to DD; 24D2D1 should be less than 24D2D2.

Step 12. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24C2T <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 13. Purpose: Apply balanced three-phase voltage and change the voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24D2P1 setting. The 24C2T LED should illuminate 24D2D1 seconds later, within ±0.1% of setting ±4.2 ms (at 60 Hz).

Step 14. Purpose: Verify the Level 2 volts/hertz delay setting, when 24CCS = DD and 24D2D2 < 24D2D1.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24CCS <Enter>**, **SHO 24D2D2 <Enter>**). 24CCS should be set to DD; 24D2D2 should be less than 24D2D1.

Step 15. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24C2T <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 16. Purpose: Apply balanced three-phase voltage and change the voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24D2P2 setting. The 24C2T LED should illuminate 24D2D2 seconds later, within ±0.1% of setting ±4.2 ms (at 60 Hz).

Step 17. Purpose: Verify the Level 2 volts/hertz delay settings, when 24CCS = ID.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24CCS <Enter>**).

Step 18. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24C2T <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 19. Purpose: Apply balanced three-phase voltage and change the voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24IP setting and below the 24D2P2 setting until the 24C2T LED illuminates. Refer to *Section 3: Protection Functions* for the maximum inverse-time timing error. Calculate pickup time as:

$$24C2T = \frac{24ITD}{\left(\dfrac{\dfrac{\sqrt{3} \bullet V_{sec} \bullet PTR}{freq} \bullet \dfrac{NFREQ}{V_{nom} \bullet 10^3}}{\dfrac{24IP}{100\%}} - 1\right)^{24IC}}$$

| | | |
|---|---|---|
| $V_{sec}$ | = | Secondary Voltage (applied) |
| PTR | = | Potential transformer ratio (Setting) |
| freq | = | Frequency (applied) |
| NFREQ | = | Nominal Frequency (Setting) |
| $V_{nom}$ | = | Nominal Voltage in kV (Setting) |
| 24ITD | = | Inverse-time factor (Setting) |
| 24IP | = | Inverse-time pickup (Setting) |
| 24IC | = | Inverse-time curve (Setting) |

Step 20. Purpose: Verify the 24D2P2 setting and 24D2D2 delay.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage from a value below the 24IP setting to a value greater than the 24D2P2 setting. The 24C2T LED should illuminate 24D2D2 seconds later.

Step 21. Purpose: Verify the Level 2 volts/hertz delay settings, when 24CCS = I.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24CCS <Enter>**).

Step 22. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24C2T <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 23. Purpose: Apply balanced three-phase voltage and change the voltage until the appropriate LED illuminates.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24IP setting until the 24C2T LED illuminates. Refer to *Section 3: Protection Functions* for the maximum inverse-time timing error. Calculate pickup time as:

$$24C2T = \frac{24ITD}{\left(\dfrac{\dfrac{\sqrt{3} \bullet V_{sec} \bullet PTR}{freq} \bullet \dfrac{NFREQ}{V_{nom} \bullet 10^3}}{\dfrac{24IP}{100\%}} - 1\right)^{24IC}}$$

| | | |
|---|---|---|
| $V_{sec}$ | = | Secondary Voltage (applied) |
| PTR | = | Potential transformer ratio (Setting) |
| freq | = | Frequency (applied) |
| NFREQ | = | Nominal Frequency (Setting) |
| $V_{nom}$ | = | Nominal Voltage in kV (Setting) |
| 24ITD | = | Inverse-time factor (Setting) |
| 24IP | = | Inverse-time pickup (Setting) |
| 24IC | = | Inverse-time curve (Setting) |

Step 24. Purpose: Verify the Level 2 volts/hertz delay reset setting.

Method: Execute the **SHOWSET** command via the relay front panel or serial port and verify the setting (i.e., **SHO 24CR <Enter>**).

Step 25. Purpose: Display the appropriate Relay Word bit on the front-panel LEDs.

Method: Execute the **TARGET** command (i.e., **TAR F 24CR <Enter>**). The SEL-387E now displays the state of the volts/hertz elements on the bottom row of front-panel LEDs.

Step 26. Purpose: Verify the 24CR setting.

Method: Apply balanced three-phase voltages as shown in *Figure 10.5*. Change the voltage to a value greater than the 24D2P1 setting for an elapsed time of 24D2D2/2 seconds, then change the voltage to a value less than the 24D2P1 setting. The 24CR front-panel LED should illuminate after 24CR/2 seconds, within ±0.1% of setting ±4.2 ms (at 60 Hz).

## Time-Code Input (IRIG-B)

Purpose: Verify operation of the IRIG-B clock input for Serial Port 2 and the connector of Serial Port 1.

Method:

Step 1. Connect a source of demodulated IRIG-B time code to the relay Serial Port 2 (Pins 4 and 6) in series with a resistor to monitor the current. Adjust the source to obtain an “ON” current of about 10 mA.

Step 2. Execute the **IRIG** command. Make sure the relay clock displays the correct date and time.

Step 3. Optional. Connect the demodulated IRIG-B time code to the relay as in *Step 1*, but through the Serial Port 1 connector (pins 7 and 8).

# Commissioning Testing

**⚠WARNING**
Before working on a CT circuit, first apply a short to the secondary winding of the CT.

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.

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.

Use the *SEL-387E Relay Commissioning Test Worksheet on page 10.43* 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 meter.

# 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.

# Relay Troubleshooting

## Inspection Procedure

Complete the following procedure before disturbing the relay. After you finish the inspection, proceed to *Troubleshooting Procedure*.

1. Do not turn the relay off.
2. Check to see that the power is on.
3. Measure and record the power supply voltage at the power input terminals.
4. Measure and record the voltage at all control inputs.
5. Measure and record the state of all output relays.

## Troubleshooting Procedure

### All Front-Panel LEDs Dark

**NOTE:** For 1, 2, 3, and 4, the ALARM relay contacts should be closed.

1. Power is off.
2. Blown power supply fuse.
3. Input power not present.
4. Self-test failure.
5. **TAR F** command improperly set.

## Cannot See Characters on Relay LCD Screen

1. Relay is de-energized. Check to see if the ALARM contact is closed.
2. LCD contrast is out of adjustment. Use the steps below to adjust the contrast.
    a. Press any front-panel button. The relay should turn on the LCD backlighting.
    b. Locate the contrast adjust hole behind the front panel beside the serial port. (This requires unscrewing and removing the front-panel plate.)
    c. Insert a small screwdriver in this hole to adjust the contrast.

## Relay Does Not Respond to Commands From Device Connected to Serial Port

1. Communications device not connected to relay.
2. Relay or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.
3. System is processing event record. Wait several seconds.
4. System is attempting to transmit information but cannot because of handshake line conflict. Check communications cabling.
5. System is in the XOFF state, halting communications. Type **<Ctrl + Q>** to put system in XON state.

## Relay Does Not Respond to Commands From Device Connected to Ethernet Port

1. Ensure that the communications device is connected to the Ethernet port.
2. Verify relay or communications device parameters such as IP address, port, etc.
3. Check for cabling error.
4. System is processing an event report, wait several seconds.
5. For a possible Ethernet port failure, issue the STA command from serial port or check front-panel status to verify that the communications card is functional.

## Relay Does Not Respond to Faults

1. Relay improperly set. Review your settings with **SET** and **SET G** commands.
2. Improper test settings.
3. Current transformer connection wiring error.
4. Analog input cable between transformer termination and main board loose or defective.

5. Check self-test status with **STA** command.
6. Check input voltages and currents with **MET** command and TRI and EVE sequence.

## Time Command Displays the Same Time for Successive Commands

1. The digital signal processor has failed.
2. Contact the factory.

## Tripping Output Relay Remains Closed Following Fault

1. Auxiliary contact inputs improperly wired.
2. Output relay contacts burned closed.
3. Interface board failure.

## No Prompting Message Issued to Terminal When the Relay Turns On

1. Terminal not connected to system.
2. Wrong baud rate.
3. Terminal improperly connected to system.
4. SET P AUTO setting set to N (factory default).
5. Main board or interface board failure.

## Terminal Displays Meaningless Characters

1. Baud rate set incorrectly.
2. Check terminal configuration. See *Section 7: Communications*.

## Self-Test Failure: +5 V PS

1. Power supply +5 V output out-of-tolerance. See *STA (Status Report) on page 7.34*.
2. A/D converter failure.

## Self-Test Failure: +5 V REG

1. Regulated +5 V output out-of-tolerance. See *STA (Status Report)*.
2. A/D converter failure.

## Self-Test Failure: 5 V REG

1. Regulated -5 V output out-of-tolerance. See *STA (Status Report)*.
2. A/D converter failure.

## Self-Test Failure: +12 V PS

1. Power supply +12 V output out-of-tolerance. See *STA (Status Report)*.
2. A/D converter failure.

## Self-Test Failure: -12 V PS

1. Power supply -12 V output out-of-tolerance. See *STA (Status Report)*.
2. A/D converter failure.

## Self-Test Failure: +15 V PS

1. Power supply +15 V output out-of-tolerance. See *STA (Status Report)*.
2. A/D converter failure.

## Self-Test Failure: -15 V PS

1. Power supply -15 V output out-of-tolerance. See *STA (Status Report)*.
2. A/D converter failure.

## Self-Test Failure: Offset

1. Offset drift.
2. A/D converter drift.
3. Loose ribbon cable between transformers and main board.

## Self-Test Failure: ROM

1. Memory failure.
2. Contact the factory.

## Self-Test Failure: RAM

1. Failure of static RAM IC.
2. Contact the factory.

## Self-Test Failure: A/D Converter

1. A/D converter failure.
2. RAM error not detected by RAM test.

## Self-Test Failure: IO_BRD

1. Interface board has been changed. Execute the **INITIO** command.
2. Ribbon cable disconnected between upper interface board and main board. Reconnect and execute **INITIO** command. Step 2 only applies to the upper interface board in a relay that has more than one I/O board.
3. Interface board failure.

### Self-Test Failure: CR_RAM, EEPROM, and IO_BRD

1. Self-test detected EEPROM or CR_RAM reconfiguration because of Flash firmware upgrade. Execute **R_S** command.
2. Main board failure, contact the factory.

### Alarm Contacts Closed

1. Power is off.
2. Blown fuse.
3. Power supply failure.
4. Main board or interface board failure.
5. Other self-test failure.

### Self-Test Failure: Temp

1. Record **STA** command and state of all outputs.
2. Contact the factory. Powering down the relay will reset the logic.

# Relay Calibration

The SEL-387E is factory calibrated. If you suspect that the relay is out of calibration, please contact the factory.

# Technical Support

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 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

# SEL-387E Relay Commissioning Test Worksheet

## System Information

### System Settings

RID (Relay identification) = _____

TID (Terminal identification) = _____

MVA (Maximum transformer rating) = _____

| | Winding 1 | Winding 2 | Winding 3 |
|---|---|---|---|
| Current transformer connection: | W1CT = _____ | W2CT = _____ | W3CT = _____ |
| Current transformer ratio: | CTR1 = _____ | CTR2 = _____ | CTR3 = _____ |
| Connection compensation: | W1CTC = _____ | W2CTC = _____ | W3CTC= _____ |
| Nominal line-to-line voltage (kV): | VWDG1 = _____ | VWDG2= _____ | VWDG3= _____ |
| Tap calculation: | TAP1 = _____ | TAP2 = _____ | TAP3 = _____ |

### Differential Settings

O87P = _____ SLP1 = _____ SLP2 = _____ IRS1 = _____ U87P = _____

### Metered Load (Data taken from substation panel meters, not the SEL-387E Relay)

| ± Readings from meters | Winding 1 | Winding 2 | Winding 3 |
|---|---|---|---|
| Megawatts: | MW1 = _____ | MW2 = _____ | MW3 = _____ |
| Megavars: | MVAR1= _____ | MVAR2= _____ | MVAR3= _____ |
| MVA calculation: $MVAn = \sqrt{MWn^2 + MVARn^2}$ | MVA1= _____ | MVA2= _____ | MVA3= _____ |

### Calculated Relay Load

| | Winding 1 | Winding 2 | Winding 3 |
|---|---|---|---|
| Primary Amperes calculation: $Inpri = \frac{MVAn \cdot 1000}{\sqrt{3} \cdot VWDGn}$ | I1pri = _____ | I2pri = _____ | I3pri = _____ |
| Secondary Amperes calculation: $WnCT = Y,\ Insec = \frac{Inpri}{CTRn}$ $WnCT = D,\ Insec = \frac{Inpri \cdot \sqrt{3}}{CTRn}$ | I1sec= _____ | I2sec= _____ | I3sec = _____ |

## Connection Check

**Differential Connection (issue MET DIF<Enter> to serial port or front panel)**

**Note:** System load conditions should be higher than 0.1 A secondary. 0.5 A secondary is recommended for the best results.

Operate Current: IOP1 = _____ IOP2 = _____ IOP3 = _____

Restraint Current: IRT1 = _____ IRT2 = _____ IRT3 = _____

Mismatch Calculation:

$$MMn = \frac{IOPn}{IRTn}$$

MM1 = _____ MM2 = _____ MM3 = _____

Check individual current magnitudes, phase angles, and operate and restraint currents in an event report if mismatch is not less than 0.10.

## Magnitude, Angle, and Phase Rotation Check

(issue **MET SEC<Enter>** to the serial port or front panel)

| | Winding 1 | Winding 2 | Winding 3 |
|---|---|---|---|
| A-Phase Secondary Amperes: | IAW1 = _____ | IAW2 = _____ | IAW3 = _____ |
| A-Phase Angle: | _____ | _____ | _____ |
| B-Phase Secondary Amperes: | IBW1 = _____ | IBW2 = _____ | IBW3 = _____ |
| B-Phase Angle: | _____ | _____ | _____ |
| C-Phase Secondary Amperes: | ICW1 = _____ | ICW2 = _____ | ICW3 = _____ |
| 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, because CT polarity marks normally face away from the transformer on all windings.)

# Appendix A

# Firmware and Manual Versions

## Firmware

### Determining the Firmware Version in Your Relay

**NOTE:** The hardware in SEL-387E Relays with R601 and subsequent firmware is different than the hardware in SEL-387E Relays with R1xx and R2xx series firmware. The hardware associated with R6xx firmware is incompatible with R1xx and R2xx series firmware. You can upgrade R1xx or R2xx firmware to any other firmware numbered R1xx or R2xx. However, you cannot upgrade R1xx or R2xx firmware to R6xx firmware. Similarly, you cannot downgrade R6xx firmware to R1xx or R2xx firmware.

**NOTE:** With the addition of Ethernet capabilities introduced in R701, the main board changes made to support this functionality are not backwards compatible with any previous versions of firmware (R1xx, R2xx, R6xx).

**NOTE:** ACSELERATOR QuickSet® SEL-5030 Software is supported by SEL-387E relays using R602 and later firmware only.

To find the firmware revision number in your relay, view the status report using the serial port **STATUS** command or the front-panel **STATUS** pushbutton. The status report displays the firmware identification (FID) label with the Part/Revision number in bold:

FID=**SEL-387E-Rxxx-Vx-Z001001-Dxxxxxxxx**

The FID string is included near the top of each long event report and is also available using the **STA** or **SER** serial port commands. Part of it is available using the **STATUS** pushbutton, as noted above. The firmware revision number follows the "R" and the date code follows the "D." The version number (follows the "V") is zero for the SEL-387E because there are no version options at this time.

For example:

FID=**SEL-387E-R100-V0-Z001001-D20000216**

is SEL-387E Relay firmware revision number 100 which was released on February 16, 2000.

*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 3)

| Firmware Identification (FID) Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| SEL-387E-R709-V0-Z102003-D20140313<br>SEL-387E-R611-V0-Z003003-D20140313 | ➤ Improved the accuracy of DNP Delay Measurement response. In previous firmware, the Delay Measurement response could be incorrect by as much as 150 ms, which, in applications where the DNP master uses this function code to measure the communication channel delay, could cause the master to set the wrong relay time. | 20140313 |
| SEL-387E-R708-V0-Z102003-D20130426<br>SEL-387E-R610-V0-Z003003-D20130426 | ➤ Modified the **IRIG** command response to not display `IRIG-B Data Error` when IRIG is connected to Serial Port 2.<br>➤ Modified the **IRIG** command response to not display `IRIG SYNC IN PROGRESS` when multiple **IRIG** commands are issued. | 20130426 |
| SEL-387E-R707-V0-Z102003-D20130307<br>SEL-387E-R609-V0-Z003003-D20130307 | ➤ Added MW and MVAR demand and peak metering<br>➤ Added minimum threshold for energy metering. | 20130307 |
| SEL-387E-R706-V0-Z102003-D20110811<br>SEL-387E-R608-V0-Z003003-D20110811 | ➤ Improved relay DSP diagnostics. | 20110811 |

**Table A.1 Firmware Revision History** (Sheet 2 of 3)

| Firmware Identification (FID) Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| SEL-387E-R705-V0-Z102003-D20110728<br>SEL-387E-R607-V0-Z003003-D20110728 | **Note:** This firmware version did not production release. | 20110728 |
| SEL-387E-R704-V0-Z102003-D20110111<br>SEL-387E-R606-V0-Z003003-D20110111 | ➤ Corrected DC ratio blocking data pointer.<br>➤ Removed password echo upon entry.<br>➤ Increased maximum password characters from 6 to 12. | 20110111 |
| SEL-387E-R703-V0-Z102003-D20100226 | ➤ Added Relay Word bits LNKFAIL, P5SEL, and P6SEL to support Ethernet failover.<br>➤ Added Port 5 settings to support Ethernet failover and embedded web server.<br>➤ Removed password echo upon entry.<br>➤ Increased maximum password characters from six to twelve. | 20100226 |
| SEL-387E-R702-V0-Z101003-D20071025<br>SEL-387E-R605-V0-Z003003-D20071025 | ➤ Corrected CHSG Relay Word Bit so that it will maintain the correct state through a relay setting group transition.<br>➤ Set the default event record length equal to relay LER setting. | 20071025 |
| SEL-387E-R701-V0-Z101003-D20060801 | ➤ Added support for Ethernet ports and IEC 61850.<br>➤ Added new breaker-level command, **TEST DB**.<br>➤ Fixed **PUL NOTALM** command. Previous firmware versions may not recognize the **PUL NOTALM** command.<br>**Note:** Previous versions of firmware cannot be upgraded to R701 because of changes in main board hardware. | 20060801 |
| SEL-387E-R604-V0-Z003003-D20060320<br>**Supports PROTO=DNP**<br>SEL-387E-R208-V0-Z102102-D20060320 | ➤ Fixed DNP3 message dropout problem when using EIA-485 networks.<br>➤ Fixed 24D1 Element indication in digital event report. | 20060320 |
| SEL-387E-R603-V0-Z003003-D20050614<br>**Supports PROTO=DNP**<br>SEL-387E-R207-V0-Z102102-D20050614 | ➤ Fixed DNP3 Index 175, 176, 177 Fault Time data types to provide DNP3 Type 30, default variation 2 data (16 bit signed analog input). | 20050614 |
| SEL-387E-R602-V0-Z003003-D20040312<br>**Supports PROTO=DNP**<br>SEL-387E-R206-V0-Z102102-D20040312<br>**Does Not Support PROTO=DNP**<br>SEL-387E-R105-V0-Z002002-D20040312 | ➤ Added through-fault event monitor, including the **TFE** serial port commands. | 20040312 |
| SEL-387E-R601-V0-Z002002-D20020218 | ➤ Added support for new DSP.<br>➤ Added support for faster CPU.<br>➤ Added harmonic restraint function.<br>➤ Added dc ratio blocking feature.<br>➤ Added energy metering with the **MET E** and **MET RE** commands.<br>➤ Added DC Battery Voltage (VDC) to Fast Meter.<br>➤ Added **EVE T** that displays short event summary.<br>➤ Changed front-panel breaker monitor display scroll time from 0.5 second to 2 seconds.<br>➤ Increased O87P setting range resolution.<br>➤ Changed !ALARM Relay Word bit to NOTALM.<br>➤ Corrected ADC power up.<br>➤ Corrected minimum pickup using 24IP setting in Volts/Hertz user-defined curve. | 20020218 |
| **Supports PROTO=DNP**<br>SEL-387E-R205-V0-Z101101-D20020214<br>**Does Not Support PROTO=DNP**<br>SEL-387E-R104-V0-Z001001-D20020214 | ➤ Corrected minimum pickup using 24IP setting in Volts/Hertz user-defined curve. | 20010906 |

**Table A.1 Firmware Revision History** (Sheet 3 of 3)

| Firmware Identification (FID) Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| **Supports PROTO=DNP**<br>SEL-387E-R204-V0-Z101101-D20010906<br>**Does Not Support PROTO=DNP**<br>SEL-387E-R103-V0-Z001001-D20010906 | ➤ Removed 32IOP as input to "REF Directional Element" logic AND gate. With 32IOP removed as an input, the AND gate only uses 32IE and 50GC as inputs. Changed 50GP multiplier from 0.9 to 0.8 in 50GC logic. This change only affects R103 (without DNP) because R203 (with DNP) already incorporated the change.<br>➤ Corrected front-panel PWR meter display to properly scroll to the bottom of the list of power quantities when the up arrow is used and VIWDG is set to either 1 or 2.<br>➤ Corrected front-panel METER display to support PWR when TPVI = N, W*n*CT = D, and VIWDG = N. | 20010906 |
| **Supports PROTO=DNP**<br>SEL-387E-R203-V0-Z101101-D20010102 | ➤ Included W1, W2 combination in combined overcurrent metering.<br>➤ Enhanced Object 32.<br>➤ Removed 32IOP as input to "REF Directional Element" logic AND gate. With 32IOP removed as an input, the AND gate only uses 32IE and 50GC as inputs. Changed 50GP multiplier from 0.9 to 0.8 in 50GC logic. | 20010102 |
| **Supports PROTO=DNP**<br>SEL-387E-R202-V0-Z101101-D20001116<br>**Does Not Support PROTO=DNP**<br>SEL-387E-R102-V0-Z001001-D20001116 | ➤ Different checksum. | 20001116 |
| SEL-387E-R101-V0-Z001001-D20000606 | ➤ Fixed the second- and fifth-harmonic blocking elements.<br>➤ Added DS1302 battery-backed clock support. | 20000606 |
| SEL 387E-R100-V0-Z001001-D20000216 | ➤ Initial version. | 20000216 |

# Ethernet Card Firmware

**NOTE:** This information only applies to relays equipped with optional Ethernet cards.

*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** (Sheet 1 of 2)

| Firmware Identification (FID) Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| SEL-E3-R114-V0-Z001001-D20190111 | ➤ Resolved an issue where certain Ethernet traffic could cause the Ethernet card to safely restart. | 20190222 |
| SEL-E3-R113-V0-Z001001-D20160812 | ➤ Enhanced Telnet interface to issue a QUIT command when a session is terminated.<br>➤ Modified GOOSE processing to initialize values following a diagnostic restart or **STA C** command. | 20160812 |
| SEL-E3-R112-V0-Z001001-D20140313 | ➤ Modified IEC 61850 processing to ensure Ethernet communication is maintained when exactly four buffered reports are enabled. In previous firmware revisions, Ethernet communication can cease if E61850 = Y, IEC 61850 buffered reports are enabled via an MMS command, and exactly four buffered reports are defined in the CID file. | 20140313 |

**Table A.2 Ethernet Card Firmware Revision History** (Sheet 2 of 2)

| Firmware Identification (FID) Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| SEL-E3-R111-V0-Z001001-D20111031 | ➤ Corrected error message generated in response to IEC 61850 MMS control failure.<br>➤ Corrected GOOSE reception issue after Ethernet failover operation.<br>➤ SEL-E3-R110 not released. | 20111031 |
| SEL-E3-R109-V0-Z001001-D20110517 | ➤ Improved IEC 61850 conformance. | 20110517 |
| SEL-E3-R108-V0-Z001001-D20100226 | ➤ Added select before operate (SBO) and enhanced security SBO modes to IEC 61850 MMS.<br>➤ Added web server.<br>➤ Activated Ethernet Port 6 and added Ethernet failover. | 20100226 |
| SEL-E3-R107-V0-Z001001-D20090205 | ➤ Improved IEC 61850 security (see selinc.com/support/security-notifications/ for details). | 20090205 |
| SEL-E3-R106-V0-Z001001-D20081022 | ➤ Updated IEC 61850 firmware to streamline MMS processing and improve TCP/IP connections.<br>➤ Improved security (see selinc.com/support/security-notifications/ for details). | 20081022 |
| SEL-E3-R105-V0-Z001001-D20080808 | ➤ Corrected timing issue on disconnection or connection that would result in an Ethernet port failure. | 20080808 |
| SEL-E3-R104-V0-Z001001-D20080110 | ➤ Enhanced IEC 61850 functionality with KEMA certification updates.<br>➤ Made improvements to IEC 61850 control operation priorities when using IEC 61850 GOOSE messaging.<br>➤ Improved CID parse failure notification for the **STA** and **ID** commands. | 20080110 |
| SEL-E3-R102-V0-Z001001-D20060814 | ➤ Initial version. | 20060801 |

Newer Ethernet card firmware (R104 and higher) uses a different software library from earlier versions and is unable to process version 001 CID files. ACSELERATOR Architect® SEL-5032 Software generates CID files from ICD files so the ICD file version number and CID file version number are the same. If downloaded to the Ethernet card, an incompatible CID file will generate file parse errors during processing and disable the IEC 61850 protocol.

If you perform an Ethernet card firmware upgrade that spans different file version compatibilities, the relay may not be able to process the stored CID file. See *Ethernet Card Firmware Upgrade Instructions on page B.17* for CID file conversion procedures.

See *Table A.3* for compatibilities between ACSELERATOR Architect, ICD/CID file, and Ethernet card firmware versions.

**Table A.3 ACSELERATOR Architect CID File Compatibility**

| ACSELERATOR Architect Software Version | ACSELERATOR Architect ICD/CID File Version | Ethernet Card Firmware |
|---|---|---|
| R.1.1.69.0 or higher | Ver 002 | R104–R107 |
| R1.1.91.3 or higher | Ver 003 | R108 |
| R.1.1.95.0 or higher | Ver 004 | R109–R114 |

# 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 date codes 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 9)

| Date Code | Summary of Revisions |
|---|---|
| 20250127 | Appendix B<br>➤ Removed references to CD throughout. |
| 20221103 | Section 1<br>➤ Added UKCA Mark in *Specifications*. |
| 20211203 | Section 1<br>➤ Updated *Type Tests* in *Specifications*. |
| 20190809 | Section 7<br>➤ Updated *SEL ASCII Protocol Details* to include the SEL-5601-2 instead of SEL-5601.<br>Section 9<br>➤ Updated *Compressed ASCII Event Reports* in *Standard 15-, 30-, or 60-Cycle Event Reports.*<br>Appendix K<br>➤ Added *Appendix K: PC Software*. |
| 20190222 | Appendix A<br>➤ Updated for Ethernet card firmware version R114. |
| 20170601 | General<br>➤ Added *Appendix J: Protection Application Examples*.<br>Section 3<br>➤ Updated *Setting Calculation* in *Differential Element*.<br>➤ Updated *Example of Setting the SEL-387E for a Three-Winding Transformer* in *Differential Element*.<br>➤ Added *Figure 3.8: Primary Currents and Secondary Currents as Measured by the Relay*. |
| 20160812 | Appendix A<br>➤ Updated for Ethernet card firmware version R113 (see *Table A.2*).<br>➤ Updated *Table A.3: ACSELERATOR Architect CID File Compatibility*. |
| 20160122 | Section 1<br>➤ Updated *Specifications*. |
| 20150126 | Preface<br>➤ Added *Safety Information*.<br>Section 1<br>➤ Updated *Specifications*. |
| 20140313 | Appendix A<br>➤ Updated for firmware version R611 and R709 (see *Table A.1*).<br>➤ Updated for Ethernet card firmware version R112 (see *Table A.2* and *Table A.3*). |
| 20130426 | Appendix A<br>➤ Updated for firmware version R610 and R708 (see *Table A.1*). |
| 20130307 | Section 5<br>➤ Added descriptions of MW and MVAR demand and peak demand features.<br>➤ Added descriptions of MW and MVAR demand and peak reset functions.<br>➤ Revised **METER D** and **METER P** screen figures.<br>➤ Corrected *Equation 5.1*. |

**Table A.4 Instruction Manual Revision History** (Sheet 2 of 9)

| Date Code | Summary of Revisions |
|---|---|
| | **Section 6**<br>➤ Added description of MW and MVAR demand metering.<br>**Section 8**<br>➤ Added MW and MVAR demand metering to *Figure 8.7: METER Menu and Display Structure (continued)*.<br>**Appendix A**<br>➤ Updated for firmware versions R609 and R707 (see *Table A.1*). |
| 20111031 | **Section 7**<br>➤ Corrected description of Ethernet failover operation *in Redundant Ethernet Network Using FAILOVER Mode*.<br>**Appendix A**<br>➤ Updated for Ethernet card firmware version R111 (see *Table A.2*). |
| 20110825 | **Section 1**<br>➤ Added *Horizontal or Vertical Mounting*.<br>**Section 2**<br>➤ Added *Figure 2.4: Front-Panel Drawings-Vertical Mount Models 0387Ex1xxx4 (Panel) and 0387Ex1xxxV (Rack)*.<br>**Section 3**<br>➤ Corrected connections shown in *Figure 3.3: Differential Element (87-1) Quantities*.<br>➤ Corrected logic in *Figure 3.34: Overvoltage Element Logic Diagram*.<br>➤ Added definition of "c" constant in harmonic restraint equation.<br>**Section 6**<br>➤ Added information on COMPANG setting.<br>**Section 7**<br>➤ Updated cable part numbers.<br>**Section 10**<br>➤ Corrected compensation factors shown in *Table 10.3: Connection Compensation Factor*.<br>**Appendix I**<br>➤ Added *Appendix I: Relay Power Calculations*. |
| 20110811 | **Appendix A**<br>➤ Updated for firmware versions R608 and R706 (see *Table A.1*). |
| 20110728 | **Appendix A**<br>➤ Updated for firmware versions R607 and R705 (see *Table A.1*). |
| 20110517 | **Appendix A**<br>➤ Updated for Ethernet card firmware version R109.<br>➤ Updated *Table A.3: ACSELERATOR Architect CID File Compatibility*.<br>**Appendix H**<br>➤ Updated *Table H.4: Buffered Report Control Block Client Access* and *Table H5: Unbuffered Report Control Block Client Access*.<br>➤ Updated number of ACSELERATOR Architect ICD files from four to three.<br>➤ Removed references to 001 and 002L ICD files.<br>➤ Added description of ICD file 004.<br>➤ Added *Table H.7: Logical Node MMZU With Windings Phase Currents* and *Table H.8: Logical Node MSQI With Windings Sequence Currents*.<br>➤ Updated *Table H.21: GetVariableAccessAttributes Conformance Statement* and *Table H.28: ASCI Services Conformance Statement*. |
| 20110111 | **Section 1**<br>➤ Updated specifications for Optoisolated Inputs and added Fiber-Optic specifications. |

**Table A.4 Instruction Manual Revision History** (Sheet 3 of 9)

| Date Code | Summary of Revisions |
|---|---|
| | Section 3<br>➤ Updated *Figure 3.41: Volts/Hertz Inverse-Time Characteristic, 24IC = 0.5*, *Figure 3.42: Volts/Hertz Inverse-Time Characteristic, 24IC = 1*, and *Figure 3.43: Volts/Hertz Inverse-Time Characteristic, 24IC = 2*.<br>Section 7<br>➤ Updated the list of compatible Ethernet cables.<br>Section 10<br>➤ Updated *Figure 10.1: Low-Level Test Interface*.<br>➤ Updated *Table 10.3: Connection Compensation Factor*.<br>Appendix A<br>➤ Updated for firmware versions R606 and R704 (see *Table A.1*). |
| 20100226 | Section 1<br>➤ Updated Ethernet port specifications to include dual-failover functionality.<br>Section 4<br>➤ Added Relay Word bits LNKFAIL, P5SEL, and P6SEL.<br>➤ Added Port 5 settings for dual failover Ethernet and embedded web server.<br>Section 7<br>➤ Added description and example uses of dual failover Ethernet in fixed and failover modes of operation.<br>➤ Added description of embedded web server with screen shots of sample web pages.<br>➤ Updated description of **PAS** command.<br>Appendix A<br>➤ Updated for firmware version R703 (see *Table A.1*).<br>➤ Updated for Ethernet card firmware version R108 (see *Table A.2*).<br>Appendix H<br>➤ Updated for select before operate (SBO) and enhanced security SBO.<br>➤ Added dual failover Ethernet descriptions.<br>➤ Added description of SEL-387E ICD file version 003. |
| 20090205 | Section 7<br>➤ Added reference to Access Level C and changing passwords.<br>Appendix A<br>➤ Updated for Ethernet card firmware version R107. |
| 20081022 | Appendix A<br>➤ Updated for Ethernet card firmware version R106. |
| 20080808 | Appendix A<br>➤ Updated for Ethernet card firmware version R105. |
| 20080110 | Appendix A<br>➤ Added *Ethernet Card Firmware* subsection.<br>Appendix B<br>➤ Added *F. Verify or Restart IEC 61850 Operation to Ethernet Card Firmware Upgrade Instructions* subsection.<br>Appendix H<br>➤ Added *SEL ICD File Versions* subsection.<br>➤ Added *Table H.7: Logical Nodes Summary*.<br>➤ Updated *Table H.11: Logical Device: ANN*. |
| 20071025 | Appendix A<br>➤ Updated for firmware versions R605 and R702. |

**Table A.4 Instruction Manual Revision History** (Sheet 4 of 9)

| Date Code | Summary of Revisions |
|---|---|
| 20060829 | Appendix H<br>➤ Corrected object model information.<br>➤ Added Logical Device table.<br>➤ Added more detail in *Report Processing* subsection.<br>➤ Added *Protocol Implementation Conformance Statement (PICS)* subsection. |
| 20060801 | Section 1<br>➤ Added Ethernet port information to *Specifications*.<br>Section 2<br>➤ Added new *Figure 2.7*.<br>Section 5<br>➤ Updated **STATUS** command example screen capture.<br>Section 6<br>➤ Added Ethernet port information.<br>➤ Added Telnet and Ethernet Port settings to the Setting Sheets.<br>Section 7<br>➤ Added *Ethernet Interfaces* subsection.<br>➤ Edited *Serial Port Interfaces* subsection.<br>➤ Edited *Communications Protocols* subsection.<br>➤ Added *Ethernet Protocols* subsection.<br>➤ Updated **STATUS** command example screen capture.<br>➤ Updated **SET P** command description.<br>➤ Added *Ethernet Port Command Explanation* subsection.<br>Command Summary<br>➤ Added Ethernet port commands and organized commands by access level.<br>Section 8<br>➤ Updated *Figure 8.10*.<br>Appendix A<br>➤ Updated for firmware version R701.<br>Appendix B<br>➤ Updated entire appendix.<br>Appendix E<br>➤ Updated CASCII command description.<br>Appendix H<br>➤ Added new *Appendix H: IEC 61850 Communications*. |
| 20060320 | Appendix A<br>➤ Updated for firmware versions R604 and R208. |
| 20050614 | Appendix A<br>➤ Updated *Firmware Revision History and Manual Revision History*. |
| 20040312 | Section 1<br>➤ Made typographical corrections in specifications.<br>➤ Added general description of new through-fault event monitor.<br>Section 2<br>➤ Corrected *Figure 2.8: Example AC Connections (three-winding transformer; wye-connected voltages)* and *Figure 2.9: Example AC Connections (three-winding transformer; open-delta-connected voltages)*.<br>Section 3<br>➤ Corrected *Figure 3.3: Differential Element (87-1) Quantitie*s and made typographical corrections.<br>➤ Added information about CT connection settings W*n*CT = D (delta) causing current modification before the current is displayed or used in breaker monitoring, metering, or through-fault event monitoring. |

**Table A.4 Instruction Manual Revision History** (Sheet 5 of 9)

| Date Code | Summary of Revisions |
|---|---|
| | **Section 4**<br>➤ Added new Relay Word bit ISQTAL for through-fault event monitoring.<br>**Section 5**<br>➤ Added detailed explanation of new through-fault event monitor.<br>**Section 6**<br>➤ Added Global settings ETHRU, THRU, and ISQT for through-fault event monitoring.<br>**Section 7**<br>➤ Added SEL-2032 where SEL communications processors are mentioned.<br>➤ Added TFE serial port commands for through-fault event monitoring.<br>**Section 9**<br>➤ Added SEL-2032 where SEL communications processors are mentioned.<br>**Section 10**<br>➤ Added Step 5 in Restricted Earth Fault (REF) Function test.<br>**Appendix B**<br>➤ Updated to latest version of SEL-300 Series Relays Firmware Upgrade Instructions.<br>**Appendix G**<br>➤ Added new Relay Word bit ISQTAL to *Table G.4: SEL-387E Relay Binary Input Lookup Table*. |
| 20020730 | **Manual Change Information**<br>➤ Deleted this page from the instruction manual.<br>**Section 3**<br>➤ Made typographical corrections.<br>**Section 4**<br>➤ Corrected row ordering in *Table 4.10: Relay Word Bits Sorted Alphabetically*.<br>**Section 5**<br>➤ Made typographical corrections.<br>**Section 6**<br>➤ Made typographical corrections.<br>**Section 8**<br>➤ Made typographical corrections.<br>**Section 10**<br>➤ Added Step 5 in Restricted Earth Fault (REF) Function test.<br>**Appendix A**<br>➤ Changed the name of the appendix to Firmware and Manual Versions.<br>➤ Revised the firmware versions table to include the corresponding manual date code for firmware versions.<br>➤ Added *Table A.4: Instruction Manual Revision History* to replace the Manual Change Information page previously included in the manual.<br>**Appendix B**<br>➤ Updated to latest version of SEL-300 Series Relays Firmware Upgrade Instructions. |
| 20020218 | **Section 1**<br>➤ Clarified the tightening torque information, corrected values in AC Current Inputs and Power Supply, and added power supply rated 48/125 Vdc or 125 Vac in the Specifications.<br>**Section 2**<br>➤ Updated front- and rear-panel drawings.<br>**Section 3**<br>➤ Added harmonic restraint function necessitating changes to text and figures.<br>➤ Corrected typographical errors. |

**Table A.4 Instruction Manual Revision History** (Sheet 6 of 9)

| Date Code | Summary of Revisions |
|---|---|
| | **Section 4**<br>➤ Added harmonic restraint function necessitating changes to the Relay Word bit tables.<br>➤ Changed Relay Word bit !ALARM to NOTALM necessitating changes in the section text and in the Relay Word bit tables.<br>**Section 5**<br>➤ Added information about energy metering.<br>**Section 6 and Settings Sheets**<br>➤ Added harmonic restraint function necessitating changes to text.<br>➤ Clarified settings for Three-Phase Voltage Input and Phase Potential Connection.<br>**Section 7**<br>➤ Added information about energy metering.<br>**Command Summary**<br>➤ Added information about energy metering.<br>**Section 8**<br>➤ Added information about energy metering.<br>➤ Updated figures.<br>**Section 9**<br>➤ Removed remote bits from *Table 9.6: Differential Event Report Element Columns*.<br>**Section 10**<br>➤ Added harmonic restraint function necessitating changes to text.<br>➤ Corrected typographical errors.<br>**Appendix A**<br>➤ Updated for new firmware versions.<br>**Appendix B**<br>➤ Replaced the appendix with a revised, more comprehensive version.<br>**Appendix D**<br>➤ Corrected typographical errors.<br>**Appendix G**<br>➤ Added harmonic restraint function necessitating changes to Binary Input Table.<br>➤ Changed Relay Word bit !ALARM to NOTALM necessitating changes in the Binary Input Table. |
| 20010906 | **Section 3**<br>➤ Removed 32IOP as input to “REF Directional Element” logic AND gate. With 32IOP removed as an input, the AND gate only uses 32IE and 50GC as inputs. Changed 50GP multiplier from 0.9 to 0.8 in 50GC logic (*Figure 3.8* and *Figure 3.9*).<br>➤ Clarified voltage settings.<br>**Appendix A**<br>➤ Updated for new firmware versions information. |
| 20010521 | ➤ Manual reissue.<br>**Section 1**<br>➤ Made typographical changes under Model Options and in Specifications.<br>**Section 2**<br>➤ Updated front- and rear-panel drawings, rearranged some text, added description of a four-position prewired connector for PT wiring.<br>**Section 3**<br>➤ Changed the title to *Section 3: Differential, Restricted Earth Fault, Overcurrent, Voltage, and Frequency Elements*.<br>➤ Moved overcurrent element application guidelines and descriptions of differential and overcurrent elements from *Section 6* to *Section 3*.<br>➤ Rearranged order of text and figures. |

**Table A.4 Instruction Manual Revision History** (Sheet 7 of 9)

| Date Code | Summary of Revisions |
|---|---|
| | **Section 4**<br>➤ Rearranged and renamed.<br>**Section 5**<br>➤ Rearranged and renamed.<br>➤ Added figures illustrating the station dc battery monitor alarm logic and the undervoltage and overvoltage warning and alarm regions.<br>**Section 6, Settings Sheets, and Settings Sheets Example**<br>➤ Changed the section title.<br>➤ Moved information on differential elements and overcurrent elements and application guidelines for overcurrent elements to *Section 3*.<br>➤ Made typographical corrections.<br>**Section 7**<br>➤ Made text changes throughout to advise the user to change default passwords to private, strong passwords at installation.<br>**Section 8**<br>➤ Made typographical corrections.<br>**Section 9**<br>➤ Made typographical corrections.<br>➤ Added information about Compressed ASCII event reports.<br>**Section 10**<br>➤ Made typographical corrections.<br>**Appendix A**<br>➤ Changed the title.<br>**Appendix E**<br>➤ Replaced specific Relay Word bit names in examples of CASCII messages with “NAMES OF ELEMENTS IN ALL RELAY WORD ROWS.”<br>**Appendix F**<br>➤ Added Function Disabled to list of response codes in Acknowledge Message.<br>**Appendix G**<br>➤ Reordered rows in *SET P Settings Sheet* to match order in relay. |
| 20010130 | **Section 1**<br>➤ Deleted unavailable power supply option from *Specifications*. |
| 20010102 | **Appendix A**<br>➤ Updated.<br>**Appendix G**<br>➤ Updated. |
| 20000116 | **Title Page (Reverse)**<br>➤ Added cautions, warnings, and dangers in English and French.<br>**Section 1**<br>➤ Restructured introduction.<br>➤ Corrected *Figure 1.1: SEL-387E Relay Functional Overview*.<br>➤ Added information about restricted earth fault protection, overvoltage and undervoltage protection, and frequency protection.<br>➤ Made typographical corrections to *Specifications*.<br>**Section 3**<br>➤ Made typographical corrections.<br>**Section 4**<br>➤ Corrected format for the METER report. |

**Table A.4 Instruction Manual Revision History** (Sheet 8 of 9)

| Date Code | Summary of Revisions |
|---|---|
| | **Section 5**<br>➤ Added clarifying information about local control switches.<br>➤ Moved text.<br>➤ Corrected note on page 5-9 to indicate that only one setting group change per day should be made.<br>➤ Added note about making latch bit settings with care on page 5-12.<br>➤ Corrected *Figure 5.7: SEL-387E Relay Trip Logic (TRIP1)* on page 5-17.<br>➤ Clarified *Limitations of SELOGIC® Control Equations* subsection starting on page 5-24.<br>➤ Corrected *Table 5.8*, *Table 5.9*, and *Table 5.10* to add Relay Word bit rows 48 and 49.<br>**Section 6**<br>➤ Text changes to reflect addition of Distributed Network Protocol (DNP) 3.00.<br>**Section 7**<br>➤ Text changes to reflect addition of Distributed Network Protocol (DNP) 3.00.<br>➤ Included SEL-387 Relay Command Summary.<br>➤ Corrected *Table 7.2 on page 7-3*.<br>➤ Deleted information about cable connection SEL-PRTU to SEL-387E and added information about connection of Cable 272A between SEL 2020/2030 and SEL-387E Relay on page 7-5.<br>➤ Added warning about changing default passwords to private passwords at relay installation on page 7-22.<br>➤ Added notes about taking care when setting the date and time on pages 7-17 and 7-32.<br>➤ Added note about making SER settings with care on page 7-28.<br>**Section 8**<br>➤ Text changes to reflect addition of Distributed Network Protocol (DNP) 3.00.<br>➤ Added warning about changing default passwords to private passwords at relay installation on page 8-10.<br>➤ Added notes about taking care when setting the date and time on pages 8-6 and 8-7.<br>➤ Added Winding 1 and 2 current sum for power calculations.<br>**Appendix A**<br>➤ Updated firmware versions.<br>**Appendix D**<br>➤ Made typographical corrections.<br>**Appendix E**<br>➤ Made typographical corrections.<br>**Appendix G**<br>➤ Appendix added to reflect addition of Distributed Network Protocol (DNP) 3.00. |
| 20000728 | **Section 3**<br>➤ Corrected equation on page 3-25.<br>**Section 6**<br>➤ Added detailed information about differential element application and setting and overcurrent protection. |
| 20000606 | **Section 3**<br>➤ Corrected *Figure 3.4: Differential Element Harmonic Blocking Logic* and *Figure 3.6: REF Enable/Block Logic* and made typographical corrections.<br>**Section 6, Settings Sheets and Settings Sheets Example**<br>➤ Made typographical corrections.<br>**Appendix A**<br>➤ Added firmware SEL-387E-R101-V0-Z001001-D20000606 to correct second-harmonic and fifth-harmonic elements' failure to block when required. |

**Table A.4 Instruction Manual Revision History** (Sheet 9 of 9)

| Date Code | Summary of Revisions |
|---|---|
| 20000414 | **Section 2**<br>➤ Clarified PT connections in *Figure 2.16: Example AC Connections (three-winding transformer; open-delta-connected voltages)*.<br>**Section 3**<br>➤ Clarified independent harmonic blocking selection in *Figure 3.4: Differential Element Harmonic Blocking Logic*.<br>➤ Rearranged data in *Table 3.3: Overcurrent Element Summary*.<br>➤ Corrected 50Q*n*1, 50N*n*1, 51Q*n*, and 51N*n* logic and text to show the elements use 3I2 and IR instead of I2 and I0, respectively.<br>➤ Corrected *Figure 3.12: Combined Overcurrent Example*.<br>➤ Made other minor miscellaneous changes.<br>**Section 6**<br>➤ Added information on settings changes via the front panel and serial port, added missing settings descriptions, and consolidated settings sheets.<br>**Section 9**<br>➤ Made minor miscellaneous changes. |
| 20000216 | ➤ Initial version. |

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# Appendix B

# SEL-300 Series Relays Firmware Upgrade Instructions

## Overview

From time to time, SEL issues firmware upgrades. The instructions that follow explain how you can install new firmware in your SEL-300 series relay.

If the relay is equipped with Ethernet communications, upgrade the Ethernet card firmware to the latest available version, or ensure the Ethernet card firmware is the latest available version, *before* upgrading the relay firmware. To obtain the latest available version, contact SEL customer service. Issue the **STATUS** command to the Ethernet card to compare the Ethernet firmware version number to the revision. Follow the *Ethernet Card Firmware Upgrade Instructions on page B.17*, then return here and continue to upgrade the relay firmware.

## Relay Firmware Upgrade Instructions

### Introduction

These firmware upgrade instructions apply to SEL-300 series relays except those listed in *Table B.1*.

**Table B.1 Relays Not Covered by These Instructions**

| |
|---|
| SEL-311C-1, -2 |
| SEL-321 (uses EPROM) |
| SEL-351 Relays equipped with Ethernet |

SEL occasionally offers firmware upgrades to improve the performance of your relay. Changing physical components is unnecessary because the relay stores firmware in Flash memory.

A firmware loader program called SELBOOT resides in the relay. To upgrade firmware, use the SELBOOT program to download an SEL-supplied file from a personal computer to the relay via any communications port. This procedure is described in the following steps.

**NOTE:** SEL strongly recommends that you upgrade firmware at the location of the relay and with a *direct connection* from the personal computer to one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

Perform the firmware upgrade process in the following sequence:

*A. Prepare the Relay*

*B. Establish a Terminal Connection*

*C. Save Settings and Other Data*

*D. Start SELBOOT*

*E. Download Existing Firmware*

*F. Upload New Firmware*

*G. Check Relay Self-Tests*

*H. Verify Settings, Calibration, Status, Breaker Wear, and Metering*

*I. Return the Relay to Service*

### Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer (PC)
- Terminal emulation software that supports 1K Xmodem or Xmodem (these instructions use HyperTerminal from a Microsoft Windows operating system)
- Serial communications cable (SEL Cable SEL-C234A cable or equivalent)
- Firmware Upgrade Instructions (these instructions)

### Optional Equipment

These items help you manage relay settings and understand firmware upgrade procedures:

- SEL-5010 Relay Assistant Software or ACSELERATOR QuickSet® SEL-5030 Software

  The SEL-5010 has a feature that guides you through the conversion process. This upgrade guide will assist you with steps C, D, E, F, and G of these upgrade instructions. If you do not have the latest SEL-5010 software, please contact your customer service representative or the factory for details on getting the SEL-5010.
- Your relay instruction manual

## Upgrade Procedure

### A. Prepare the Relay

Step 1. If the relay is in use, follow your company practices for removing a relay from service.

Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. From the relay front panel, press the **SET** pushbutton.

Step 4. Use the arrow pushbuttons to navigate to `PORT`.

Step 5. Press the **SELECT** pushbutton.

Step 6. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port).

Step 7. Press the **SELECT** pushbutton.

Step 8. With `SHOW` selected, press the **SELECT** pushbutton.

Step 9. Press the down arrow pushbutton to scroll through the port settings; write down the value for each setting.

Step 10. At the `EXIT SETTINGS?` prompt, select `Yes` and press the **SELECT** pushbutton.

Step 11. Connect an SEL-C234A cable (or equivalent) serial communications cable to the relay serial port selected in *Step 6* above.

## B. Establish a Terminal Connection

To establish communication between the relay and a PC, you must be able to modify the computer serial communications parameters (i.e., data transmission rate, data bits, parity) and set the file transfer protocol to 1K Xmodem or Xmodem protocol.

Step 1. Connect a serial communications cable to the computer serial port.

a. Check the computer for a label identifying the serial communications ports.

b. Choose a port and connect an SEL-C234A cable (or equivalent) serial communications cable to the PC serial port.

If there is no identification label, connect the cable to any computer serial port. Note that you might later change this computer serial port to a different port to establish communication between the relay and the computer.

Step 2. Disconnect any other serial port connection(s).

Step 3. From the computer, open **HyperTerminal**.

On a PC running Windows, you would typically click **Start > Programs > Accessories**.

Step 4. Enter a name, select any icon, and click **OK** (*Figure B.1*).

**Figure B.1 Establishing a Connection**

Step 5. Select the computer serial port you are using to communicate with the relay (*Figure B.2*) and click **OK**. This port matches the port connection that you made in *Step 1 on page B.3*.

**Figure B.2 Determining the Computer Serial Port**

Step 6. Establish serial port communications parameters.

The settings for the computer (*Figure B.3*) must match the relay settings you recorded earlier.

a. Enter the serial port communications parameters (*Figure B.3*) that correspond to the relay settings you recorded in *Step 9 on page B.3*.

If the computer settings do not match the relay settings, change the computer settings to match the relay settings.

b. Click **OK**.

**Figure B.3 Determining Communications Parameters for the Computer**

Step 7. Set the terminal emulation to VT100.

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Firmware Upgrade Properties** dialog box (*Figure B.4*).

c. Select **VT100** from the **Emulation** list box and click **OK**.

**Figure B.4 Setting Terminal Emulation**

Step 8. Confirm serial communication.

Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 **=** prompt, similar to that in *Figure B.5*.

If this is successful, proceed to *C. Save Settings and Other Data on page B.6*.

**Figure B.5 Terminal Emulation Startup Prompt**

## Failure to Connect

If you do not see the Access Level 0 **=** prompt, press **<Enter>** again. If you still do not see the Access Level 0 **=** prompt, you have either selected the incorrect serial communications port on the computer, or the computer speed setting does not match the data transmission rate of the relay. Perform the following steps to reattempt a connection.

Step 9. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 10. Correct the port setting.

a. From the **File** menu, choose **Properties**.

You should see a dialog box similar to *Figure B.6*.

b. Select a different port in the **Connect using** list box.

**Figure B.6 Correcting the Port Setting**

Step 11. Correct the communications parameters.

a. From the filename **Properties** dialog box shown in *Figure B.6*, click **Configure**.

You will see a dialog box similar to *Figure B.7*.

b. Change the settings in the appropriate list boxes to match the settings you recorded in *Step 9 on page B.3* and click **OK** twice to return to the terminal emulation window.

**Figure B.7 Correcting the Communications Parameters**

Step 12. Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 **=** prompt, similar to that in *Figure B.5*.

## C. Save Settings and Other Data

Before upgrading firmware, retrieve and record any History (**HIS**), Event (**EVE**), Metering (**MET**), Breaker Wear Monitor (**BRE**), Communications Log Summary (**COM X** or **COM Y**), or Sequential Events Recorder (**SER**) data that you want to retain (see the relay instruction manual for these procedures).

## Enter Access Level 2

NOTE: If the relay does not prompt you for Access Level 1 and Access Level 2 passwords, check whether the relay has a password jumper in place. With this jumper in place, the relay is unprotected from unauthorized access (see the relay instruction manual).

Step 1. Type **ACC <Enter>** at the Access Level 0 **=** prompt.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 **=>** prompt.

Step 3. Type **2AC <Enter>**.

Step 4. Type the Access Level 2 password and press **<Enter>**.

You will see the Access Level 2 **=>>** prompt.

## Backup Relay Settings

The relay preserves settings and passwords during the firmware upgrade process. However, interruption of relay power during the upgrade process can cause the relay to lose settings. Make a copy of the original relay settings in case you need to reenter the settings. Use either the SEL-5010 or QuickSet to record the existing relay settings and proceed to *D. Start SELBOOT*. Otherwise, perform the following steps.

Step 1. From the **Transfer** menu in **HyperTerminal**, select **Capture Text**.

Step 2. Enter a directory and filename for a text file where you will record the existing relay settings.

Step 3. Click **Start**.

The **Capture Text** command copies all the information you retrieve and all the keystrokes you type until you send the command to stop capturing text. The terminal emulation program stores these data in the text file.

Step 4. Execute the Show Calibration (**SHO C**) command to retrieve the relay calibration settings.

Use the following Show commands to retrieve the relay settings: **SHO G**, **SHO 1**, **SHO L 1**, **SHO 2**, **SHO L 2**, **SHO 3**, **SHO L 3**, **SHO 4**, **SHO L 4**, **SHO 5**, **SHO L 5**, **SHO 6**, **SHO L 6**, **SHO P 1**, **SHO P 2**, **SHO P 3**, **SHO P F**, **SHO R**, and **SHO T**.

NOTE: Settings classes can vary among SEL relays. See the relay instruction manual for a listing.

Step 5. From the **Transfer** menu in **HyperTerminal**, select **Capture Text** and click **Stop**.

The computer saves the text file you created to the directory you specified in *Step 2 on page B.7*.

Step 6. Write down the present relay data transmission setting (SPEED).

This setting is SPEED in the **SHO P** relay settings output. The SPEED value should be the same as the value you recorded in *A. Prepare the Relay on page B.2*.

# D. Start SELBOOT

Step 1. Find and record the firmware identification string (FID).

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Properties** dialog box (*Figure B.4*).

c. Click **ASCII Setup**.

You should see a dialog box similar to *Figure B.8*.

d. Under **ASCII Receiving**, select the check box to **Append line feeds to incoming line ends**.

**Figure B.8 Preparing HyperTerminal for ID Command Display**

e. Click **OK** twice to go back to the terminal emulation window.

f. Type **ID <Enter>** and record the FID number the relay displays.

g. Repeat *Step a* through *Step c*, then uncheck the **Append line feeds to incoming line ends** check box. (This feature can cause problems when uploading firmware to the relay.)

Step 2. From the computer, start the SELBOOT program.

a. From the Access Level 2 **=>>** prompt, type **L_D <Enter>**.

The relay responds with the following:

```
Disable relay to send or receive firmware
(Y/N)?
```

b. Type **Y <Enter>**.

The relay responds with the following:

```
Are you sure (Y/N)?
```

c. Type **Y <Enter>**.

The relay responds with the following:

```
Relay Disabled
```

Step 3. Wait for the SELBOOT program to load.

The front-panel LCD screen displays the SELBOOT firmware number (e.g., `SLBT-3xx-R100`). The number following the `R` is the SELBOOT revision number. This number is different from the relay firmware revision number.

After SELBOOT loads, the computer will display the SELBOOT !> prompt.

Step 4. Press **<Enter>** to confirm that the relay is in SELBOOT.

You will see another SELBOOT !> prompt.

## Commands Available in SELBOOT

For a listing of commands available in SELBOOT, type **HELP <Enter>**. You should see a screen similar to *Figure B.9*.

```
!>HELP <Enter>
SELboot-3xx-Rxxx
bau "rate"  ; Set baud rate to 300, 1200, 2400, 4800, 9600, 19200, or 38400 baud
era         ; Erase the existing relay firmware
exi         ; Exit this program and restart the device
fid         ; Print the relays firmware id
rec         ; Receive new firmware for the relay using xmodem
sen         ; Send the relays firmware to a pc using xmodem
hel         ; Print this list

FLASH Type : 040         Checksum = 370E  OK
```

**Figure B.9 List of Commands Available in SELBOOT**

## Establish a High-Speed Connection

Step 5. Type **BAU 38400 <Enter>** at the SELBOOT !> prompt.

## Match Computer Communications Speed to the Relay

Step 6. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 7. Correct the communications parameters.

a. From the **File** menu, choose **Properties**.

b. Choose **Configure**.

c. Change the computer communications speed to match the new data transmission rate in the relay (*Figure B.10*).

d. Click **OK** twice.

Step 8. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication is successful.

**Figure B.10 Matching Computer to Relay Parameters**

## E. Download Existing Firmware

Copy the firmware presently in the relay, in case the new firmware upload is unsuccessful. To make a backup of the existing firmware, the computer will need as much as 3 MB of free disk space. This backup procedure takes 5–10 minutes at 38400 bps.

Step 1. Type **SEN <Enter>** at the SELBOOT !> prompt to initiate the firmware transfer from the relay to the computer.

Step 2. From the **Transfer** menu in **HyperTerminal**, select **Receive File**.

You should see a dialog box similar to *Figure B.11*.

Step 3. Enter the path of a folder on the computer hard drive where you want to record the existing relay firmware.

Step 4. Select **1K Xmodem** if this protocol is available on the PC.

If the computer does not have **1K Xmodem**, choose **Xmodem**.

Step 5. Click **Receive**.

**Figure B.11 Example Receive File Dialog Box**

Step 6. Enter a filename that clearly identifies the existing firmware version (*Figure B.12*), using the version number from the FID you recorded earlier in *Step 1 on page B.7* and click **OK**.

SEL lists the firmware revision number first, then the product number.

**Figure B.12 Example Filename Identifying Old Firmware Version**

If Xmodem times out before the download completes, repeat the process from *Step 1 on page B.10*.

For a successful download, you should see a dialog box similar to *Figure B.13*. After the transfer, the relay responds with the following:

**NOTE:** HyperTerminal stored any path you entered in Step 3 and any filename you entered in Step 6 during the earlier download attempt; this saves you from reentering these on a subsequent attempt.

```
Download completed successfully!
```

**Figure B.13 Downloading Old Firmware**

## F. Upload New Firmware

Step 1. Obtain the latest available firmware version from SEL customer service in preparation to load the firmware.

Step 2. Type **REC <Enter>** at the SELBOOT !> prompt to command the relay to receive new firmware.

```
!>REC <Enter>
Caution! -  This command erases the relays firmware.
If you erase the firmware, new firmware must be loaded into the relay
before it can be put back into service.
```

The relay asks whether you want to erase the existing firmware.

```
Are you sure you wish to erase the existing firmware? (Y/N) Y <Enter>
```

Step 3. Type **Y** to erase the existing firmware and load new firmware. (To abort, type **N** or press **<Enter>**).

The relay responds with the following:

```
Erasing
Erase successful
Press any key to begin transfer, then start transfer at the PC <Enter>
```

Step 4. Press **<Enter>** to start the file transfer routine.

Step 5. Send new firmware to the relay.

a. From the **Transfer** menu in **HyperTerminal**, choose **Send File** (*Figure B.14*).

b. In the **Filename** text box, type the location and filename of the new firmware or use the **Browse** button to select the firmware file.

c. In the **Protocol** text box, select **1K Xmodem** if this protocol is available.

If the computer does not have **1K Xmodem**, select **Xmodem**.

d. Click **Send** to send the file containing the new firmware.

You should see a dialog box similar to *Figure B.14*. Incrementing numbers in the **Packet** box and a bar advancing from left to right in the **File** box indicate that a transfer is in progress.

Receiving software takes 10–15 minutes at 38400 bps, depending on the relay. If you see no indication of a transfer in progress within a few minutes after clicking **Send**, use the **REC** command again and reattempt the transfer.

After the transfer completes, the relay displays the following:

**NOTE:** Unsuccessful uploads can result from Xmodem time-out, a power failure, loss of communication between the relay and the computer, or voluntary cancelation. Check connections, reestablish communication, and start again at Step 2 on page B.11.

If you want to reload the previous firmware, begin at Step 2 on page B.11 and use the firmware you saved in E. Download Existing Firmware on page B.10. Contact the factory for assistance in achieving a successful firmware upgrade.

```
Upload completed successfully. Attempting a restart.
```

A successful restart sequence can take as long as two minutes, after which time the relay leaves SELBOOT. You will see no display on your PC to indicate a successful restart.

**Figure B.14 Selecting New Firmware to Send to the Relay**

**NOTE:** The relay restarts in SELBOOT if relay power fails while receiving new firmware. Upon power-up, the relay serial port will be at the default 2400 baud. Perform the steps beginning in B. Establish a Terminal Connection on page B.3 to increase the serial connection data speed. Then resume the firmware upgrade process at F. Upload New Firmware on page B.11.

**Figure B.15 Transferring New Firmware to the Relay**

Step 6. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on the computer screen.

Step 7. If you see the Access Level 0 = prompt, proceed to *G. Check Relay Self-Tests on page B.13*.

## No Access Level 0 = Prompt

If no Access Level 0 = prompt appears in the terminal emulation window, one of three things could have occurred. Refer to *Table B.2* to determine the best solution.

**Table B.2 Troubleshooting New Firmware Upload**

| Problem | Solution |
|---|---|
| The restart was successful, but the relay data transmission rate reverted to the rate at which the relay was operating prior to entering SELBOOT (the rate you recorded in *A. Prepare the Relay on page B.2*). | Change the computer terminal speed to match the relay data transmission rate you recorded in *A. Prepare the Relay* (see *Match Computer Communications Speed to the Relay on page B.9*).<br>Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication.<br>Step 2. Change the communications software settings to the values you recorded in *A. Prepare the Relay*.<br>Step 3. From the **Call** menu, choose **Connect** to reestablish communication.<br>Step 4. Press **<Enter>** to check for the Access Level 0 **=** prompt indicating that serial communication is successful.<br>Step 5. If you get no response, proceed to *Match Computer Communications Speed to the Relay*. |
| The restart was successful, but the relay data transmission rate reverted to 2400 bps (the settings have been reset to default). | Match the computer terminal speed to a relay data transmission rate of 2400 bps.<br>Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication.<br>Step 2. Change the communications software settings to 2400 bps, 8 data bits, no parity, and 1 stop bit (see *Match Computer Communications Speed to the Relay*).<br>Step 3. From the **Call** menu, choose **Connect** to reestablish communication.<br>Step 4. Press **<Enter>** to check for the Access Level 0 **=** prompt indicating successful serial communication.<br>If you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. Check for the Access Level 0 **=** prompt.<br>If you see the Access Level 0 **=** prompt, proceed to *G. Check Relay Self-Tests*. |
| The restart was unsuccessful, in which case the relay is in SELBOOT. | Reattempt to upload the new firmware (beginning at *Step 5* under *Establish a High-Speed Connection on page B.9*) or contact the factory for assistance. |

## G. Check Relay Self-Tests

The relay can display various self-test fail status messages. The troubleshooting procedures that follow depend upon the status message the relay displays.

Step 1. Type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 **=>** prompt.

Step 3. Enter the **STATUS** command (**STA <Enter>**) to view relay status messages.

If the relay displays no fail status message, proceed to *H. Verify Settings, Calibration, Status, Breaker Wear, and Metering on page B.15*.

## IO_BRD Fail Status Message

Perform this procedure only if you have only an IO_BRD Fail Status message; for additional fail messages, proceed to *CR_RAM, EEPROM, and IO_BRD Fail Status Messages on page B.14*.

Step 1. From Access Level 2, type **INI <Enter>** to reinitialize the I/O board(s). If this command is unavailable, go to *CR_RAM, EEPROM, and IO_BRD Fail Status Messages*.

The relay asks the following:

```
Are the new I/O board(s) correct (Y/N)?
```

a. Type **Y <Enter>**.

b. After a brief interval (as long as a minute), the **EN** LED will illuminate.

If the **EN** LED does not illuminate and you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. After a brief interval, the **EN** LED will illuminate. Check for Access Level 0 **=** prompt.

c. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

**NOTE:** Depending upon the relay, n can be 1–6, G, P, L, T, R, X, or Y.

d. Enter the **SHO *n*** command to view relay settings and verify that these match the settings you saved (see *Backup Relay Settings on page B.7*).

Step 2. If the settings do not match, reenter the settings you saved earlier.

a. If you have SEL-5010 Relay Assistant software or QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 Relay Assistant software or QuickSet, restore the original settings by issuing the necessary **SET *n*** commands, where *n* can be 1–6, G, P, L, T, R, X, or Y (depending upon the settings classes in the relay).

Step 3. Use the **PAS** command to set the relay passwords.

For example, type **PAS 1 <Enter>** to set the Access Level 1 password.

Use a similar format for other password levels. SEL relay passwords are case sensitive, so the relay treats lowercase and uppercase letters as different letters.

Step 4. Go to *H. Verify Settings, Calibration, Status, Breaker Wear, and Metering*.

## CR_RAM, EEPROM, and IO_BRD Fail Status Messages

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

The factory-default passwords are in effect; use the default relay passwords listed in the **PAS** command description in the relay instruction manual.

Step 2. Type **R_S <Enter>** to restore factory-default settings in the relay (type **R_S 1 <Enter>** for a 1 A SEL-387 or 1 A SEL-352 relay).

The relay asks whether to restore default settings. If the relay does not accept the **R_S** (or **R_S 1**) command, contact your customer service representative or the factory for assistance.

Step 3. Type **Y <Enter>**.

**NOTE:** If the relay prompts you to enter a part number, use either the number from the firmware envelope label or the number from the new part number sticker (if supplied).

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the **EN** LED illuminates.

Step 4. Press **<Enter>** to check for the Access Level 0 **=** prompt indicating that serial communication is successful.

Step 5. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

Step 6. Restore the original settings.

a. If you have the SEL-5010 or QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 or QuickSet, restore the original settings by issuing the necessary **SET *n*** commands, where *n* can be 1–6, G, P, L, T, R, X, or Y (depending upon the settings classes available in the relay).

Step 7. Use the **PAS** command to set the relay passwords.

For example, type **PAS 1 <Enter>** to set the Access Level 1 password.

Use a similar format for other password levels. SEL relay passwords are case sensitive, so the relay treats lowercase and uppercase letters as different letters.

Step 8. If any failure status messages still appear on the relay display, see *Section 13: Testing and Troubleshooting* or contact your customer service representative or the factory for assistance.

## H. Verify Settings, Calibration, Status, Breaker Wear, and Metering

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Use the **SHO** command to view the relay settings and verify that these match the settings you saved earlier (see *Backup Relay Settings on page B.7*).

If the settings do not match, reenter the settings you saved earlier (see *Step 6* under *CR_RAM, EEPROM, and IO_BRD Fail Status Messages on page B.14*).

Step 3. Type **SHO C <Enter>** to verify the relay calibration settings.

If the settings do not match the settings contained in the text file you recorded in *C. Save Settings and Other Data on page B.6*, contact your customer service representative or the factory for assistance.

Step 4. Use the firmware identification string (FID) to verify download of the correct firmware.

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Firmware Upgrade Properties** dialog box (*Figure B.4*).

c. Click **ASCII Setup**.

You should see a dialog box similar to *Figure B.16*.

d. Under **ASCII Receiving**, select the check box to **Append line feeds to incoming line ends**.

**Figure B.16 Preparing HyperTerminal for ID Command Display**

e. Click **OK** twice to return to the terminal emulation window.

f. Type **ID <Enter>** and compare the number the relay displays against the number from the firmware envelope label.

g. If the label FID and part number match the relay display, proceed to *Step 5*.

h. For a mismatch between a displayed FID or part number, and the firmware envelope label, reattempt the upgrade or contact the factory for assistance.

Step 5. Type **STA <Enter>** and verify that all relay self-test parameters are within tolerance.

Step 6. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data and see if the relay retained breaker wear data through the upgrade procedure.

If the relay did not retain these data, use the **BRE W*n*** command to reload the percent contact wear values for each pole of Circuit Breaker *n* (*n* = 1, 2, 3, or 4) you recorded in *C. Save Settings and Other Data on page B.6*.

Step 7. Apply current and voltage signals to the relay.

Step 8. Type **MET <Enter>** and verify that the current and voltage signals are correct.

Step 9. Use the **TRIGGER** and **EVENT** commands to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report.

If these values do not match, check the relay settings and wiring.

### I. Return the Relay to Service

Step 1. Follow your company procedures for returning a relay to service.

Step 2. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay.

This step reestablishes automatic data collection between the SEL communications processor and the 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.

# Ethernet Card Firmware Upgrade Instructions

## Introduction

**NOTE:** This section only applies to products equipped with an optional Ethernet card.

Perform the firmware upgrade process in the following sequence:

*A. Prepare the Relay*

*B. Establish an FTP Connection and Transfer New Firmware*

*C. Establish a Telnet Connection*

*D. Verify Firmware Transfer*

*E. Verify or Restart IEC 61850 Operation (Optional)*

### Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer (PC)
- FTP client software (may be included with the PC operating system)
- Latest firmware version file from SEL customer service
- Firmware upgrade instructions (these instructions)

## Upgrade Procedure

### A. Prepare the Relay

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. Apply the following **PORT 1** setting and leave all others at default.

PROTO = TELNET

Step 4. These instructions assume that the Ethernet port (**PORT 5**) settings are set as follows:

IPADDR = 10.201.0.213

SUBNETM = 255.255.0.0

**NOTE:** Use IP settings (IPADDR, SUBNETM, DEFRTR) that are compatible with your PC's network settings.

DEFRTR = 10.201.0.1
ETELNET = Y
TPORTC = 1024
EFTPSERV = Y
FTPUSER = 2AC

## B. Establish an FTP Connection and Transfer New Firmware

The following instructions use the Microsoft Windows command line and FTP client to establish an FTP connection between a PC and the relay. Consult your operating system or FTP client manuals if your equipment or software differs. These instructions assume that both devices are on the same side of any firewalls.

Step 1. Connect an Ethernet cable from the relay Ethernet port to an Ethernet switch and another cable from the PC Ethernet port to the same Ethernet switch.

Alternatively, connect a crossover Ethernet cable between the relay Ethernet port (**PORT 5**) and the PC Ethernet port.

Step 2. Copy the firmware upgrade file to the root directory of the PC's primary drive (usually C:\).

Step 3. Open a Command Prompt window.

a. Click **Start > Run**.

b. Type **cmd** in the dialog box.

c. Click **OK**.

Step 4. In the Command Prompt window, set the current directory to the root of the primary drive (usually C:\).

a. Type **C: <Enter>**.

b. Type **cd \ <Enter>**.

Step 5. In the Command Prompt window, type **FTP <IP Address> <Enter>** (substitute the IP address of the Ethernet port for *<IP Address>*, e.g., **FTP 10.201.0.213**).

Step 6. When prompted, type the relay FTPUSER user name (the default user name is 2AC) and press **<Enter>**. After that, type the FTP user password (the default password is TAIL) and press **<Enter>**.

Step 7. Set the FTP file transfer mode to Binary by typing **BIN <Enter>** at the FTP prompt.

Step 8. Transfer the new firmware to the relay by typing **PUT C:\filename.s19 <Enter>** at the FTP prompt (substitute the firmware file name for *filename.s19*).

Step 9. The FTP file transfer will begin immediately. As the transfer progresses, and upon completion, messages similar to the following will be displayed.

```
200 PORT Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
ftp: 2926780 bytes sent in 46.80 Seconds
62.54 Kbytes/sec.
```

Step 10. Type **QUIT <Enter>** to exit the FTP session when the transfer is complete.

Step 11. (Optional) Delete the firmware upgrade file from the root directory of the computer's primary drive by typing **DELETE C:\filename.s19 <Enter>** at the command prompt.

## C. Establish a Telnet Connection

To establish a Telnet-to-card connection, perform the following steps.

Step 1. Click **Start > Run**.

Step 2. Type **cmd <Enter>** to launch a Command Prompt window.

Step 3. Type **Telnet <IP Address> port** at the prompt (e.g., **Telnet 10.201.0.213 1024**).

Step 4. Press **<Enter>** several times until you see the = prompt.

## D. Verify Firmware Transfer

To verify the firmware transfer completed properly, perform the following steps after establishing a Telnet connection.

Step 1. Issue a Status (**STA**) command.

Step 2. Verify that the Status report does not include any warnings or failures.

Step 3. Verify that the Status report includes `Device Enabled` at the end of the report.

Step 4. Verify that the Status report FID matches the FID of the firmware you transferred.

## E. Verify or Restart IEC 61850 Operation (Optional)

SEL-300 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 because 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 card 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 card firmware upgrade.

Step 1. Establish an FTP connection to the relay Ethernet port (see *B. Establish an FTP Connection and Transfer New Firmware on page B.18*).

Step 2. Open the ERR.TXT file for reading.

If the ERR.TXT file contains error messages relating to CID file parsing, this indicates that the relay has disabled the IEC 61850 protocol. If this file is empty, the relay found no errors during CID file processing and IEC 61850 should remain enabled. Skip to *Step 3* if ERR.TXT is empty.

If the IEC 61850 protocol has been disabled because of 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 Architect software upgrade that supports your required CID file version.

b. Run 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, Architect will detect the upgraded Ethernet card firmware and prompt you to allow it to convert 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 3. In the Telnet session, type **GOO <Enter>**.

Step 4. View the GOOSE status and verify that the transmitted and received messages are as expected.

If you are upgrading both relay firmware and Ethernet card firmware, return to *Upgrade Procedure on page B.2*.

# Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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# Appendix C

# SEL Distributed Port Switch Protocol

## Overview

SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. It is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement.

## Settings

Use the front-panel SET pushbutton or the serial port **SET P** command to activate the LMD protocol. Change the port PROTO setting from the default SEL to LMD to reveal the following settings:

- PREFIX: One character to precede the address.

  This should be a character that does not occur in the course of other communications with the relay. Valid choices are one of the following:

  - @
  - #
  - $
  - %
  - &

  The default is @.

- ADDR: Two-character ASCII address.

  The range is 01 to 99. The default is 01.

- SETTLE: Time in seconds that transmission is delayed after the request to send (RTS line) asserts.

  This delay accommodates transmitters with a slow rise time.

# Operation

1. The relay ignores all input from this port until it detects the prefix character and the two-byte address.
2. Upon receipt of the prefix and address, the relay enables echo and message transmission.
3. Wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is warming up.
4. Until the relay connection terminates, you can use the standard commands that are available when PROTO is set to SEL.
5. The **QUIT** (**QUI**) command terminates the connection.

   If no data are sent to the relay before the port time-out period, it automatically terminates the connection.
6. Enter the sequence **<Ctrl+X> QUIT <CR>** before entering the prefix character if all relays in the multidrop network do not have the same prefix setting.

NOTE: You can use the front-panel SET pushbutton to change the port settings to return to SEL protocol.

# Appendix D

# Configuration, Fast Meter, and Fast Operate Commands

## Introduction

SEL relays have two separate data streams that share the same serial port. The human data communications with the relay consist of ASCII character commands and reports that are intelligible to humans using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering data. To exploit this feature, the device connected to the other end of the link must have software that uses the separate data streams. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

SEL Application Guide *AG95-10: Configuration and Fast Meter Messages*, is a comprehensive description of the SEL binary messages. Below is a description of the messages provided in the SEL-387E Relay.

## Message Lists

### Binary Message List

**Table D.1 Binary Message List**

| Request to Relay (hex) | Response From Relay |
|---|---|
| A5C0 | Relay Definition Block |
| A5C1 | Fast Meter Configuration Block |
| A5D1 | Fast Meter Data Block |
| A5B9 | Fast Meter Status Clear Command |
| A5C2 | Demand Fast Meter Configuration Block |
| A5D2 | Demand Fast Meter Data Message |
| A5C3 | Peak Demand Fast Meter Configuration Block |
| A5D3 | Peak Demand Fast Meter Data Message |
| A5CE | Fast Operate Configuration Block |
| A5E0 | Fast Operate Remote Bit Control |
| A5E3 | Fast Operate Breaker Control |
| A5ED | Fast Operate Reset Command |

## ASCII Configuration Message List

**Table D.2 ASCII Configuration Message List**

| Request to Relay (ASCII) | Response From Relay |
|---|---|
| ID | ASCII Firmware ID String and Terminal ID Setting (TID) |
| DNA | ASCII Names of Relay Word bits |
| BNA | ASCII Names of bits in the Fast Meter Status Byte |

# Message Definitions

## A5C0 Relay Definition Block

In response to the A5C0 request, the relay sends the following block:

**Table D.3 A5C0 Relay Definition Block**

| Data | Description |
|---|---|
| A5C0 | Command |
| 40 | Message length (64 bytes) |
| 02 | Support SEL and LMD protocols |
| 03 | Support Fast Meter, Fast Demand, and Fast Peak |
| 05 | Status flag commands supported: Warn, Fail, Group, or Settings change |
| A5C1 | Fast Meter configuration |
| A5D1 | Fast Meter message |
| A5C2 | Fast Demand configuration |
| A5D2 | Fast Demand message |
| A5C3 | Fast Peak configuration |
| A5D3 | Fast Peak message |
| 0002 | Self-test warning bit |
| 5354410D0000 (**STA<CR>**) | Check status |
| 0003 | Self-test failure bit |
| 5354410D0000 (**STA<CR>**) | Check status |
| 0004 | Settings change bit |
| A5C100000000 | Reconfigure Fast Meter on settings change |
| 0004 | Settings change bit |
| 53484F0D0000 (**SHO<CR>**) | Check the settings |
| 0004 | |
| 53484F20470D (**SHO G<CR>**) | Check the Group settings |
| 0300 | SEL protocol has Fast Operate |
| 0301 | LMD protocol has Fast Operate |
| 00 | Reserved |
| 1-byte | Checksum |

## A5C1 Fast Meter Configuration Block

In response to the A5C1 request, the relay sends the following block:

**Table D.4 A5C1 Fast Meter Configuration Block** (Sheet 1 of 3)

| Data | Description |
|---|---|
| A5C1 | Fast Meter command |
| E0 | Message length (224 bytes) |
| 01 | One status flag byte |
| 01 | Scale factors in configuration message |
| 05 | # scale factors |
| 0D | # analog input channels |
| 02 | # samples per channel |
| 32 | # digital banks (50 bytes) |
| 04 | # calculation blocks |
| 0004 | Analog channel data offset |
| 0038 | Time stamp offset (56 bytes) |
| 0040 | Digital data offset (64 bytes) |
| 494157310000 (IAW1) | Analog channel name |
| 00 | Analog channel type (integer) |
| 01 | Scale factor type (4-byte float) |
| 00CA | Scale factor offset (Winding 1) |
| 494257310000 (IBW1) | |
| 00 | |
| 01 | |
| 00CA | |
| 494357310000 (ICW1) | |
| 00 | |
| 01 | |
| 00CA | |
| 494157320000 (IAW2) | |
| 00 | |
| 01 | |
| 00CE | (Winding 2) |
| 494257320000 (IBW2) | |
| 00 | |
| 01 | |
| 00CE | |
| 494357320000 (ICW2) | |
| 00 | |
| 01 | |
| 00CE | |
| 494157330000 (IAW3) | |
| 00 | |
| 01 | |

**Table D.4 A5C1 Fast Meter Configuration Block** (Sheet 2 of 3)

| Data | Description |
|---|---|
| 00D2 | (Winding 3) |
| 494257330000 (IBW3) | |
| 00 | |
| 01 | |
| 00D2 | |
| 494357330000 (ICW3) | |
| 00 | |
| 01 | |
| 00D2 | |
| 564157580000 (VAWX) | |
| 00 | |
| 01 | |
| 00D6 | (voltages) |
| 564257580000 (VBWX) | |
| 00 | |
| 01 | |
| 00D6 | |
| 564357580000 (VCWX) | |
| 00 | |
| 01 | |
| 00D6 | |
| 564443000000 (VDC) | |
| 00 | |
| 01 | |
| 00DA | |
| 1-byte | Connection byte—Based on PHROT and W1CT settings (Calculation block #1) |
| 03 | Current calculation only |
| FFFF | No skew adjustment |
| FFFF | No RS offset |
| FFFF | No XS offset |
| 00 | IAW1 |
| 01 | IBW1 |
| 02 | ICW1 |
| FF | NA |
| FF | NA |
| FF | NA |
| 1-byte | Connection byte—Based on PHROT and W2CT settings (Calculation block #2) |
| 03 | Current calculation only |
| FFFF | No skew adjustment |
| FFFF | No RS offset |

**Table D.4 A5C1 Fast Meter Configuration Block** (Sheet 3 of 3)

| Data | Description |
|---|---|
| FFFF | No XS offset |
| 03 | IAW2 |
| 04 | IBW2 |
| 05 | ICW2 |
| FF | NA |
| FF | NA |
| FF | NA |
| 1-byte | Connection byte—Based on PHROT and W3CT settings (Calculation block #3) |
| 03 | Current calculation only |
| FFFF | No skew adjustment |
| FFFF | No RS offset |
| FFFF | No XS offset |
| 06 | IAW3 |
| 07 | IBW3 |
| 08 | ICW3 |
| FF | NA |
| FF | NA |
| FF | NA |
| 1-byte | Connection byte—Based on PHROT and DELTA_Y settings (Calculation block #4) |
| 00 | For VIWDG = 1 or 2 or 3 |
| 02 | For VIWDG = 12 |
| FFFF | No skew adjustment |
| FFFF | No RS offset |
| FFFF | No XS offset |
| xx | 00 if VIWDG = 1; 03 if VIWDG = 2; 06 if VIWDG = 3; FF if VIWDG = 12 |
| xx | 01 if VIWDG = 1; 04 if VIWDG = 2; 07 if VIWDG = 3; FF if VIWDG = 12 |
| xx | 02 if VIWDG = 1; 05 if VIWDG = 2; 08 if VIWDG = 3; FF if VIWDG = 12 |
| 09 | VAWX |
| 0A | VBWX |
| 0B | VCWX |
| 4-bytes | Scale factor (200 • $I_{nom}$) • CTR1 Winding 1 |
| 4-bytes | Scale factor (200 • $I_{nom}$) • CTR2 Winding 2 |
| 4-bytes | Scale factor (200 • $I_{nom}$) • CTR2 Winding 3 |
| xxxxxxxx | Scale factor 100 • PTR voltage |
| 3C23D70A | Scale factor (1/100) |
| 1-byte | Reserved |
| 1-byte | Checksum |

## A5D1 Fast Meter Data Block

In response to the A5D1 request, the relay sends the following block:

**Table D.5 A5D1 Fast Meter Data Block**

| Data | Description |
|---|---|
| A5D1 | Command |
| 74 | Message length (116 bytes) |
| 1-byte | Status byte<br>Bit — Usage<br>2 — Self-test warning<br>3 — Self-test failure<br>4 — Settings change |
| 52-bytes | Integers for the following: IAW1, IBW1, ICW1, IAW2, IBW2, ICW2, IAW3, IBW3, ICW3, VAWX, VBWX, VCWX, VDC (Imaginary values first, followed by Real values). Note: The imaginary value for VDC is always zero. |
| 8-bytes | Time stamp |
| 50-bytes | Digital banks—targets 0 through 49 |
| 1-byte | Reserved |
| 1-byte | Checksum |

## A5B9 Fast Meter Status Acknowledge Message

In response to the A5B9 request, the SEL-387E clears the Settings change (STSET) bit in the Status Byte of the Fast Meter messages (A5D1, A5D2, and A5D3). The bit is set when the relay turns on and on settings changes. If the STSET bit is set, the external device should request the A5C1, A5C2, and A5C3 messages to determine if the scale factors or line configuration parameters have been modified. No return response is given to the A5B9 request.

## A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages

In response to the A5C2 or A5C3 request, the relay sends the following block:

**Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages** (Sheet 1 of 3)

| Data | Description |
|---|---|
| A5C2 or A5C3 | Command; Demand (A5C2) or Peak Demand (A5C3) |
| A8 | Message length (168 bytes) |
| 00 | No status byte |
| 01 | Scale factors in Fast Meter configuration |
| 00 | No scale factors used |
| 0F | 15 analog input channels |
| 01 | One sample per channel |
| 00 | No digital banks |
| 00 | No calculations |
| 0004 | Analog channel offset |
| FFFF | No time stamp |
| FFFF | No digital data |
| 494157310000 (IAW1) | Analog channel name |
| 02 | Analog channel type—double precision float |
| FF | No scale factor |

**Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages** (Sheet 2 of 3)

| Data | Description |
|---|---|
| 0000 | No scale factor offset |
| 494257310000 (IBW1) | |
| 02 | |
| FF | |
| 0000 | |
| 494357310000 (ICW1) | |
| 02 | |
| FF | |
| 0000 | |
| 334932573100 (3I2W1) | |
| 02 | |
| FF | |
| 0000 | |
| 495257310000 (IRW1) | |
| 02 | |
| FF | |
| 0000 | |
| 494157320000 (IAW2) | |
| 02 | |
| FF | |
| 0000 | |
| 494257320000 (IBW2) | |
| 02 | |
| FF | |
| 0000 | |
| 494357320000 (ICW2) | |
| 02 | |
| FF | |
| 0000 | |
| 334932573200 (3I2W2) | |
| 02 | |
| FF | |
| 0000 | |
| 495257320000 (IRW2) | |
| 02 | |
| FF | |
| 0000 | |
| 494157330000 (IAW3) | |
| 02 | |
| FF | |

**Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages** (Sheet 3 of 3)

| Data | Description |
|---|---|
| 0000 | |
| 494257330000 (IBW3) | |
| 02 | |
| FF | |
| 0000 | |
| 494357330000 (ICW3) | |
| 02 | |
| FF | |
| 0000 | |
| 334932573300 (3I2W3) | |
| 02 | |
| FF | |
| 0000 | |
| 495257330000 (IRW3) | |
| 02 | |
| FF | |
| 0000 | |
| 1-byte | Reserved |
| 1-byte | Checksum |

## A5D2/A5D3 Demand/ Peak Demand Fast Meter Message

In response to the A5D2 or A5D3 request, the relay sends the following block:

**Table D.7 A5D2/A5D3 Demand/Peak Demand Fast Meter Message**

| Data | Description |
|---|---|
| A5D2 or A5D3 | Command |
| 7E | Message length (126 bytes) |
| 1-byte | Reserved |
| 120-bytes | Demand meter values in double floats in the same order as channel listings in A5C2. |
| 1-byte | Reserved |
| 1-byte | Checksum |

## A5CE Fast Operate Configuration Block

In response to the A5CE request, the relay sends the following block:

**Table D.8 A5CE Fast Operate Configuration Block** (Sheet 1 of 3)

| Data | Description |
|---|---|
| A5CE | Command |
| 40 | Message length, #bytes (64) |
| 03 | # circuit breakers supported |
| 0010 | 16 remote bits |
| 01 | Remote bit pulse supported |

**Table D.8 A5CE Fast Operate Configuration Block** (Sheet 2 of 3)

| Data | Description |
|---|---|
| 00 | Reserved |
| 31 | Open breaker 1 |
| 11 | Close breaker 1 |
| 32 | Open breaker 2 |
| 12 | Close breaker 2 |
| 33 | Open breaker 3 |
| 13 | Close breaker 3 |
| 00 | Clear remote bit RB1 |
| 20 | Set remote bit RB1 |
| 40 | Pulse remote bit RB1 |
| 01 | Clear remote bit RB2 |
| 21 | Set remote bit RB2 |
| 41 | Pulse remote bit RB2 |
| 02 | Clear remote bit RB3 |
| 22 | Set remote bit RB3 |
| 42 | Pulse remote bit RB3 |
| 03 | Clear remote bit RB4 |
| 23 | Set remote bit RB4 |
| 43 | Pulse remote bit RB4 |
| 04 | Clear remote bit RB5 |
| 24 | Set remote bit RB5 |
| 44 | Pulse remote bit RB5 |
| 05 | Clear remote bit RB6 |
| 25 | Set remote bit RB6 |
| 45 | Pulse remote bit RB6 |
| 06 | Clear remote bit RB7 |
| 26 | Set remote bit RB7 |
| 46 | Pulse remote bit RB7 |
| 07 | Clear remote bit RB8 |
| 27 | Set remote bit RB8 |
| 47 | Pulse remote bit RB8 |
| 08 | Clear remote bit RB9 |
| 28 | Set remote bit RB9 |
| 48 | Pulse remote bit RB9 |
| 09 | Clear remote bit RB10 |
| 29 | Set remote bit RB10 |
| 49 | Pulse remote bit RB10 |
| 0A | Clear remote bit RB11 |
| 2A | Set remote bit RB11 |
| 4A | Pulse remote bit RB11 |
| 0B | Clear remote bit RB12 |

**Table D.8 A5CE Fast Operate Configuration Block** (Sheet 3 of 3)

| Data | Description |
|---|---|
| 2B | Set remote bit RB12 |
| 4B | Pulse remote bit RB12 |
| 0C | Clear remote bit RB13 |
| 2C | Set remote bit RB13 |
| 4C | Pulse remote bit RB13 |
| 0D | Clear remote bit RB14 |
| 2D | Set remote bit RB14 |
| 4D | Pulse remote bit RB14 |
| 0E | Clear remote bit RB15 |
| 2E | Set remote bit RB15 |
| 4E | Pulse remote bit RB15 |
| 0F | Clear remote bit RB16 |
| 2F | Set remote bit RB16 |
| 4F | Pulse remote bit RB16 |
| 1-byte | Reserved |
| 1-byte | Checksum |

## A5E0 Fast Operate Remote Bit Control

The external device sends the following message to perform a remote bit operation (set, clear, pulse):

**Table D.9 A5E0 Fast Operate Remote Bit Control**

| Data | Description |
|---|---|
| A5E0 | Command |
| 06 | Message length |
| 1-byte | Operate code (0-F, 20-2F, 40-4F for remote bit clear, set or pulse) |
| 1-byte | Operate validation: 4 * operate code + 1 |
| 1-byte | Checksum |

Remote bit set and clear operations are latched by the relay. Remote bit pulse operations assert the remote bit for one processing interval.

## A5E3 Fast Operate Breaker Control

The external device sends the following message to perform a fast breaker open/close of Breakers 1 through 4:

**Table D.10 A5E3 Fast Operate Breaker Control**

| Data | Description |
|---|---|
| A5E3 | Command |
| 06 | Message length |
| 1-byte | Operate code (hex 31–33 open, hex 11–13 close breakers 1 through 3) |
| 1-byte | Operate validation: 4 * operate code + 1 |
| 1-byte | Checksum |

## A5CD Fast Operate Reset Definition Block

In response to an A5CD request, the relay sends the configuration block for the Fast Operate Reset message.

**Table D.11 A5CD Fast Operate Reset Definition Block**

| Data | Description |
|---|---|
| A5CD | Command |
| 0E | Message length |
| 01 | The number of Fast Operate reset codes supported |
| 1-byte | Reserved for future use |
| | **Per Fast Operate reset code, repeat:** |
| 00 | Fast Operate reset code (e.g., “00” for target reset) |
| 54415220520000 | Fast Operate reset description string (e.g., “TAR R”) |
| 1-byte | Checksum |

## A5ED Fast Operate Reset Command

The Fast Operate Reset commands take the following form:

**Table D.12 A5ED Fast Operate Reset Command**

| Data | Description |
|---|---|
| A5ED | Command |
| 06 | Message length—always 6 |
| 00 | Operate Code (e.g., “00 for target reset, “TAR R”) |
| 00 | Operate Validation—(4 + Operate Code) +1 |
| 1-byte | Checksum |

## ID Command

In response to the **ID** command, the relay sends the firmware ID, the relay TID setting, and the Modbus device code, as described below.

```
<STX>          (STX character, 02)
"FID STRING ENCLOSED IN QUOTES","yyyy"<CR>
"THE CHECKSUM OF THE ROM CODE","yyyy"<CR>
"THE TERMINAL ID AS SET BY THE TID SETTING","yyyy"<CR>
"DEVCODE=54","yyyy"<CR>
"PARTNO=0387EXXXXXXXXXp","yyyy"<CR>
"CONFIG=111100","0387"<CR>
<ETX>          (ETX character, 03)
```

where:

`yyyy` = the 4-byte ASCII representation of the hex checksum for the line

`54` = the device code used by the SEL-2020 to identify the relay to Modbus users

`PARTNO` = the part number. The last digit of the part number (*p*) indicates whether the firmware supports DNP communications or not. For *p* = 1, the communications protocol will be Standard plus DNP3 Level 2 Outstation; for *p* = X, it will be Standard with no DNP.

## DNA Command

In response to the **DNA** command, the relay sends names of the Relay Word bits, as described below:

```
<STX>        (STX character, 02)
"xxxxxx","xxxxxx","xxxxxx","xxxxxx","xxxxxx","xxxxxx","xxxxxx","xxxxxx","yyyy"<CR>
... (49 more, where xxxxxx is a relay word element name)
<ETX>        (ETX character, 03)
```

where:

`xxxxxx` = each name in ASCII. "*" indicates an unused bit position. The labels shall appear in order from Most Significant Bit (MSB) to Least Significant Bit (LSB).

`yyyy` = the 4-byte ASCII representation of the hex checksum for the line

## BNA Command

In response to the **BNA** command, the relay sends the names of the bits transmitted in the Status Byte of the Fast Meter messages (A5D1, A5D2, and A5D3) as shown below:

```
<STX>(STX character, 02)
"*","*","*","STSET","STFAIL","STWARN","*","*","yyyy"<CR>
<ETX>(ETX character, 03)
```

where:

`yyyy` = the 4-byte ASCII representation of the hex checksum for the line

The bits named are defined as follows:

- STSET: Set when the relay turns on or a settings change has occurred. It is cleared by the A5B9 request (see *A5B9 Fast Meter Status Acknowledge Message*).
- STFAIL: One or more of the monitored status quantities are in a FAIL state.
- STWARN: One or more of the monitored status quantities are in a WARN state.

## SNS Message

In response to the **SNS** command, the relay sends the name string of the SER (SER1, SER2, SER3, and SER4) settings. The **SNS** command is available at Access Level 1.

The relay responds to the **SNS** command with the name string in the SER settings. The name string starts with SER1, followed by SER2, SER3, and SER4.

For example, if SER1 = 50P11 OUT101; SER2 = 87U1 32IF; SER3 = OUT102 52A, SER4 = 0; the name string will be "50P11","OUT101","87U1","32IF","OUT02","52A".

If there are more than eight settings in SER, the SNS message will have several rows. Each row will have eight strings, followed by the checksum and cartridge return. The last row may have fewer than eight strings.

The ALIAS settings are ignored for the **SNS** command (i.e., if ALIAS1 = OUT101 CL_BKR_1, SNS includes "OUT101", *not* the custom label). Refer to *Section 6: Settings*.

SNS message for the SEL-387E is:

```
<STX>"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR>
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR>
"xxxx","xxxx","xxxx",<CR><ETX>
```

where:

`xxxx` = a string from the settings in SER (SER1, SER2, SER3, and SER4).

`yyyy` = the 4-byte ASCII representation of the checksum

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# Appendix E

# Compressed ASCII Commands

## Introduction

The SEL-387E Relay provides Compressed ASCII versions of some relay ASCII commands. The Compressed ASCII commands allow an external device to obtain data from the relay, in a format which directly imports into spreadsheet or database programs, and which can be validated with a checksum.

The SEL-387E provides the following Compressed ASCII commands:

**Table E.1 Compressed ASCII Commands**

| Command | Description |
|---|---|
| **CASCII** | Configuration message |
| **CSTATUS** | Status message |
| **CHISTORY** | History message |
| **CEVENT** | Event report (winding) |
| **CEVENT DIF** | Event report (differential) |
| **CHISTORY** | History report |
| **CSTATUS** | Status report |
| **CTARGET** | Target display |

## CASCII Command—General Format

The Compressed ASCII configuration message provides data for an external computer to extract data from other Compressed ASCII commands. To obtain the configuration message for the Compressed ASCII commands available in an SEL relay, type:

**CAS <CR>**

The relay sends:

```
<STX>"CAS",n,"yyyy"<CR>
"COMMAND 1",l1,"yyyy" <CR>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy" <CR>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy" <CR>
"COMMAND 2",l1,"yyyy" <CR>
"#h","ddd","ddd",......,"ddd","yyyy" <CR>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy" <CR>
.
.
.
"COMMAND n",l1,"yyyy" <CR>
"#H","xxxxx","xxxxx",......,"xxxxx","yyyy" <CR>
"#D","ddd","ddd","ddd","ddd",......,"ddd","yyyy"<CR><ETX>
```

where:

`n` = the number of Compressed ASCII command descriptions to follow.

`COMMAND` = the ASCII name for the Compressed ASCII command as sent by the requesting device. The naming convention for the Compressed ASCII commands is a “C” preceding the typical command. For example, **CSTATUS** (abbreviated to CST) is the Compressed **STATUS** command.

`l1` = the minimum access level (e.g., 1, B, or 2) at which the command is available.

`"#H"` identifies a header line to precede one or more data lines; “#” is the number of subsequent ASCII names. For example, “21H” identifies a header line with 21 ASCII labels.

`"#h"` identifies a header line to precede one or more data lines; “#” is the number of subsequent format fields. For example, “8h” identifies a header line with 8 format fields.

`"xxxxx"` = an ASCII name for corresponding data on following data lines. Maximum ASCII name width is 10 characters.

`"#D"` identifies a data format line; “#” is the maximum number of subsequent data lines.

`"ddd"` identifies a format field containing one of the following type designators:

- I Integer data
- F Floating point data
- mS String of maximum m characters (e.g., 10S for a 10-character string

`"yyyy"` is the 4-byte HEX ASCII representation of the checksum

A Compressed ASCII command may require multiple header and data configuration lines.

If a Compressed ASCII request is made for data that are not available, (e.g., the history buffer is empty or invalid event request), the relay responds with the following message:

```
<STX>"No Data Available","0668"<CR><ETX>
```

# CASCII Command—SEL-387E

Display the SEL-387E Compressed ASCII configuration message by sending:

**CAS <CR>**

The relay sends:

```
<STX>
"CAS",7,"yyyy"<CR>
"CST",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","35S","yyyy"<CR>
"7H","MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
"1D","I","I","I","I","I","I","I","yyyy"<CR>
"26H","IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","VAWX",
"VBWX","VCWX","+5V_PS","+5V_REG","-5V_REG","+12V_PS","-12V_PS","+15V_PS",
"-15V_PS","TEMP","RAM","ROM","A/D","CR_RAM","EEPROM","IO_BRD","CCRAM",
"CCROM","PORT5","PORT6","CCFPGA","CCBOARD","CCDPRAM","CCPS","yyyy"<CR>
"1D","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S
    ","9S",
"9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S
    ",
"yyyy"<CR>
"CBR",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","35S","yyyy"<CR>
"7H","MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
"1D","I","I","I","I","I","I","I","yyyy"<CR>
"19H","BREAKER","INT_TRIPS","IAW","IBW","ICW","EXT_TRIPS","IAW","IBW","ICW","POLE1"
    ,"POLE2","POLE3","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC",
"yyyy"<CR>
"3D","I","I","F","F","F","I","F","F","F","I","I","I","I","I","I","I","I","I","I","y
    yyy"<CR>
"CHI",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","35S","yyyy"<CR>
"7H","MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
"1D","I","I","I","I","I","I","I","yyyy"<CR>
"11H","REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","EVENT",
"GROUP","TARGETS","yyyy"<CR>
"99D","I","I","I","I","I","I","I","I","7S","I","52S","yyyy"<CR>
"CEV",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","35S","yyyy"<CR>
"7H","MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
"1D","I","I","I","I","I","I","I","yyyy"<CR>
"5H","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","yyyy"<CR>
"1D","F","I","I","F","7S","yyyy"<CR>
"16H","IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","VAWX",
"VBWX","VCWX","VDC","FREQ","TRIG","NAMES OF ELEMENTS IN ALL RELAY WORD ROWS
    ","yyyy"<CR>
"60D","F","F","F","F","F","F","F","F","F","F","F","F","F","F","F","1S","88S","yyyy"<CR>
"CEV C",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","35S","yyyy"<CR>
"7H","MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
"1D","I","I","I","I","I","I","I","yyyy"<CR>
"5H","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","yyyy"<CR>
"1D","F","I","I","F","7S","yyyy"<CR>
"16H","IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","VAWX",
"VBWX","VCWX","VDC","FREQ","TRIG","NAMES OF ELEMENTS IN ALL RELAY WORD
    ROWS","yyyy"<CR>
"120D","F","F","F","F","F","F","F","F","F","F","F","F","F","F","F","1S","88S","yyyy"<CR
    >
"CEV S64 R",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","35S","yyyy"<CR>
"7H","MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
"1D","I","I","I","I","I","I","I","yyyy"<CR>
"5H","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","yyyy"<CR>
"1D","F","I","I","F","7S","yyyy"<CR>
"16H","IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","VAWX",
"VBWX","VCWX","VDC","FREQ","TRIG","NAMES OF ELEMENTS IN ALL RELAY WORD ROWS
    ","yyyy"<CR>
"1056D","F","F","F","F","F","F","F","F","F","F","F","F","F","F","F","1S","88S","yyyy"<C
    R>
"CTA",1,"yyyy"<CR>
"8h","6S","6S","6S","6S","6S","6S","6S","6S","yyyy"<CR>
"1D","I","I","I","I","I","I","I","I","yyyy"<CR>
<ETX>
```

where:

"yyyy" = the 4-byte ASCII representation of the hex checksum for the line.

"#H" identifies a header line to precede one or more data lines; "#" is the number of subsequent ASCII labels. For example, "21H" identifies a header line with 8 ASCII labels.

"#h" identifies a header line to precede one or more data lines; "#" is the number of subsequent format fields. For example, "8h" identifies a header line with 8 format fields.

"#D" identifies a data format line; "#" is the maximum number of subsequent data lines, each format field containing one of the following type designators:

- I Integer data
- F Floating point data
- mS String of maximum m characters (e.g., 10S for a 10-character string

**NOTE:** If the analog current input names (IAW1, etc.) have been changed via the Analog Input Labels Global settings, they will appear in the above report as set.

If a Compressed ASCII request is made for data that are not available, (e.g., the history buffer is empty or invalid event request), the relay responds with the following message:

```
<STX>"No Data Available","0668"<CR><ETX>
```

# CBREAKER Command

Display the SEL-387E Compressed ASCII breaker report by sending:

**CBR <CR>**

The relay sends:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387E-XXXX-V-ZXXXXXX-DXXXXXXXX","yyyy"<CR>
"MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR>
"BREAKER","INT_TRIPS","IAW","IBW","ICW","EXT_TRIPS","IAW","IBW","ICW",
"POLE1","POLE2","POLE3","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC",
"yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
    xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx"yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
    xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx"yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
    xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx"yyyy"<CR>
<ETX>
```

where: The data are a summation of breaker information collected since the last summary clear.

"xxxx" = the data values corresponding to the first line labels.

"yyyy" = the 4-byte hex ASCII representation of the checksum.

# CEVENT Command

The CEV report contains every analog and digital element found in an EVE report, and displays the information in Compressed ASCII format by sending:

**CEV [DIF R] [*n* S*x* L*y*[–[*w*]] C] <Enter>**

The command parameters, all optional, can be entered in any order. They are:

| **Report Types:** | |
|---|---|
| DIF | Display differential information for the all elements |
| R | Displays raw (unfiltered) analog data and raw station battery<br>Displays preceding 1.5 cycles (including reports with "L" options)<br>Allows S4, S8, S16, S32, and S64<br>Defaults to S16 samples/cycle |
| (default) | Display cosine filtered fundamental currents on all windings and station battery averaged for 1 cycle |
| **Report Options:** | |
| *n* | Event number (Defaults to 1) |
| S*x* | Samples per cycle (*x* = 4 or 8 [See "R" option])<br>Defaults to 4 if Sx not specified |
| L*y* | Display first *y* cycles of event report ( *y* = 1 – LER)<br>Defaults to L15 if L*y* not specified |
| L*y*– | Displays event report from cycle *y* to end of report |
| L*y*–w | Displays event report from cycle *y* to cycle *w* |
| C | Default to 8 samples/cycle (same as **EVE C**) |

**NOTE:** If Sx and/or Ly are given, they override all other parameters.

**NOTE:** The L and U parameters are supported for consistency with the SEL-321 Relay. The C parameter is used for SEL-2020 compatibility.

## CEVENT Winding Report (Default)

If DIF is not specified in the command line, the default report is the winding currents report. To obtain a report, send the following:

```
CEV <Enter>
```

The relay responds:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387E-XXXX-V-ZXXXXXX-DXXXXXXXX","yyyy"<CR>
"MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR>
"FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,"xxxx","yyyy"<CR>
"IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","VAWX",
"VBWX","VCWX","VDC","TRIG","FREQ","DIGITAL_ELEMENT_NAMES","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
    xxxx,xxxx,"z","RLY_BITS"<CR>
... (previous line repeated for SAM/CYC_A*NUM_OF_CYC)
"SETTINGS","yyyy"<CR>
"SETTINGS text","yyyy"<CR>
<ETX>
```

**NOTE:** "DIGITAL_ELEMENT_NAMES" consists of the text strings representing the names for the Relay Word bits from the element store visible to the user, excluding the first two front-panel rows.

where:

"xxxx" = the data values corresponding to the first line labels.

"yyyy" = the 4-byte hex ASCII representation of the checksum.

**NOTE:** If the analog current input names (IAW1, etc.) have been changed via the Analog Input Labels Global settings, they will appear in the above report as set.

"z" = ">" to mark where the event was triggered, "*" to mark the maximum current for the event, with the "*" overriding the ">"

RLY_BITS = relay element data, in hex ASCII, corresponding to the DIGITAL_ELEMENT_NAMES

SETTINGS = text refers to the current settings of the relay as described in the event report section.

## CEVENT Differential Report

If DIF is specified in the command line, the report on differential element quantities is provided. To obtain the report, send the following:

```
CEV DIF <Enter>
```

The relay responds:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387E-XXXX-V-ZXXXXXX-DXXXXXXXX","yyyy"<CR>
"MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR>
"FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,"xxxx","yyyy"<CR>
"IOP1","IRT1","I1F2","I1F5",
    "IOP2","IRT2","I2F2","I2F5","IOP3","IRT3","I3F2","I3F5",
    "TRIG","DIGITAL_ELEMENT_NAMES","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"z","RLY_BITS","yyyy"
<CR> ... (previous line repeated for SAM/CYC_A*NUM_OF_CYC)
"SETTINGS","yyyy"<CR>
"SETTINGS text","yyyy"<CR>
<ETX>
```

**NOTE:** "DIGITAL_ELEMENT_NAMES" consists of the text strings representing the names for the Relay Word bits from the element store visible to the user, excluding the first 2 front-panel rows.

where:

"xxxx" = the data values corresponding to the first line labels.

"yyyy" = the 4-byte hex ASCII representation of the checksum.

"z" = ">" to mark where the event was triggered, "*" to mark the maximum current for the event, with the "*" overriding the ">"

RLY_BITS = relay element data, in hex ASCII, corresponding to the DIGITAL_ELEMENT_NAMES

SETTINGS = text refers to the current settings of the relay as described in the event report section.

# CHISTORY Command

Display the SEL-387E Compressed ASCII history report by sending:

```
CHI <Enter>
```

The relay sends:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387E-XXXX-V-ZXXXXXX-DXXXXXXXX","yyyy"<CR>
"MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR>
"REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","EVENT",
"GROUP", "TARGETS", "yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"xxxx",xxxx,"xxxx", " yyyy"<CR>
... (continue previous line until all events are listed-max 99)
<ETX>
```

where: The data comprise a list of all events since the last history clear.

"xxxx" = the data values corresponding to the first line labels.

"yyyy" = the 4-byte hex ASCII representation of the hex checksum for the line.

# CSTATUS Command

Display the SEL-387E Compressed ASCII status report by sending:

```
CST <Enter>
```

**NOTE:** If the analog current input names (IAW1, etc.) have been changed via the Analog Input Labels Global settings, they will appear in the above report as set.

The relay sends:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387E-XXXX-V-ZXXXXXX-DXXXXXXXX","yyyy"<CR>
"MONTH_","DAY_","YEAR_","HOUR_","MIN_","SEC_","MSEC_","yyyy"<CR>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR>
"IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3", "VAWX",
"VBWX","VCWX",
"+5V_PS","+5V_REG","-5V_REG","+12V_PS","-12V_PS","+15V_PS",
"-15V_PS","TEMP","RAM","ROM","A/D","CR_RAM","EEPROM","IO_BRD","CCRAM",
"CCROM","PORT5","PORT6","CCFPGA","CCBOARD","CCDPRAM","CCPS","yyyy"<CR>
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx"
    ,
    "xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","x
    xxx",
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR>
<ETX>
```

where:

"xxxx" = the data values corresponding to the first line labels.

"yyyy" = the 4-byte hex ASCII representation of the hex checksum for the line.

# CTARGET Command

Display the SEL-387E Compressed ASCII target display by sending:

```
CTA N <Enter>
```

where N is one of the target numbers or element names accepted by the **TAR** command. If N is omitted, 0 is used.

The relay responds:

```
<STX>
"LLLL","LLLL","LLLL","LLLL","LLLL","LLLL","LLLL","LLLL","yyyy"<CR>
x,x,x,x,x,x,x,x,"yyyy"<CR>
<ETX>
```

where:

`LLLL` = the labels for the given target.

`"xxxx"` = 0 or 1 corresponding to the first line labels.

`"yyyy"` = the 4-byte hex ASCII representation of the hex checksum for the line.

# Appendix F

# Unsolicited SER Protocol

## Introduction

This appendix describes special binary Sequential Events Recorder (SER) messages that are not included in *Section 9: Analyzing Events*. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary SER messages from the SEL-387E Relay.

SEL relays and communications processors have two separate data streams that share the same serial port. The normal serial interface consists of ASCII character commands and reports that are intelligible to people using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering or SER data. To exploit this feature, the device connected to the other end of the link requires software that uses the separate data streams. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

### Note: Make Sequential Events Recorder (SER) Settings With Care

The relay triggers a row in the Sequential Events Recorder (SER) event report for any change of state in any one of the elements listed in the SER1, SER2, SER3, or SER4 trigger settings. Nonvolatile memory is used to store the latest 512 rows of the SER event report so they can be retained during power loss. The nonvolatile memory is rated for a finite number of "writes." Exceeding the limit can result in an EEPROM self-test failure. *An average of four state changes per minute can be made for a 25-year relay service life.*

## Recommended Message Usage

Use the following sequence of commands to enable unsolicited binary SER messaging in the SEL-387E:

1. On initial connection, send the **SNS** command to retrieve and store the ASCII names for the digital I/O points assigned to trigger SER records. The order of the ASCII names matches the point indices in the unsolicited binary SER messages. Send the "Enable Unsolicited Data Transfer" message to enable the SEL-387E to transmit unsolicited binary SER messages.
2. When SER records are triggered in the SEL-387E, the relay responds with an unsolicited binary SER message. If this message has a valid checksum, it must be acknowledged by sending an acknowledge message with the same response

number as contained in the original message. The relay will wait approximately 100 ms to 500 ms to receive an acknowledge message, at which time the relay will resend the same unsolicited SER message with the same response number.

3. Upon receiving an acknowledge message with a matching response number, the relay increments the response number and continues to send and seek acknowledgment for unsolicited SER messages, if additional SER records are available. When the response number reaches three, it wraps around to zero on the next increment.

# Functions and Function Codes

In the messages shown below, all numbers are in hexadecimal unless otherwise noted.

## 0x01—Function Code: Enable Unsolicited Data Transfer

When the SEL-387E turns on, it disables its own unsolicited transmissions. This function enables the SEL-387E to begin sending unsolicited data to the device which sent the enable message, if the SEL-387E has such data to transfer. The message format for function code 0x01 is shown below.

| Data | Description |
|---|---|
| A546 | Message header |
| 12 | Message length in bytes (18 decimal) |
| 0000000000 | Five bytes reserved for future use as a routing address |
| YY | Status byte (LSB = 1 indicates an acknowledge is requested) |
| 01 | Function code |
| C0 | Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.) |
| XX | Response number (XX = 00, 01, 02, 03, 00, 01...) |
| 18 | Function to enable (0x18—unsolicited SER messages) |
| 0000 | Reserved for future use as function code data |
| nn | Maximum number of SOE records per message, 01–20 hex) |
| cccc | Two-byte CRC-16 check code for message |

The SEL-387E verifies the message by checking the header, length, function code, and enabled function code against the expected values. It also checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to enable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

The “nn” field is used to set the maximum number of SER records per message. The relay checks for SER records approximately every 500 ms. If there are new records available, the relay immediately creates a new unsolicited SER message and transmits it. If there are more than “nn” new records available, or if the first and last records are separated by more than

16 seconds, the relay will break the transmission into multiple messages so that no message contains more than “nn” records, and the first and last records of each message are separated by no more than 16 seconds.

If the function to enable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing a response code 01 (function code unrecognized), and no functions are enabled. If the SER triggers are disabled, (SER1, SER2, SER3, and SER4 are all set to NA), the unsolicited SER messages are still enabled, but the only SER records generated are due to settings changes and power being applied to the relay. If the SER1, SER2, SER3, or SER4 settings are subsequently changed to any non-NA value and SER entries are triggered, unsolicited SER messages will be generated with the new SER records.

## 0x02—Function Code: Disable Unsolicited Data Transfer

This function disables the SEL-387E from transferring unsolicited data. The message format for function code 0x02 is shown below.

| Data | Description |
|---|---|
| A546 | Message header |
| 10 | Message length (16 decimal) |
| 0000000000 | Five bytes reserved for future use as a routing address. |
| YY | Status byte (LSB = 1 indicates an acknowledge is requested) |
| 02 | Function code |
| C0 | Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.) |
| XX | Response number (XX = 00, 01, 02, 03, 01, 02...) |
| 18 | Function to disable (0x18 = Unsolicited SER) |
| 00 | Reserved for future use as function code data |
| cccc | Two-byte CRC-16 check code for message |

The SEL-387E verifies the message by checking the header, length, function code, and disabled function code against the expected values, and checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to disable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

If the function to disable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing the response code 01 (function code unrecognized) and no functions are disabled.

## 0x18—Function: Unsolicited Sequential Events Response

The function 0x18 is used for the transmission of unsolicited Sequential Events Recorder (SER) data from the SEL-387E. This function code is also passed as data in the `Enable Unsolicited Data Transfer` and the `Disable Unsolicited Data Transfer` messages to indicate which type of unsolicited data should be enabled or disabled. The message format for function code 0x18 is shown below.

| Data | Description |
|---|---|
| A546 | Message header |
| ZZ | Message length (Up to 34 + 4 • nn decimal, where nn is the maximum number of SER records allowed per message as indicated in the `Enable Unsolicited Data Transfer` message.) |
| 0000000000 | Five bytes reserved for future use as a routing address |
| YY | Status Byte (01 = need acknowledgment; 03 = settings changed and need acknowledgment) |
| 18 | Function code |
| C0 | Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.) |
| XX | Response number (XX = 00, 01, 02, 03, 01, 02...) |
| 00000000 | Four bytes reserved for future use as a return routing address |
| dddd | Two-byte day of year (1–366) |
| yyyy | Two-byte, four-digit year (e.g., 1999 or 07CF hex) |
| mmmmmmmm | Four-byte time of day in milliseconds since midnight |
| XX | 1st element index (match with the response to the SNS command; 00 for 1st element, 01 for second element, and so on) |
| uuuuuu | Three-byte time tag offset of 1st element in microseconds since time indicated in the time of day field. |
| XX | 2nd element index |
| uuuuuu | Three-byte time tag offset of 2nd element in microseconds since time indicated in the time of day field. |
| .<br>.<br>. | |
| xx | Last element index |
| uuuuuu | Three-byte time tag offset of last element in microseconds since time indicated in the time of day field. |
| FFFFFFFE | Four-byte end-of-records flag |
| ssssssss | Packed four-byte element status for as many as 32 elements (LSB for the 1st element) |
| cccc | Two-byte CRC-16 checkcode for message |

If the relay determines that SER records have been lost, it sends a message with the following format:

| Data | Description |
|---|---|
| A546 | Message header |
| 22 | Message length (34 decimal) |
| 0000000000 | Five bytes reserved for future use as a routing address. |
| YY | Status Byte (01 = need acknowledgment; 03 = settings changed and need acknowledgment) |
| 18 | Function code |
| C0 | Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.) |
| XX | Response number (XX = 00, 01, 02, 03, 00, 01, ...) |
| 00000000 | Four bytes reserved for future use as a return routing address |

| Data | Description |
|---|---|
| dddd | Two-byte day of year (1–366) of overflow message generation |
| yyyy | Two-byte, four-digit year (e.g., 1999 or 07CF hex) of overflow message generation. |
| mmmmmmmm | Four-byte time of day in milliseconds since midnight |
| FFFFFFFE | Four-byte end-of-records flag |
| 00000000 | Element status (unused) |
| cccc | Two-byte CRC-16 checkcode for message |

## Acknowledge Message

The acknowledge message is constructed and transmitted for every received message which contains a status byte with the LSB set (except another acknowledge message) and which passes all other checks, including the CRC. The acknowledge message format is shown below.

| Data | Description |
|---|---|
| A546 | Message header |
| 0E | Message length (14 decimal) |
| 0000000000 | Five bytes reserved for future use as a routing address |
| 00 | Status byte (always 00) |
| XX | Function code, echo of acknowledged function code with MSB set. |
| RR | Response code (see below) |
| XX | Response number (XX = 00, 01, 02, 03, 00, 01, ...) must match response number from message being acknowledged. |
| cccc | Two-byte CRC-16 checkcode for message |

The SEL-387E supports the following response codes:

| RR | Response |
|---|---|
| 00 | Success |
| 01 | Function code not recognized |
| 02 | Function disabled |

### Examples

1. Successful acknowledge for `Enable Unsolicited Data Transfer` message from a relay with at least one of SER1, SER2, or SER3 not set to NA:

   A5 46 0E 00 00 00 00 00 00 81 00 XX cc cc

   (XX is the same as the Response Number in the `Enable Unsolicited Data Transfer` message to which it responds.)

2. Unsuccessful acknowledge for `Enable Unsolicited Data Transfer` message from a relay with all of SER1, SER2, and SER3 set to NA:

   A5 46 0E 00 00 00 00 00 00 81 02 XX cc cc

   (XX is the same as the response number in the `Enable Unsolicited Data Transfer` message to which it responds.)

3. Disable Unsolicited Data Transfer message, acknowledge requested:

   A5 46 10 00 00 00 00 00 01 02 C0 XX 18 00 cc cc

   (XX = 0, 1, 2, 3)

4. Successful acknowledge from the relay for the `Disable Unsolicited Data Transfer` message:

   A5 46 0E 00 00 00 00 00 00 82 00 XX cc cc

   (XX is the same as the response number in the `Disable Unsolicited Data Transfer` message to which it responds.)

5. Successful acknowledge message from the master for an unsolicited SER message:

   A5 46 0E 00 00 00 00 00 00 98 00 XX cc cc

   (XX is the same as the response number in the unsolicited SER message to which it responds.)

## Notes:

Once the relay receives an acknowledge with response code 00 from the master, it will clear the settings changed bit (bit 1) in its status byte, if that bit is asserted, and it will clear the settings changed bit in Fast Meter, if that bit is asserted.

An element index of 0xFE indicates that the SER record is because of the relay turning on. An element index of 0xFF indicates that the SER record is due to setting change. An element index of 0xFD indicates that the element identified in this SER record is no longer in the SER trigger settings.

When the relay sends an SER message packet, it will put a sequential number (0, 1, 2, 3, 0, 1, ...) into the response number. If the relay does not receive an acknowledge from the master before approximately 500 ms, the relay will resend the same message packet with the same response number until it receives an acknowledge message with that response number. For the next SER message, the relay will increment the response number (it will wrap around to zero from three).

A single SER message packet from the relay can have a maximum of 32 records and the data may span a time period of no more than 16 seconds. The master may limit the number of records in a packet with the third byte of function code data in the `Enable Unsolicited Data Transfer` message (function code 01). The relay may generate an SER packet with less than the requested number of records, if the record time stamps span more than 16 seconds.

The relay always requests acknowledgment in unsolicited SER messages (LSB of the status byte is set).

Unsolicited SER messages can be enabled on multiple ports simultaneously.

# Appendix G

# Distributed Network Protocol (DNP3)

## Overview

Some versions of the SEL-387E family of relays support Distributed Network Protocol (DNP3) L2 Slave protocol. This includes access to metering data, protection elements (Relay Word), contact I/O, targets, Sequential Events Recorder, breaker monitor, relay summary event reports, settings groups, and time synchronization. The SEL-387E supports DNP point remapping and virtual terminal object.

## Configuration

To configure a port for DNP, set the port PROTO setting to DNP. Although DNP may be selected on any of the available ports, DNP may not be enabled on more than one port at a time. The following information is required to configure a port for DNP operation:

| Label | Description | Default |
|---|---|---|
| SPEED | Baud rate (300–19200) | 2400 |
| T_OUT | Port time-out (0–30 minutes) | 5 |
| DNPADR | DNP Address (0–65534) | 0 |
| MODEM | Modem connected to port (Y, N) | N |
| MSTR | Modem startup string (as many as 30 characters) | E0X0&D0S0=2 |
| PH_NUM | Phone number to dial-out to (as many as 30 characters) | |
| MDTIME | Time to attempt dial (5–300 seconds) | 60 |
| MDRETI | Time between dial-out attempts (5–3600 seconds) | 120 |
| MDRETN | Number of dial-out attempts (0–5) | 3 |
| ECLASSA | Class for Analog event data (0 for no event, 1–3) | 2 |
| ECLASSB | Class for Binary event data (0 for no event, 1–3) | 1 |
| ECLASSC | Class for Counter event data (0 for no event, 1–3) | 0 |
| DECPLA | Currents scaling (0–3 decimal places) | 1 |
| DECPLV | Voltage scaling (0–3 decimal places) | 1 |
| DECPLM | Misc. scaling (0–3 decimal places) | 1 |
| TIMERQ | Time-set request interval (0–32767 min.) | 0 |
| STIMEO | Select/operate time-out (0.0–30.0 sec.) | 1.0 |
| DTIMEO | Data-link time-out (0–5 sec.) | 1 |
| MINDLY | Minimum time from DCD to TX (0.00–1.00 sec.) | 0.05 |

| Label | Description | Default |
|---|---|---|
| MAXDLY | Maximum time from DCD to TX (0.00–1.00 sec.) | 0.10 |
| PREDLY | Settle time from RTS on to TX (OFF, 0.00230.00 sec.) | 0 |
| PSTDLY | Settle time after TX to RTS off (0.00–30.00 sec.) | 0 |
| ANADBA | Current analog reporting deadband (0–32767 counts) | 100 |
| ANADBV | Voltage analog reporting deadband (0–32767 counts) | 100 |
| ANADBM | Misc. analog reporting deadband (0–32767 counts) | 100 |
| ETIMEO | Event data confirmation time-out (0.1–50.0 sec) | 2.0 |
| DRETRY | Data-link retries (0–15) | 3 |
| UNSOL | Enable unsolicited reporting (Y, N) | N |
| PUNSOL | Enable unsolicited reporting when the relay turns on (Y, N) | N |
| REPADR | DNP Address to report to (0–65534) | 0 |
| NUMEVE | Number of events to transmit on (1–200) | 10 |
| AGEEVE | Age of oldest event to transmit on (0–60 sec.) | 2.0 |

The RTS signal may be used to control an external transceiver. The CTS signal is used as a DCD input, indicating when the medium is in use. Transmissions are only initiated if DCD is deasserted. When DCD drops, the next pending outgoing message may be sent once an idle time is satisfied. This idle time is randomly selected between the minimum and maximum allowed idle times (i.e., MAXDLY and MINDLY). In addition, the SEL-387E monitors received data and treats receipt of data as a DCD indication. This allows RTS to be looped back to CTS in cases where the external transceiver does not support DCD. When the SEL-387E transmits a DNP message, it delays transmitting after asserting RTS by at least the time in the PREDLY setting. After transmitting the last byte of the message, the SEL-387E delays for at least PSTDLY milliseconds before deasserting RTS. If the PSTDLY time delay is in progress (RTS still high) following a transmission and another transmission is initiated, the SEL-387E transmits the message without completing the PSTDLY delay and without any preceding PREDLY delay. The RTS/CTS handshaking may be completely disabled by setting PREDLY to OFF. In this case RTS is forced high and CTS is ignored, with only received characters acting as a DCD indication. The timing is the same as above, but PREDLY functions as if it were set to 0, and RTS is not actually deasserted after the PSTDLY time delay expires.

# Data-Link Operation

It is necessary to make two important decisions about the data-link layer operation. One is how to handle data-link confirmation, the other is how to handle data-link access. If a highly reliable communications link exists, the data-link access can be disabled altogether, which significantly reduces communications overhead. Otherwise, it is necessary to enable confirmation and determine how many retries to allow and what the data-link time-out should be. The noisier the communications channel, the more likely a message will be corrupted. Thus, the number of retries should be set higher on noisy channels. Set the data-link time-out long enough to allow for the worst-case response of the master plus transmission time. When the SEL-387E decides to transmit on the DNP link, it has to wait if the physical connection is in use.

The SEL-387E monitors physical connections by using CTS input (treated as a Data Carrier Detect) and monitoring character receipt. Once the physical link goes idle, as indicated by CTS being deasserted and no characters being received, the SEL-387E will wait a configurable amount of time before beginning a transmission. This hold-off time will be a random value between the MINDLY and MAXDLY setting values. The hold-off time is random, which prevents multiple devices waiting to communicate on the network from continually colliding.

# Data Access Method

Based on the capabilities of the system, it is necessary to choose a method for retrieving data on the DNP connection. The following table summarizes the main options, listed from least to most efficient, and indicates corresponding key related settings.

**Table G.1 Data Access Methods**

| Data Retrieval Method | Description | Relevant SEL-387E Settings |
|---|---|---|
| Polled Static | The master polls for static (Class 0) data only. | Set CLASS = 0<br>Set UNSOL = N |
| Polled Report-by-Exception | The master polls frequently for event data and occasionally for static data. | Set CLASS to a non-zero value<br>Set UNSOL = N |
| Unsolicited Report-by-Exception | The slave devices send unsolicited event data to the master and the master occasionally sends integrity polls for static data. | Set CLASS to a non-zero value<br>Set UNSOL = Y<br>Set NUMEVE and AGEEVE according to how often messages are desired to be sent |
| Quiescent | The master never polls and relies on unsolicited reports only. | Set CLASS to a non-zero value<br>Set UNSOL = Y<br>Set NUMEVE and AGEEVE according to how often messages are desired to be sent |

# Device Profile

*Table G.2* contains the standard DNP3 device profile information. Rather than check boxes in the example Device Profile in the DNP3 Subset Definitions, only the relevant selections are shown.

**Table G.2 SEL-387E DNP3 Device Profile** (Sheet 1 of 2)

| Parameter | Value |
|---|---|
| Vendor name | Schweitzer Engineering Laboratories |
| Device name | SEL-387E Relay |
| Highest DNP request level | Level 2 |
| Highest DNP response level | Level 2 |
| Device function | Slave |
| Notable objects, functions, and/or qualifiers supported | Supports enabling and disabling of unsolicited reports on a class basis.<br>Supports Virtual Terminal |

**Table G.2 SEL-387E DNP3 Device Profile** (Sheet 2 of 2)

| Parameter | Value |
|---|---|
| Maximum data-link frame size transmitted/received (octets) | 292 |
| Maximum data-link retries | Configurable, range 0–15 |
| 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 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 | Never |
| Sends unsolicited responses | Configurable with unsolicited message enable settings. Increases retry time (configurable) when a maximum retry setting is exceeded. |
| Sends static data in unsolicited responses | Never |
| Default counter object/variation | Object 20, Variation 6 |
| Counter roll-over | 16 bits |
| Sends multifragment responses | Yes |

In all cases of a configurable item within the device profile, the item is controlled by SEL-387E settings.

# Object Table

The following object table lists supported objects, functions, and qualifier code combinations.

**Table G.3 SEL-387E DNP Object List** (Sheet 1 of 5)

| 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 | 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 | | | | |
| 21 | 0 | Frozen Counter—All Variations | | | | |
| 21 | 1 | 32-Bit Frozen Counter | | | | |

**Table G.3 SEL-387E DNP Object List** (Sheet 2 of 5)

| Obj. | Var. | Description | Request[a] | | Response[b] | |
|---|---|---|---|---|---|---|
| | | | Funct. Codes[c] | Qual. Codes[d] | Funct. Codes[c] | Qual. Codes[d] |
| 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 | | | | |

**Table G.3 SEL-387E DNP Object List** (Sheet 3 of 5)

| Obj. | Var. | Description | Request[a] | | Response[b] | |
|---|---|---|---|---|---|---|
| | | | Funct. Codes[c] | Qual. Codes[d] | Funct. Codes[c] | Qual. Codes[d] |
| 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 | | | | |
| 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 |

**Table G.3 SEL-387E DNP Object List** (Sheet 4 of 5)

| Obj. | Var. | Description | Request[a] | | Response[b] | |
|---|---|---|---|---|---|---|
| | | | Funct. Codes[c] | Qual. Codes[d] | Funct. Codes[c] | Qual. Codes[d] |
| 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, quantity = 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, quantity = 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 | | |

**Table G.3 SEL-387E DNP Object List** (Sheet 5 of 5)

| Obj. | Var. | Description | Request[a] | | Response[b] | |
|---|---|---|---|---|---|---|
| | | | Funct. Codes[c] | Qual. Codes[d] | Funct. Codes[c] | Qual. Codes[d] |
| 70 | 1 | File Identifier | | | | |
| 80 | 1 | Internal Indications | 2 | 0,1<br>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 | | | | |
| 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 |
| No object | | | 13,14,23 | | | |

[a] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation

# Data Map

*Table G.4* is the default object map supported by the SEL-387E (see *Appendix A: Firmware and Manual Versions*).

**Table G.4 SEL-387E Wye/Delta DNP Map** (Sheet 1 of 4)

| DNP Object Type | Index | Description |
|---|---|---|
| 01,02 | 000–799 | Relay Word, where OCA is 0 and LB9 is 383. |
| 01,02 | 800–1599 | Relay Word from the SER, encoded same as inputs 000–799 with 800 added. |
| 01,02 | 1600–1615 | Relay front-panel targets, where 1615 is A, 1608 is 50/51, 1607 is EN, and 1600 is 24. |
| 01,02 | 1616 | Relay disabled. |
| 01,02 | 1617 | Relay diagnostic failure. |

**Table G.4 SEL-387E Wye/Delta DNP Map** (Sheet 2 of 4)

| DNP Object Type | Index | Description |
|---|---|---|
| 01,02 | 1618 | Relay diagnostic warning. |
| 01,02 | 1619 | New relay event available. |
| 01,02 | 1620 | Settings change or relay restart. |
| 10,12 | 00–15 | Remote bits RB1–RB16. |
| 10,12 | 16 | Pulse Open breaker 1 command OC. |
| 10,12 | 17 | Pulse Close breaker 1 command CC. |
| 10,12 | 18 | Pulse Open breaker 2 command OC. |
| 10,12 | 19 | Pulse Close breaker 2 command CC. |
| 10,12 | 20 | Pulse Open breaker 3 command OC. |
| 10,12 | 21 | Pulse Close breaker 3 command CC. |
| 10,12 | 22–29 | Remote bit pairs RB1–RB16. |
| 10,12 | 30 | Open/Close pair for breaker 1. |
| 10,12 | 31 | Open/Close pair for breaker 2. |
| 10,12 | 32 | Open/Close pair for breaker 3. |
| 10,12 | 33 | Reset demands. |
| 10,12 | 34 | Reset demand peaks. |
| 10,12 | 35 | Reset breaker monitor. |
| 10,12 | 36 | Reset front-panel targets. |
| 10,12 | 37 | Read next relay event. |
| 10,12 | 38 | Reset energy metering. |
| 20,22 | 00 | Active settings group. |
| 20,22 | 01 | Internal breaker trips 1. |
| 20,22 | 02 | Internal breaker trips 2. |
| 20,22 | 03 | Internal breaker trips 3. |
| 20,22 | 04 | External breaker trips 1. |
| 20,22 | 05 | External breaker trips 2. |
| 20,22 | 06 | External breaker trips 3. |
| 30,32 | 00,01 | IA magnitude and angle for Wdg. 1. |
| 30,32 | 02,03 | IB magnitude and angle for Wdg. 1. |
| 30,32 | 04,05 | IC magnitude and angle for Wdg. 1. |
| 30,32 | 06,07 | 3I1 magnitude and angle for Wdg. 1. |
| 30,32 | 08,09 | 3I2 magnitude and angle for Wdg. 1. |
| 30,32 | 10,11 | IRW magnitude and angle for Wdg. 1. |
| 30,32 | 12,13 | IA magnitude and angle for Wdg. 2. |
| 30,32 | 14,15 | IB magnitude and angle for Wdg. 2. |
| 30,32 | 16,17 | IC magnitude and angle for Wdg. 2. |
| 30,32 | 18,19 | 3I1 magnitude and angle for Wdg. 2. |
| 30,32 | 20,21 | 3I2 magnitude and angle for Wdg. 2. |
| 30,32 | 22,23 | IRW magnitude and angle for Wdg. 2. |
| 30,32 | 24,25 | IA magnitude and angle for Wdg. 3. |
| 30,32 | 26,27 | IB magnitude and angle for Wdg. 3. |

**Table G.4 SEL-387E Wye/Delta DNP Map** (Sheet 3 of 4)

| DNP Object Type | Index | Description |
|---|---|---|
| 30,32 | 28,29 | IC magnitude and angle for Wdg. 3. |
| 30,32 | 30,31 | 3I1 magnitude and angle for Wdg. 3. |
| 30,32 | 32,33 | 3I2 magnitude and angle for Wdg. 3. |
| 30,32 | 34,35 | IRW magnitude and angle for Wdg. 3. |
| 30,32 | 36,37 | VA magnitude and angle. |
| 30,32 | 38,39 | VB magnitude and angle. |
| 30,32 | 40,41 | VC magnitude and angle. |
| 30,32 | 42,43 | 3V1 magnitude and angle. |
| 30,32 | 44,45 | 3V2 magnitude and angle. |
| 30,32 | 46,47 | 3V0 magnitude and angle. |
| 30,32 | 48–51 | MW 3-phase, A,B,C. |
| 30,32 | 52–55 | MVAR 3-phase, A,B,C. |
| 30,32 | 56–59 | MVA 3-phase, A,B,C. |
| 30,32 | 60 | IOP1 Operate Current. |
| 30,32 | 61 | IOP2 Operate Current. |
| 30,32 | 62 | IOP3 Operate Current. |
| 30,32 | 63 | IRT1 Restraint Current. |
| 30,32 | 64 | IRT2 Restraint Current. |
| 30,32 | 65 | IRT3 Restraint Current. |
| 30,32 | 66 | I1F2 Second-Harmonic Current. |
| 30,32 | 67 | I2F2 Second-Harmonic Current. |
| 30,32 | 68 | I3F2 Second-Harmonic Current. |
| 30,32 | 69 | I1F5 Fifth-Harmonic Current. |
| 30,32 | 70 | I2F5 Fifth-Harmonic Current. |
| 30,32 | 71 | I3F5 Fifth-Harmonic Current. |
| 30,32 | 72 | Volts/Hertz. |
| 30,32 | 73 | Frequency. |
| 30,32 | 74 | VDC. |
| 30,32 | 75–79 | Demand A, B, C, 3I2, and IR magnitudes for Wdg. 1. |
| 30,32 | 80–84 | Demand A, B, C, 3I2, and IR magnitudes for Wdg. 2. |
| 30,32 | 85–89 | Demand A, B, C, 3I2, and IR magnitudes for Wdg. 3. |
| 30,32 | 90 | Peak demand IA mag. for Wdg. 1. |
| 30 | 91–93 | Peak demand IA time in DNP format for Wdg. 1. |
| 30,32 | 94 | Peak demand IB mag. for Wdg. 1. |
| 30 | 95–97 | Peak demand IB time in DNP format for Wdg. 1. |
| 30,32 | 98 | Peak demand IC mag. for Wdg. 1. |
| 30 | 99–101 | Peak demand IC time in DNP format for Wdg. 1. |
| 30,32 | 102 | Peak demand 3I2 mag. for Wdg. 1. |
| 30 | 103–105 | Peak demand 3I2 time in DNP format for Wdg. 1. |
| 30,32 | 106 | Peak demand IR mag. for Wdg. 1. |
| 30 | 107–109 | Peak demand IR time in DNP format for Wdg. 1. |

**Table G.4 SEL-387E Wye/Delta DNP Map** (Sheet 4 of 4)

| DNP Object Type | Index | Description |
|---|---|---|
| 30,32 | 110 | Peak demand IA mag. for Wdg. 2. |
| 30 | 111–113 | Peak demand IA time in DNP format for Wdg. 2. |
| 30,32 | 114 | Peak demand IB mag. for Wdg. 2. |
| 30 | 115–117 | Peak demand IB time in DNP format for Wdg. 2. |
| 30,32 | 118 | Peak demand IC mag. for Wdg. 2. |
| 30 | 119–121 | Peak demand IC time in DNP format for Wdg. 2. |
| 30,32 | 122 | Peak demand 3I2 mag. for Wdg. 2. |
| 30 | 123–125 | Peak demand 3I2 time in DNP format for Wdg. 2. |
| 30,32 | 126 | Peak demand IR mag. for Wdg. 2. |
| 30 | 127–129 | Peak demand IR time in DNP format for Wdg. 2. |
| 30,32 | 130 | Peak demand IA mag. for Wdg. 3. |
| 30 | 131–133 | Peak demand IA time in DNP format for Wdg. 3. |
| 30,32 | 134 | Peak demand IB mag. for Wdg. 3. |
| 30 | 135–137 | Peak demand IB time in DNP format for Wdg. 3. |
| 30,32 | 138 | Peak demand IC mag. for Wdg. 3. |
| 30 | 139–141 | Peak demand IC time in DNP format for Wdg. 3. |
| 30,32 | 142 | Peak demand 3I2 mag. for Wdg. 3. |
| 30 | 143–145 | Peak demand 3I2 time in DNP format for Wdg. 3. |
| 30,32 | 146 | Peak demand IR mag. for Wdg. 3. |
| 30 | 147–149 | Peak demand IR time in DNP format for Wdg. 3. |
| 30,32 | 150–152 | Breaker contact wear percentage (A, B, C) for Wdg. 1. |
| 30,32 | 153–155 | Breaker contact wear percentage (A, B, C) for Wdg. 2. |
| 30,32 | 156–158 | Breaker contact wear percentage (A, B, C) for Wdg. 3. |
| 30,32 | 159 | Event Type. |
| 30,32 | 160 | Fault Targets. |
| 30,32 | 161–172 | Fault values (all windings, all phases). |
| 30,32 | 173 | Volts/Hertz. |
| 30,32 | 174 | Fault settings group. |
| 30 | 175–177 | Fault time in DNP format (high, middle, and low 16 bits). |
| 30,32 | 178,179 | 3-phase MWhr in and out. |
| 30,32 | 180,181 | A-phase MWhr in and out. |
| 30,32 | 182,183 | B-phase MWhr in and out. |
| 30,32 | 184,185 | C-phase MWhr in and out. |
| 30,32 | 186,187 | 3-phase MVARhr in and out. |
| 30,32 | 188,189 | A-phase MVARhr in and out. |
| 30,32 | 190,191 | B-phase MVARhr in and out. |
| 30,32 | 192,193 | C-phase MVARhr in and out. |
| 30 | 194–196 | Last reset time in DNP format. |
| 40,41 | 00 | Active settings group. |

Binary inputs (objects 1 and 2) are supported as defined by the previous table. Binary inputs 0–799 and 1600–1619 are scanned approximately once every 128 ms to generate events. When time is reported with these event objects, it is the time at which the scanner observed the bit change. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination. To determine an element's point index, see *Table G.6*. It is derived from the Relay Word Bits tables in *Section 4: Control Logic*. Locate the element in question in the table and note the Relay Word row number. From that row number, subtract the row number of the first Relay Word row (usually 2) and multiply that result by 8. This is the index of the right-most element of the Relay Word row of the element in question. Count over to the original element and add that to get the point index. Binary Inputs 800–1599 are derived from the Sequential Events Recorder (SER) and carry the time stamp of actual occurrence. Add 800 to the Binary Input Point column to get the point mapping for points 800–1599. Static reads from these inputs will show the same data as a read from the corresponding index in the 0–799 group. Only points that are actually in the SER list (SET R) will generate events in the 800–1599 group.

Analog Inputs (objects 30 and 32) are supported as defined by the preceding table. The values are reported in primary units. Current magnitudes are scaled according to the DECPLA setting, voltage magnitudes by DECPLV, and other magnitudes by DECPLM. For example, if DECPL*x* is 3, then its value is multiplied by 1000. Event-class messages are generated whenever an input changes beyond the value given by the appropriate analog deadband setting (ANADBA, ANADBV, ANADBM). The deadband check is done after any scaling is applied. The angles will only generate an event if, in addition to their deadband check, the corresponding magnitude (the preceding point) contains a value greater than the value given by the deadband setting. Analog inputs are scanned at approximately a half-second rate, except for analogs 159–177. During a scan, all events generated will use the time the scan was initiated. Analogs 159–177 are derived from the history queue data for the most recently read fault and do not generate event messages. Analog 159 is defined as follows:

| Value | Event Cause |
|---|---|
| 1 | **TRIGGER** command |
| 2 | **PULSE** command |
| 4 | ER element |
| 16 | Trip 4 |
| 32 | Trip 3 |
| 64 | Trip 2 |
| 128 | Trip 1 |

If Analog 159 is 0, no more new events are available (i.e., all events have been read).

Control Relay Output Blocks (object 12, variation 1) are supported. The control relays correspond to the remote bits and other functions, as shown above. The Trip/Close bits take precedence over the control field. If either the Trip or Close bit is set, one of the other control field bits must be set as well. The control field is interpreted in *Table G.5*.

**Table G.5 Object 12 Trip/Close Pair Operation**

| Index | Close (0x4X) | Trip (0x8X) | Latch On (3) | Latch Off (4) | Pulse On (1) | Pulse Off (2) |
|---|---|---|---|---|---|---|
| 0–15 | Set | Clear | Set | Clear | Pulse | Clear |
| 16–21 | Pulse | Do nothing | Pulse | Do nothing | Pulse | Do nothing |
| 22 | Pulse RB2 | Pulse RB1 | Pulse RB2 | Pulse RB1 | Pulse RB2 | Pulse RB1 |
| 23 | Pulse RB4 | Pulse RB3 | Pulse RB4 | Pulse RB3 | Pulse RB4 | Pulse RB3 |
| 24 | Pulse RB6 | Pulse RB5 | Pulse RB6 | Pulse RB5 | Pulse RB6 | Pulse RB5 |
| 25 | Pulse RB8 | Pulse RB7 | Pulse RB8 | Pulse RB7 | Pulse RB8 | Pulse RB7 |
| 26 | Pulse RB10 | Pulse RB9 | Pulse RB10 | Pulse RB9 | Pulse RB10 | Pulse RB9 |
| 27 | Pulse RB12 | Pulse RB11 | Pulse RB12 | Pulse RB11 | Pulse RB12 | Pulse RB11 |
| 28 | Pulse RB14 | Pulse RB13 | Pulse RB14 | Pulse RB13 | Pulse RB14 | Pulse RB13 |
| 29 | Pulse RB16 | Pulse RB15 | Pulse RB16 | Pulse RB15 | Pulse RB16 | Pulse RB15 |
| 30 | Pulse CC1 | Pulse OC1 | Pulse CC1 | Pulse OC1 | Pulse CC1 | Pulse OC1 |
| 31 | Pulse CC2 | Pulse OC2 | Pulse CC2 | Pulse OC2 | Pulse CC2 | Pulse OC2 |
| 32 | Pulse CC3 | Pulse OC3 | Pulse CC3 | Pulse OC3 | Pulse CC3 | Pulse OC3 |
| 33–37 | Pulse | Do nothing | Pulse | Do nothing | Pulse | Do nothing |

If the Trip bit is set, a Latch Off operation is performed, and if the Close bit is set, a Latch On operation is performed on the specified index. The Status field is used exactly as defined. All other fields are ignored. A pulse operation asserts a point for a single processing interval. Caution should be exercised with multiple remote bit pulses in a single message (i.e., point count > 1), as this may result in some of the pulse commands being ignored and returning an already active status.

Analog Outputs (objects 40 and 41) are supported as defined by the preceding table. Flags returned with object 40 responses are always set to 0. The Control Status field of object 41 requests is ignored. If the value written to index 0 is outside of the range 1 through 6, the relay will not accept the value and will return a hardware error status.

**Table G.6 SEL-387E Relay Binary Input Lookup Table** (Sheet 1 of 2)

| Row | SEL-387E Relay Word Bits | | | | | | | | Binary Input Point |
|---|---|---|---|---|---|---|---|---|---|
| **2** | 50P11 | 50P11T | 50P12 | 51P1 | 51P1T | 51P1R | PDEM1 | OCA | 7–0 |
| **3** | 50A13 | 50B13 | 50C13 | 50P13 | 50A14 | 50B14 | 50C14 | 50P14 | 15–8 |
| **4** | 50N11 | 50N11T | 50N12 | 51N1 | 51N1T | 51N1R | NDEM1 | OC1 | 23–16 |
| **5** | 50Q11 | 50Q11T | 50Q12 | 51Q1 | 51Q1T | 51Q1R | QDEM1 | CC1 | 31–24 |
| **6** | 50P21 | 50P21T | 50P22 | 51P2 | 51P2T | 51P2R | PDEM2 | OCB | 39–32 |
| **7** | 50A23 | 50B23 | 50C23 | 50P23 | 50A24 | 50B24 | 50C24 | 50P24 | 47–40 |
| **8** | 50N21 | 50N21T | 50N22 | 51N2 | 51N2T | 51N2R | NDEM2 | OC2 | 55–48 |
| **9** | 50Q21 | 50Q21T | 50Q22 | 51Q2 | 51Q2T | 51Q2R | QDEM2 | CC2 | 63–56 |
| **10** | 50P31 | 50P31T | 50P32 | 51P3 | 51P3T | 51P3R | PDEM3 | OCC | 71–64 |
| **11** | 50A33 | 50B33 | 50C33 | 50P33 | 50A34 | 50B34 | 50C34 | 50P34 | 79–72 |
| **12** | 50N31 | 50N31T | 50N32 | 51N3 | 51N3T | 51N3R | NDEM3 | OC3 | 87–80 |
| **13** | 50Q31 | 50Q31T | 50Q32 | 51Q3 | 51Q3T | 51Q3R | QDEM3 | CC3 | 95–88 |
| **14** | *[a] | 27V1 | 27PP2 | 27PP1 | 27P2 | 27P1 | *[a] | CTS | 103–96 |

**Table G.6 SEL-387E Relay Binary Input Lookup Table** (Sheet 2 of 2)

| Row | SEL-387E Relay Word Bits | | | | | | | | Binary Input Point |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 59Q | 59G2 | 59G1 | 59V1 | 59PP2 | 59PP1 | 59P2 | 59P1 | 111–104 |
| 16 | 81D1 | 81D2 | 81D3 | 81D4 | 81D5 | 81D6 | ISQTAL | 27B81 | 119–112 |
| 17 | 81D1T | 81D2T | 81D3T | 81D4T | 81D5T | 81D6T | *[a] | *[a] | 127–120 |
| 18 | 87U1 | 87U2 | 87U3 | 87U | 87R1 | 87R2 | 87R3 | 87R | 135–128 |
| 19 | 2HB1 | 2HB2 | 2HB3 | 5HB1 | 5HB2 | 5HB3 | TH5 | TH5T | 143–136 |
| 20 | 87BL1 | 87BL2 | 87BL3 | 87BL | 87E1 | 87E2 | 87E3 | 32IE | 151–144 |
| 21 | 87O1 | 87O2 | 87O3 | 24D1 | 24D1T | 24C2 | 24C2T | 24CR | 159–152 |
| 22 | 51PC1 | 51PC1T | 51PC1R | 51NC1 | 51NC1T | 51NC1R | DC1 | DC2 | 167–160 |
| 23 | *[a] | *[a] | *[a] | *[a] | *[a] | *[a] | DC3 | DC4 | 175–168 |
| 24 | RB1 | RB2 | RB3 | RB4 | RB5 | RB6 | RB7 | RB8 | 183–176 |
| 25 | RB9 | RB10 | RB11 | RB12 | RB13 | RB14 | RB15 | RB16 | 191–184 |
| 26 | SG1 | SG2 | SG3 | SG4 | SG5 | SG6 | CHSG | *[a] | 199–192 |
| 27 | 4HBL | DCBL | IN106 | IN105 | IN104 | IN103 | IN102 | IN101 | 207–200 |
| 28 | IN208 | IN207 | IN206 | IN205 | IN204 | IN203 | IN202 | IN201 | 215–208 |
| 29 | IN216 | IN215 | IN214 | IN213 | IN212 | IN211 | IN210 | IN209 | 223–216 |
| 30 | IN308 | IN307 | IN306 | IN305 | IN304 | IN303 | IN302 | IN301 | 231–224 |
| 31 | IN316 | IN315 | IN314 | IN313 | IN312 | IN311 | IN310 | IN309 | 239–232 |
| 32 | S1V1 | S1V2 | S1V3 | S1V4 | S1V1T | S1V2T | S1V3T | S1V4T | 247–240 |
| 33 | S2V1 | S2V2 | S2V3 | S2V4 | S2V1T | S2V2T | S2V3T | S2V4T | 255–248 |
| 34 | S3V1 | S3V2 | S3V3 | S3V4 | S3V5 | S3V6 | S3V7 | S3V8 | 263–256 |
| 35 | S3V1T | S3V2T | S3V3T | S3V4T | S3V5T | S3V6T | S3V7T | S3V8T | 271–264 |
| 36 | S1LT1 | S1LT2 | S1LT3 | S1LT4 | S2LT1 | S2LT2 | S2LT3 | S2LT4 | 279–272 |
| 37 | S3LT1 | S3LT2 | S3LT3 | S3LT4 | S3LT5 | S3LT6 | S3LT7 | S3LT8 | 287–280 |
| 38 | *[a] | *[a] | *[a] | 50GC | 50G3 | 32IR | 32IF | REFP | 295–288 |
| 39 | BCWA1 | BCWB1 | BCWC1 | BCW1 | BCWA2 | BCWB2 | BCWC2 | BCW2 | 303–296 |
| 40 | BCWA3 | BCWB3 | BCWC3 | BCW3 | *[a] | P5SEL | P6SEL | LNKFAIL | 311–304 |
| 41 | TRIP1 | TRIP2 | TRIP3 | TRIP4 | *[a] | TRIPL | *[a] | TRGTR | 319–312 |
| 42 | CLS1 | CLS2 | CLS3 | *[a] | CF1T | CF2T | CF3T | *[a] | 327–320 |
| 43 | NOTALM | OUT107 | OUT106 | OUT105 | OUT104 | OUT103 | OUT102 | OUT101 | 335–328 |
| 44[b] | OUT201 | OUT202 | OUT203 | OUT204 | OUT205 | OUT206 | OUT207 | OUT208 | 343–336 |
| 45[b] | OUT209 | OUT210 | OUT211 | OUT212 | OUT213 | OUT214 | OUT215 | OUT216 | 351–344 |
| 46[b] | OUT301 | OUT302 | OUT303 | OUT304 | OUT305 | OUT306 | OUT307 | OUT308 | 359–352 |
| 47[b] | OUT309 | OUT310 | OUT311 | OUT312 | OUT313 | OUT314 | OUT315 | OUT316 | 367–360 |
| 48 | LB1 | LB2 | LB3 | LB4 | LB5 | LB6 | LB7 | LB8 | 375–368 |
| 49 | LB9 | LB10 | LB11 | LB12 | LB13 | LB14 | LB15 | LB16 | 383–376 |

[a] Reserved for future use.
[b] These rows will show asterisks in response to the **TAR** command if the optional interface board is not installed.

## Relay Summary Event Data

Whenever there is unread relay event summary data (fault data), binary input point 1619 will be set. To load the next available relay event summary, the master should pulse binary output point 41. This will cause the event summary analogs (points 159–177) to be loaded with information from the next oldest relay event summary. Because the summary data are stored in a first-in, first-out manner, loading the next event will cause the data from the previous load to be discarded. The event summary analogs will retain this information until the next event is loaded. If no further event summaries are available, attempting to load the next event will cause the event type analog (point 159) to be set to 0.

# Point Remapping

## Introduction

The **DNP** command is available to view and remap the DNP data. This command is available at Level 1 for viewing data, but only from Level 2 can it be used to remap the DNP map.

### Inputs

Command Syntax: **DNP [A|B|S|T]**

**DNP [AI|AO|BI|BO|C] [VIEW]**

The DNP analog input, analog output, counter, binary output, and binary input points may be remapped via the **DNP** command. The map is composed of five lists of indices: one for the analog inputs (30 and 32), one for the binary inputs (1 one 2), one for the binary outputs (10 and 12), one for the analog outputs (40 and 41), and the other for the counters (20 and 22). The indices correspond to those given by the relay's DNP data map. The order in which they occur in the list determines the index that the corresponding value is reported to the DNP master. If a value is not in the list, it is not available to the DNP master. All points of the corresponding type may be included in the list, but must only occur once. The maps are stored in nonvolatile memory and are protected with a checksum. The **DNP** command is only available if DNP has been selected on one of the ports.

If the **DNP** command is issued without parameters, the relay displays all of the maps with the following format:

```
=>DNP <Enter>

Binary Inputs  = Default Map
Binary Outputs = Default Map
Counters       = Default Map
Analog Inputs  = 112 28 17 35 1 56 57 58 59 60 61 62 63 64 65 \
                 66 67 100 101 102 103
Analog Outputs = Off

=>
```

If the **DNP** command is issued with an object type specified (AI, AO, BI, BO, C) and the VIEW parameter, the relay displays only the corresponding map. The S parameter is equivalent to AI VIEW and the T parameter is equivalent to BI VIEW; they are available for consistency with the older products. If the map checksum is determined to be invalid, the map will be reported as corrupted during a display command, as follows:

```
=>DNP BI VIEW  <Enter>
Binary Inputs  = Map Corrupted
=>
```

If the **DNP** command is issued with just an object type specifier (AI, AO, BI, BO, C) at Level 2 or greater, the relay asks the user to enter indices for the corresponding list. (The A parameter is the same as AI and B is the same as BI; these parameters are available for consistency with older products.) The relay accepts lines of indices until a line without a final continuation character (\) is entered. Each line of input is constrained to 80 characters, but all the points may be remapped, using multiple lines with continuation characters (\) at the end of the intermediate lines. If a single blank line is entered as the first line, the remapping is disabled for that type (i.e., the relay uses the default map). If a single entry of OFF or NA is entered, all objects of that type will be disabled. For example, the first example remap could be produced with the following commands:

```
==>DNP AI <Enter>
Enter the new DNP Analog Input map
112 28 17 \ <Enter>
35 1 56 57 58 59 60 61 62 63 64 65 66 67 100 101 102 \ <Enter>
103 <Enter>
Save Settings (Y/N)? Y <Enter>
==>DNP BI <Enter>
Enter the new DNP Binary Input map
<Enter>
Save Settings (Y/N)? Y <Enter>
==>DNP AO <Enter>
Enter the new DNP Analog Output map
OFF <Enter>
Save Settings (Y/N)? Y <Enter>
==>
```

The **DNP** command will report an error if an index is used twice, an invalid index is used, or non-numeric data are entered:

```
xx is referenced more than once, changes not saved

xx is not a valid index, changes not saved

Invalid format, changes not saved
```

In addition to remapping, these commands can be used on analog inputs to create custom scaling and deadbands per point. Scaling is done by adding a semicolon and scaling factor to a point reference. The base value will be multiplied by the scaling factor before reporting it. This is done instead of the DECPLA setting that would normally apply. Deadbands are added using a colon and deadband count. This deadband will override the ANADBA, ANADBV, or ANADBM setting. For example:

```
==>DNP AI <Enter>

Enter the new DNP Analog Input map
112;5 28;0.2 17:10 1;1:15 <Enter>

==>
```

These settings will cause the value at index 112 (now at index 0) to be multiplied by five before it is reported. Similarly, the value at index 28 (now at index 1) will be multiplied by 0.2 before it is reported. Both of these values will use the default deadband. The value at index 17 (now at index 2) is left for default scaling, but uses a deadband of ±10 counts. Similarly, the value that was at index 1 (now at index 3) is now scaled by 1 and uses a deadband of ±15 counts.

## Modem Support

The modem handling will only be applied when the port settings include the following:

PROTOCOL = DNP

MODEM = Y

While the relay turns on and when settings change, the relay shall initialize the modem by issuing the string "+++AT" followed by the MSTR string and <CR>. This will initialize the modem. The MSTR (modem string) is a port setting visible only when the protocol setting is DNP. The MSTR setting is a series of ASCII characters that initialize the modem by sending the modem a series of commands.

If someone calls in, the modem will send "RING" and "CONNECT" messages to the relay. These messages, as well as all messages received while DCD is low, shall be ignored. All DNP messages received while connected shall be treated normally.

If the relay needs to send an unsolicited message and it is not currently connected, it must attempt to make a connection by sending the string "+++ATDT" followed by the phone number and <CR>. It shall then wait for a "CONNECT" message. Once "CONNECT" is received and CTS is asserted, the relay can consider itself connected and continue its transaction. If connection is not achieved within MDTIME seconds of initiating the phone call, the relay shall issue the command "+++ATH<CR>" and wait at least MDRETI seconds before trying again and try MDRETN times before giving up. If it fails to connect in the first try, it will try again at a later time every six hours.

If the relay initiates a connection, it shall disconnect once there have been no transactions for TIMEOUT time, using the disconnect command "+++ATH<CR>". Also, if an outside caller connects to the modem in the SEL-387E, the SEL-387E will disconnect the modem if there have been no transactions for the TIMEOUT time.

**Note 1:** Because of the connection requirements described here, it will not be possible to use hardware flow control (RTSCTS) with the modem. This means that it is important to select a port baud rate low enough that the modem connection will not end up slower, or there will be a high likelihood of losing characters.

**Note 2:** The CTS signal shall be treated as a data carrier detect (DCD). This means that the message may only be transmitted while DCD is asserted. (Normally, a modem will be connected with an SEL-C220 or SEL-C222 cable that ties the DCD of the modem to the CTS.)

## Virtual Terminal

The purpose of this Virtual Terminal (VT) Protocol is to allow ASCII data transfers between a master and an SEL relay over a DNP port. DNP3 objects 112 and 113 are used for embedding the ASCII communications over the DNP port. At the master, each slave channel is assigned a Virtual Port number. Only one channel, with a Virtual Port number of "0" (for ASCII), is supported in the relay.

Object 112 is used with the Function code Write (FC = 2) to send data from the Master side to the Slave side (IED) of the link.

Object 113 is used to send data from the relay side to the Master side of the link. Master devices may use only Function codes Read (FC = 1). The relay uses only Function codes Response (FC = 129).

The procedure for accessing these objects is as follows. Master devices transmit data to relay devices by writing one or more of object 112 to a relay using the Virtual Port number as the DNP point number. Relays send information to the Master using the Virtual Port number by responding to a Master READ (FC = 1) request of object 113. Messages can flow in either direction at any time; however, the relay sends messages only at the request of the Master. There are no explicit procedures for the initiation or conclusion of a VT session (i.e., implicit connections exist by the mere presence of a VT-compatible Slave IED).

Virtual terminal supports all ASCII commands listed in the Command Summary at the end of this instruction manual. You do not need a password to login to a virtual terminal session through a DNP port, but you will need the appropriate access levels for setting changes and breaker operations. A virtual terminal session times out in the same way as an ASCII session.

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# SEL-387E DNP Port—SET P Settings Sheets

| | | |
|---|---|---|
| Port Protocol (SEL, LMD, DNP) | **PROTO** | =DNP _____ |
| Baud (300, 1200, 2400, 4800, 9600, 19200) | **SPEED** | = _____ |
| Port Time-out (0–30 minutes) | **T_OUT** | = _____ |
| DNP Address (0–65534) | **DNPADR** | = _____ |
| Modem connected to port (Y, N) | **MODEM** | = _____ |
| Modem startup string (up to 30 characters) | **MSTR** | = _____ |
| Phone number to dial-out to (up to 30 characters) | **PH_NUM** | = _____ |
| Time to attempt dial (5–300 seconds) | **MDTIME** | = _____ |
| Time between dial-out attempts (5–3600 seconds) | **MDRETI** | = _____ |
| Number of dial-out attempts (0–5) | **MDRETN** | = _____ |
| Class for Analog event data (0 for no event, 1–3) | **ECLASSA** | = _____ |
| Class for Binary event data (0 for no event, 1–3) | **ECLASSB** | = _____ |
| Class for Counter event data (0 for no event, 1–3) | **ECLASSC** | = _____ |
| Currents scaling (0–3 decimal places) | **DECPLA** | = _____ |
| Voltage scaling (0–3 decimal places) | **DECPLV** | = _____ |
| Misc. scaling (0–3 decimal places) | **DECPLM** | = _____ |
| Time-set request interval, minutes (0 for never, 1–32767) | **TIMERQ** | = _____ |
| Select/Operate time-out interval, seconds (0.0–30.0) | **STIMEO** | = _____ |
| Data-link time-out interval, seconds (0–5) | **DTIMEO** | = _____ |
| Minimum Delay from DCD to transmission, seconds (0.00–1.00) | **MINDLY** | = _____ |
| Maximum Delay from DCD to transmission, seconds (0.00–1.00) | **MAXDLY** | = _____ |
| Transmission delay from RTS assertion, seconds (OFF, 0.00–30.00) | **PREDLY** | = _____ |
| Post-transmit RTS deassertion delay, seconds (0.00–30.00) | **PSTDLY** | = _____ |
| Analog reporting deadband (0–32767 counts) | **ANADBA** | = _____ |
| Analog reporting deadband (0–32767 counts) | **ANADBV** | = _____ |
| Analog reporting deadband (0–32767 counts) | **ANADBM** | = _____ |
| Event Data Confirmation time-out (0.1–50.0 sec) | **ETIMEO** | = _____ |
| Number of data-link retries (0 for no confirm, 1–15) | **DRETRY** | = _____ |
| Allow unsolicited reporting (Y, N) | **UNSOL** | = _____ |

| | | |
|---|---|---|
| Enable unsolicited messages when the relay turns on (Y, N) | **PUNSOL** | = _____ |
| Address of master to report to (0–65534) | **REPADR** | = _____ |
| Number of events to transmit on (1–200) | **NUMEVE** | = _____ |
| Age of oldest event to force transmit on, seconds (0.0–60.0) | **AGEEVE** | = _____ |

# Appendix H

# IEC 61850 Communications

## Features

The SEL-387E Relay supports the following features using Ethernet and IEC 61850:

- **SCADA**—Use as many as six MMS sessions of buffered and unbuffered reports.

  Remote Bits (RB1–RB6) and CC (Close Command) bits are mapped to the CSWI logical node. See the CC bit in *Table H.9*, and the Control column in *Table H.11* for details on which logical nodes and names are used for these bits. This information can be useful with MMS browsers. Assertion of a CC control input will assert the SEL-387E CC bit and deassert the OC (Open Command) bit. Controls support the following control models:

  - Direct-with-normal-security
  - Select-before-operate (SBO)
  - SBO-with-enhanced-security

- **Real-Time Status and Control**—Use GOOSE with as many as 16 incoming (receive) and as many as 8 outgoing (transmit) messages. Controls only support the direct-with-normal-security control model.

  Remote Bits (RB1–RB16), Open Command bits (OC1–OC3) and Close Command bits (CC1–CC3) can also be mapped from GOOSE receive messages using ACSELERATOR Architect® SEL-5032 software. GOOSE provides separate bits for opening and closing the breaker because GOOSE repetitively sends the same information, which could inadvertently open or close a breaker if only a single bit was provided.

- **Configuration**—Use FTP client software or ACSELERATOR Architect to transfer the Substation Configuration Language (SCL) Configured IED Description (CID) files 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.

- **Firmware Upgrades**—Use FTP client software to transfer the Ethernet card firmware upgrade file to the relay.

**NOTE:** The SEL-387E 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.

This appendix presents the information you need to use the IEC 61850 features of the SEL-387E:

- *Introduction to IEC 61850*
- *IEC 61850 Operation*

- *IEC 61850 Configuration*
- *ACSI Conformance Statements*

# 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 H.1*.

**Table H.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 (ASCI) |
| 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—Samples 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 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 these documents.

# IEC 61850 Operation

## Ethernet Networking

IEC 61850 and Ethernet networking model options are only available when ordering a new SEL-387E. The options are not available as field upgrades. In addition to IEC 61850, the Ethernet ports provide support protocols and data exchange, including FTP and Telnet, to SEL devices. Access the SEL-387E Port 5 settings to configure all of the Ethernet settings for Port 5 and Port 6, including IEC 61850 network settings.

The SEL Ethernet port supports IEC 61850 services, including transport of Logical Node objects, over TCP/IP. The relay can coordinate a maximum of six concurrent IEC 61850 sessions.

## Object Models

The IEC 61850 standard relies heavily on the Abstract Communication Service Interface (ASCI) model to define a set of service 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 Local Nodes.

UCA2 uses 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 H.2* shows how the A-phase current expressed as MMXU$A$phsA$cVal is broken down into its component parts.

**Table H.2 Example IEC 61850 Descriptor Components**

| Components | | 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 are 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-387E Logical Nodes are grouped under Logical Devices for organization based on function. See *Table H.3* for descriptions of the Logical Devices in an SEL-387E.

**Table H.3 SEL-387E Logical Devices**

| Logical Device | Description |
|---|---|
| ANN | Annunciator elements—alarms, status values |
| CFG | Configuration elements—data sets 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 be 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 that 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 messages 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 SEL-5032 Software. Also, configure outgoing GOOSE messages for SEL devices in ACSELERATOR Architect. See the ACSELERATOR Architect 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.

## File Services

The Ethernet File System allows reading or writing data as files. The File System supports FTP. The File System provides:

- A means for the devices to transfer data as files
- A hierarchical file structure for the device data (root level only for the SEL-387E)

## 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 described 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

The SEL-387E 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 H.1* are available by default via IEC 61850.

| 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 H.1 SEL-387E Predefined Reports**

There are 12 report control blocks, six buffered reports and six unbuffered. 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 data set to present different data attributes for each report beyond the predefined data sets.

For buffered reports, connected clients may edit the report parameters shown in *Table H.4*.

**Table H.4 Buffered Report Control Block Client Access**

| RCB Attribute | User Changeable (Report Disabled) | User Changeable (Report Enabled) | Default Values |
|---|---|---|---|
| RptId | YES | | Control block's data set name |
| RptEna | YES | YES | FALSE |
| OptFlds | YES | | seqNum<br>timeStamp<br>dataSet<br>reasonCode<br>dataRef<br>confRef |
| BufTm | YES | | 500 |
| TrgOp | YES | | dchg<br>qchg |
| IntgPd | YES | | 0 |
| 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 H.5*.

**Table H.5 Unbuffered Report Control Block Client Access**

| RCB Attribute | User Changeable (Report Disabled) | User Changeable (Report Enabled) | Default Values |
|---|---|---|---|
| RptId | YES | | Control block's data set name |
| RptEna | YES | YES | FALSE |
| Resv | YES | | FALSE |
| OptFlds | YES | | seqNum<br>timeStamp<br>dataSet<br>reasonCode<br>dataRef<br>confRef |
| BufTm | YES | | 500 |
| TrgOps | YES | | dchg<br>qchg |
| IntgPd | YES | | 0 |
| GI | | YES[a] | FALSE |

[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, as many as six (6) clients can enable the RptEna attribute of the 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-387E 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.

## Datasets

The list of data sets in *Figure H.2* is the default for an SEL-387E device.

**Figure H.2 SEL-387E Data Sets**

Within Architect, IEC 61850 data sets have two main purposes:

- **GOOSE:** You can use predefined or edited data sets, or create new data sets for outgoing GOOSE transmission.
- **Reports:** Twelve predefined data sets (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 data set contains and so define what data an IEC 61850 client receives with a report. Note: do not edit the data set names used in reports. Changing or deleting any of those data set names will cause a failure in generating the corresponding report.

The last data set, Dset13, is a list of the Breaker Status and Control Data Attributes that are in the SEL-387E.

## Supplemental Software

Examine the data structure and value 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-387E 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 time stamp is determined when data or quality change is detected.

## 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 port.

Link-layered priority tagging and virtual LAN is supported as described in Annex C of IEC 61850-8-1:2004(E).

# IEC 61850 Configuration

## Settings

*Table H.6* lists IEC 61850 settings. IEC 61850 settings are only available if your device includes the optional IEC 61850 protocol.

**Table H.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
- Read non-SEL IED Capability Description (ICD) and Configured IED Description (CID) files and determine the available IEC 61850 messaging options
- Load device settings and IEC 61850 CID files into SEL IEDs
- Generate ICD files that will provide SEL IED descriptions to other manufacturer's 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 manufacturer's ICD and CID files, enabling the engineer to map the data seamlessly into SEL IED logic. See the ACSELERATOR Architect Instruction Manual or online help for more information.

## SEL ICD File Versions

ACSELERATOR Architect version R1.1.69.0 and higher supports multiple ICD file versions for each type of 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.

Please 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.

As of this writing, ACSELERATOR Architect comes with three versions of the SEL-387E ICD file. These versions are:

- **002 Short LN Prefixes:** This file has Logical Node prefixes and instances constrained to seven characters or less. This file is recommended for most applications with Ethernet card firmware R104–R107 (relay firmware R702), especially in IEC 61850 installations where Logical Node names must meet this criterion.
- **003 Short LN Prefixes:** This file is similar to version 002, but includes select-before-operate (SBO) and SBO-with-enhanced-security. This file can be used and is recommended for Ethernet card firmware R108 (relay firmware R703–R704).
- **004 (Firmware R704 and Higher, Default):** This file is similar to version 003 but uses Enum strings (instead of the ordinal numbers) for the values of enumeration attributes. This file can only be used for Ethernet card firmware R109 and higher.

### CID File Conversion

If you attempt to download a version 003 CID file to a relay with relay firmware R704 (Ethernet card firmware R109), ACSELERATOR Architect will automatically accept the file without conversion.

# Logical Node Extensions

The following Logical Nodes in *Table H.7* and *Table H.8* have been extended in this device in accordance with IEC 61850 guidelines.

**Table H.7 Logical Node MMXU With Windings Phase Currents**

| MMXU class | | | | |
|---|---|---|---|---|
| **Attribute Name** | **Attribute Type** | **Explanation** | **M/O/E** | **Remarks** |
| Measured Values | | | | |
| A1 | WYE | Winding 1 Phase Current | E | |
| A2 | WYE | Winding 2 Phase Current | E | |
| A12 | WYE | Combined Windings 1 and 2 Phase Current | E | |
| A3 | WYE | Winding 3 Phase Current | E | |

**Table H.8 Logical Node MSQI With Windings Sequence Currents**

| MSQI class | | | | |
|---|---|---|---|---|
| **Attribute Name** | **Attribute Type** | **Explanation** | **M/O/E** | **Remarks** |
| Measured Values | | | | |
| SeqA1 | SEQ | Winding 1 Positive-, Negative- and Zero-Sequence Current | E | |
| SeqA2 | SEQ | Winding 2 Positive-, Negative- and Zero-Sequence Current | E | |
| SeqA3 | SEQ | Winding 3 Positive-, Negative- and Zero-Sequence Current | E | |

# Logical Nodes

*Table H.9* through *Table H.12* show the Logical Nodes (LN) supported in the SEL-387E and the associated Relay Word bits or measured quantities. *Table H.9* shows the LNs associated with protection elements defined as Logical Device PRO.

**Table H.9 Logical Device: PRO** (Sheet 1 of 4)

| Logical Node | Status | Relay Word Bit | Comment |
|---|---|---|---|
| P12PIOC1 | Op.general | 50P12 | |
| P13PIOC2 | Op.general | 50P13 | |
| P14PIOC3 | Op.general | 50P14 | |
| N12PIOC4 | Op.general | 50N12 | |
| Q12PIOC5 | Op.general | 50Q12 | |
| P22PIOC6 | Op.general | 50P22 | |
| P23PIOC7 | Op.general | 50P23 | |
| P24PIOC8 | Op.general | 50P24 | |
| N22PIOC9 | Op.general | 50N22 | |
| Q22PIOC10 | Op.general | 50Q22 | |
| P32PIOC11 | Op.general | 50P32 | |
| P33PIOC12 | Op.general | 50P33 | |
| P34PIOC13 | Op.general | 50P34 | |
| N32PIOC14 | Op.general | 50N32 | |
| Q32PIOC15 | Op.general | 50Q32 | |
| P1PTOC1 | Str.general | 51P1 | |
| P1PTOC1 | Op.general | 51P1T | |
| P11PTOC2 | Str.general | 50P11 | |
| P11PTOC2 | Op.general | 50P11T | |
| N1PTOC3 | Str.general | 51N1 | |
| N1PTOC3 | Op.general | 51N1T | |
| N11PTOC4 | Str.general | 50N11 | |

**Table H.9 Logical Device: PRO** (Sheet 2 of 4)

| Logical Node | Status | Relay Word Bit | Comment |
|---|---|---|---|
| N11PTOC4 | Op.general | 50N11T | |
| Q1PTOC5 | Str.general | 51Q1 | |
| Q1PTOC5 | Op.general | 51Q1T | |
| Q11PTOC6 | Str.general | 50Q11 | |
| Q11PTOC6 | Op.general | 50Q11T | |
| P2PTOC7 | Str.general | 51P2 | |
| P2PTOC7 | Op.general | 51P2T | |
| P21PTOC8 | Str.general | 50P21 | |
| P21PTOC8 | Op.general | 50P21T | |
| N2PTOC9 | Str.general | 51N2 | |
| N2PTOC9 | Op.general | 51N2T | |
| N21PTOC10 | Str.general | 50N21 | |
| N21PTOC10 | Op.general | 50N21T | |
| Q2PTOC11 | Str.general | 51Q2 | |
| Q2PTOC11 | Op.general | 51Q2T | |
| Q21PTO12 | Str.general | 50Q21 | |
| Q21PTO12 | Op.general | 50Q21T | |
| P3PTOC13 | Str.general | 51P3 | |
| P3PTOC13 | Op.general | 51P3T | |
| P31PTOC14 | Str.general | 50P31 | |
| P31PTOC14 | Op.general | 50P31T | |
| N3PTOC15 | Str.general | 51N3 | |
| N3PTOC15 | Op.general | 51N3T | |
| N31PTOC16 | Str.general | 50N31 | |
| N31PTOC16 | Op.general | 50N31T | |
| Q3PTOC17 | Str.general | 51Q3 | |
| Q3PTOC17 | Op.general | 51Q3T | |
| Q31PTOC18 | Str.general | 50Q31 | |
| Q31PTOC18 | Op.general | 50Q31T | |
| PC1PTOC19 | Str.general | 51PC1 | |
| PC1PTOC19 | Op.general | 51PC1T | |
| NC1PTOC20 | Str.general | 51NC1 | |
| NC1PTOC20 | Op.general | 51NC1T | |
| D87UPDIF1 | Op.general | 87U | |
| D87UPDIF1 | Op.PhsA | 87U1 | |
| D87UPDIF1 | Op.PhsB | 87U2 | |
| D87UPDIF1 | Op.PhsC | 87U3 | |
| D87RPDIF2 | Str.general | | 87O1+87O2+87O3 |
| D87RPDIF2 | Str.PhsA | 87O1 | |
| D87RPDIF2 | Str.PhsB | 87O2 | |

**Table H.9 Logical Device: PRO** (Sheet 3 of 4)

| Logical Node | Status | Relay Word Bit | Comment |
|---|---|---|---|
| D87RPDIF2 | Str.PhsC | 87O3 | |
| D87RPDIF2 | Op.general | 87R | |
| D87RPDIF2 | Op.PhsA | 87R1 | |
| D87RPDIF2 | Op.PhsB | 87R2 | |
| D87RPDIF2 | Op.PhsC | 87R3 | |
| HB2PHAR1 | Str.general | | 2HB1+2HB2+2HB3 |
| HB2PHAR1 | Str.PhsA | 2HB1 | |
| HB2PHAR1 | Str.PhsB | 2HB2 | |
| HB2PHAR1 | Str.PhsC | 2HB3 | |
| HB5PHAR2 | Str.general | | 5HB1+5HB2+5HB3 |
| HB5PHAR2 | Str.PhsA | 5HB1 | |
| HB5PHAR2 | Str.PhsB | 5HB2 | |
| HB5PHAR2 | Str.PhsC | 5HB3 | |
| HBL4PHAR3 | Str.general | 4HBL | |
| DCBLPHAR4 | Str.general | DCBL | |
| TRIP1PTRC1 | Tr.general | TRIP1 | |
| TRIP2PTRC2 | Tr.general | TRIP2 | |
| TRIP3PTRC3 | Tr.general | TRIP3 | |
| TRIP4PTRC4 | Tr.general | TRIP4 | |
| P1PTUV1 | Str.general | 27P1 | |
| P1PTUV1 | Op.general | 27P1 | |
| P2PTUV2 | Str.general | 27P2 | |
| P2PTUV2 | Op.general | 27P2 | |
| PP1PTUV3 | Str.general | 27PP1 | |
| PP1PTUV3 | Op.general | 27PP1 | |
| PP2TUV4 | Str.general | 27PP2 | |
| PP2PTUV4 | Op.general | 27PP2 | |
| V1PTUV5 | Str.general | 27V1 | |
| V1PTUV5 | Op.general | 27V1 | |
| P1PTOV1 | Str.general | 59P1 | |
| P1PTOV1 | Op.general | 59P1 | |
| P2PTOV2 | Str.general | 59P2 | |
| P2PTOV2 | Op.general | 59P2 | |
| PP1PTOV3 | Str.general | 59PP1 | |
| PP1PTOV3 | Op.general | 59PP1 | |
| PP2PTOV4 | Str.general | 59PP2 | |
| PP2PTOV4 | Op.general | 59PP2 | |
| G1PTOV5 | Str.general | 59G1 | |
| G1PTOV5 | Op.general | 59G1 | |
| G2PTOV6 | Str.general | 59G2 | |

**Table H.9 Logical Device: PRO** (Sheet 4 of 4)

| Logical Node | Status | Relay Word Bit | Comment |
|---|---|---|---|
| G2PTOV6 | Op.general | 59G2 | |
| QPTOV7 | Str.general | 59Q | |
| QPTOV7 | Op.general | 59Q | |
| V1PTOV8 | Str.general | 59V1 | |
| V1PTOV8 | Op.general | 59V1 | |
| D1PVPH1 | Str.general | 24D1 | |
| D1PVPH1 | Op.general | 24D1T | |
| C2PVPH2 | Str.general | 24C2 | |
| C2PVPH2 | Op.general | 24C2T | |
| W1CSWI1 | Pos.stVal | CC1 | Result of SELOGIC setting for 52A1 |
| W1CSWI1 | Pos.Oper.ctlVal | CC1 | This value is actually a control value, not a status value. |
| W1CSWI1 | OpOpn.general | OC1 | |
| W1CSWI1 | OpCls.general | CC1 | |
| W2CSWI2 | Pos.stVal | CC2 | Result of SELOGIC setting for 52A2 |
| W2CSWI2 | Pos.Oper.ctlVal | CC2 | This value is actually a control value, not a status value. |
| W2CSWI2 | OpOpn.general | OC2 | |
| W2CSWI2 | OpCls.general | CC2 | |
| W3CSWI3 | Pos.stVal | CC3 | Result of SELOGIC setting for 52A3 |
| W3CSWI3 | Pos.Oper.ctlVal | CC3 | This value is actually a control value, not a status value. |
| W3CSWI3 | OpOpn.general | OC3 | |
| W3CSWI3 | OpCls.general | CC3 | |
| W1XCBR1 | OpCnt.stVal | | Operations count from BRE report |
| W1XCBR1 | Pos.stVal | | Result of SELOGIC setting for 52A1 |
| W2XCBR2 | OpCnt.stVal | | Operations count from BRE report |
| W2XCBR2 | Pos.stVal | | Result of SELOGIC setting for 52A2 |
| W3XCBR3 | OpCnt.stVal | | Operations count from BRE report |
| W3XCBR3 | Pos.stVal | | Result of SELOGIC setting for 52A3 |

*Table H.10* shows the LNs associated with measuring elements defined as Logical Device MET.

**Table H.10 Logical Device: MET** (Sheet 1 of 3)

| Logical Node | Measurand | Comment |
|---|---|---|
| METMMXU1 | TotW.instMag | Three-phase MW as defined by the VIWDG setting |
| METMMXU1 | TotVAr.instMag | Three-phase VAR as defined by the VIWDG setting |
| METMMXU1 | TotVA.instMag | Three-phase VA as defined by the VIWDG setting |
| METMMXU1 | Hz.instMag | Measured frequency |
| METMMXU1 | PPV.phsAB.instCVal.mag | AB-phase voltage magnitude when DELTA_Y=D |
| METMMXU1 | PPV.phsAB.instCVal.ang | AB-phase voltage angle when DELTA_Y=D |
| METMMXU1 | PPV.phsBC.instCVal.mag | BC-phase voltage magnitude when DELTA_Y=D |
| METMMXU1 | PPV.phsBC.instCVal.ang | BC-phase voltage angle when DELTA_Y=D |

**Table H.10 Logical Device: MET** (Sheet 2 of 3)

| Logical Node | Measurand | Comment |
|---|---|---|
| METMMXU1 | PPV.phsCA.instCVal.mag | CA-phase voltage magnitude when DELTA_Y=D |
| METMMXU1 | PPV.phsCA.instCVal.ang | CA-phase voltage angle when DELTA_Y=D |
| METMMXU1 | PhV.phsA.instCVal.mag | A-phase voltage magnitude when DELTA_Y=Y |
| METMMXU1 | PhV.phsA.instCVal.ang | A-phase voltage angle when DELTA_Y=Y |
| METMMXU1 | PhV.phsB.instCVal.mag | B-phase voltage magnitude when DELTA_Y=Y |
| METMMXU1 | PhV.phsB.instCVal.ang | B-phase voltage angle when DELTA_Y=Y |
| METMMXU1 | PhV.phsC.instCVal.mag | C-phase voltage magnitude when DELTA_Y=Y |
| METMMXU1 | PhV.phsC.instCVal.ang | C-phase voltage angle when DELTA_Y=Y |
| METMMXU1 | A1.phsA.instCVal.mag | Winding 1 A-phase current magnitude |
| METMMXU1 | A1.phsA.instCVal.ang | Winding 1 A-phase current angle |
| METMMXU1 | A1.phsB.instCVal.mag | Winding 1 B-phase current magnitude |
| METMMXU1 | A1.phsB.instCVal.ang | Winding 1 B-phase current angle |
| METMMXU1 | A1.phsC.instCVal.mag | Winding 1 C-phase current magnitude |
| METMMXU1 | A1.phsC.instCVal.ang | Winding 1 C-phase current angle |
| METMMXU1 | A2.phsA.instCVal.mag | Winding 2 A-phase current magnitude |
| METMMXU1 | A2.phsA.instCVal.ang | Winding 2 A-phase current angle |
| METMMXU1 | A2.phsB.instCVal.mag | Winding 2 B-phase current magnitude |
| METMMXU1 | A2.phsB.instCVal.ang | Winding 2 B-phase current angle |
| METMMXU1 | A2.phsC.instCVal.mag | Winding 2 C-phase current magnitude |
| METMMXU1 | A2.phsC.instCVal.ang | Winding 2 C-phase current angle |
| METMMXU1 | A12.phsA.instCVal.mag | Combined Winding 1 and 2 A-phase current magnitude |
| METMMXU1 | A12.phsA.instCVal.ang | Combined Winding 1 and 2 A-phase current angle |
| METMMXU1 | A12.phsB.instCVal.mag | Combined Winding 1 and 2 B-phase current magnitude |
| METMMXU1 | A12.phsB.instCVal.ang | Combined Winding 1 and 2 B-phase current angle |
| METMMXU1 | A12.phsC.instCVal.mag | Combined Winding 1 and 2 C-phase current magnitude |
| METMMXU1 | A12.phsC.instCVal.ang | Combined Winding 1 and 2 C-phase current angle |
| METMMXU1 | A3.phsA.instCVal.mag | Winding 3 A-phase current magnitude |
| METMMXU1 | A3.phsA.instCVal.ang | Winding 3 A-phase current angle |
| METMMXU1 | A3.phsB.instCVal.mag | Winding 3 B-phase current magnitude |
| METMMXU1 | A3.phsB.instCVal.ang | Winding 3 B-phase current angle |
| METMMXU1 | A3.phsC.instCVal.mag | Winding 3 C-phase current magnitude |
| METMMXU1 | A3.phsC.instCVal.ang | Winding 3 C-phase current angle |
| METMSQI1 | SeqA1.c1.instCVal.mag | Winding 1 positive-sequence current magnitude |
| METMSQI1 | SeqA1.c1.instCVal.ang | Winding 1 positive-sequence current angle |
| METMSQI1 | SeqA1.c2.instCVal.mag | Winding 1 negative-sequence current magnitude |
| METMSQI1 | SeqA1.c2.instCVal.ang | Winding 1 negative-sequence current angle |
| METMSQI1 | SeqA1.c3.instCVal.mag | Winding 1 zero-sequence current magnitude |
| METMSQI1 | SeqA1.c3.instCVal.ang | Winding 1 zero-sequence current angle |
| METMSQI1 | SeqA2.c1.instCVal.mag | Winding 2 positive-sequence current magnitude |
| METMSQI1 | SeqA2.c1.instCVal.ang | Winding 2 positive-sequence current angle |
| METMSQI1 | SeqA2.c2.instCVal.mag | Winding 2 negative-sequence current magnitude |

**Table H.10 Logical Device: MET** (Sheet 3 of 3)

| Logical Node | Measurand | Comment |
|---|---|---|
| METMSQI1 | SeqA2.c2.instCVal.ang | Winding 2 negative-sequence current angle |
| METMSQI1 | SeqA2.c3.instCVal.mag | Winding 2 zero-sequence current magnitude |
| METMSQI1 | SeqA2.c3.instCVal.ang | Winding 2 zero-sequence current angle |
| METMSQI1 | SeqA3.c1.instCVal.mag | Winding 3 positive-sequence current magnitude |
| METMSQI1 | SeqA3.c1.instCVal.ang | Winding 3 positive-sequence current angle |
| METMSQI1 | SeqA3.c2.instCVal.mag | Winding 3 negative-sequence current magnitude |
| METMSQI1 | SeqA3.c2.instCVal.ang | Winding 3 negative-sequence current angle |
| METMSQI1 | SeqA3.c3.instCVal.mag | Winding 3 zero-sequence current magnitude |
| METMSQI1 | SeqA3.c3.instCVal.ang | Winding 3 zero-sequence current angle |
| METMSQI1 | SeqV.c1.instCVal.mag | Positive-sequence voltage magnitude |
| METMSQI1 | SeqV.c1.instCVal.ang | Positive-sequence voltage angle |
| METMSQI1 | SeqV.c2.instCVal.mag | Negative-sequence voltage magnitude |
| METMSQI1 | SeqV.c2.instCVal.ang | Negative-sequence voltage angle |
| METMSQI1 | SeqV.c3.instCVal.mag | Zero-sequence voltage magnitude |
| METMSQI1 | SeqV.c3.instCVal.ang | Zero-sequence voltage angle |

*Table H.11* shows the LNs associated with control elements defined as Logical Device CON.

**Table H.11 Logical Device: CON**

| Logical Node | Status | Control | Relay Word Bit | Comment |
|---|---|---|---|---|
| RBGGIO1 | SPCSO01.stVal | SPCSO01.ctlVal | RB1 | |
| RBGGIO2 | SPCSO02.stVal | SPCSO02.ctlVal | RB2 | |
| RBGGIO3 | SPCSO03.stVal | SPCSO03.ctlVal | RB3 | |
| RBGGIO4 | SPCSO04.stVal | SPCSO04.ctlVal | RB4 | |
| RBGGIO5 | SPCSO05.stVal | SPCSO05.ctlVal | RB5 | |
| RBGGIO6 | SPCSO06.stVal | SPCSO06.ctlVal | RB6 | |
| RBGGIO7 | SPCSO07.stVal | SPCSO07.ctlVal | RB7 | |
| RBGGIO8 | SPCSO08.stVal | SPCSO08.ctlVal | RB8 | |
| RBGGIO9 | SPCSO09.stVal | SPCSO09.ctlVal | RB9 | |
| RBGGIO10 | SPCSO10.stVal | SPCSO10.ctlVal | RB10 | |
| RBGGIO11 | SPCSO11.stVal | SPCSO11.ctlVal | RB11 | |
| RBGGIO12 | SPCSO12.stVal | SPCSO12.ctlVal | RB12 | |
| RBGGIO13 | SPCSO13.stVal | SPCSO13.ctlVal | RB13 | |
| RBGGIO14 | SPCSO14.stVal | SPCSO14.ctlVal | RB14 | |
| RBGGIO15 | SPCSO15.stVal | SPCSO15.ctlVal | RB15 | |
| RBGGIO16 | SPCSO16.stVal | SPCSO16.ctlVal | RB16 | |

*Table H.12* shows the LNs associated with annunciation elements defined as Logical Device ANN.

**Table H.12 Logical Device: ANN** (Sheet 1 of 3)

| Logical Node | Status | Relay Word Bit | Comment |
|---|---|---|---|
| IN1GGIO1 | Ind01.stVal | IN101 | |
| IN1GGIO1 | Ind02.stVal | IN102 | |
| IN1GGIO1 | Ind03.stVal | IN103 | |
| IN1GGIO1 | Ind04.stVal | IN104 | |
| IN1GGIO1 | Ind05.stVal | IN105 | |
| IN1GGIO1 | Ind06.stVal | IN106 | |
| IN2GGIO2[a] | Ind01.stVal | IN201 | |
| IN2GGIO2[a] | Ind02.stVal | IN202 | |
| IN2GGIO2[a] | Ind03.stVal | IN203 | |
| IN2GGIO2[a] | Ind04.stVal | IN204 | |
| IN2GGIO2[a] | Ind05.stVal | IN205 | |
| IN2GGIO2[a] | Ind06.stVal | IN206 | |
| IN2GGIO2[a] | Ind07.stVal | IN207 | |
| IN2GGIO2[a] | Ind08.stVal | IN208 | |
| IN2GGIO2[a] | Ind09.stVal | IN209 | |
| IN2GGIO2[a] | Ind10.stVal | IN210 | |
| IN2GGIO2[a] | Ind11.stVal | IN211 | |
| IN2GGIO2[a] | Ind12.stVal | IN212 | |
| IN2GGIO2[a] | Ind13.stVal | IN213 | |
| IN2GGIO2[a] | Ind14.stVal | IN214 | |
| IN2GGIO2[a] | Ind15.stVal | IN215 | |
| IN2GGIO2[a] | Ind16.stVal | IN216 | |
| OUT1GGIO3 | Ind01.stVal | OUT101 | |
| OUT1GGIO3 | Ind02.stVal | OUT102 | |
| OUT1GGIO3 | Ind03.stVal | OUT103 | |
| OUT1GGIO3 | Ind04.stVal | OUT104 | |
| OUT1GGIO3 | Ind05.stVal | OUT105 | |
| OUT1GGIO3 | Ind06.stVal | OUT106 | |
| OUT1GGIO3 | Ind07.stVal | OUT107 | |
| OUT1GGIO3 | Ind08.stVal | NOTALM | |
| OUT2GGIO4[a] | Ind01.stVal | OUT201 | |
| OUT2GGIO4[a] | Ind02.stVal | OUT202 | |
| OUT2GGIO4[a] | Ind03.stVal | OUT203 | |
| OUT2GGIO4[a] | Ind04.stVal | OUT204 | |
| OUT2GGIO4[a] | Ind05.stVal | OUT205 | |
| OUT2GGIO4[a] | Ind06.stVal | OUT206 | |
| OUT2GGIO4[a] | Ind07.stVal | OUT207 | |
| OUT2GGIO4[a] | Ind08.stVal | OUT208 | |
| OUT2GGIO4[a] | Ind09.stVal | OUT209 | |
| OUT2GGIO4[a] | Ind10.stVal | OUT210 | |

**Table H.12 Logical Device: ANN** (Sheet 2 of 3)

| Logical Node | Status | Relay Word Bit | Comment |
|---|---|---|---|
| OUT2GGIO4[a] | Ind11.stVal | OUT211 | |
| OUT2GGIO4[a] | Ind12.stVal | OUT212 | |
| OUT2GGIO4[a] | Ind13.stVal | OUT213 | |
| OUT2GGIO4[a] | Ind14.stVal | OUT214 | |
| OUT2GGIO4[a] | Ind15.stVal | OUT215 | |
| OUT2GGIO4[a] | Ind16.stVal | OUT216 | |
| SVGGIO5 | Ind01.stVal | S1V1 | |
| SVGGIO5 | Ind02.stVal | S1V2 | |
| SVGGIO5 | Ind03.stVal | S1V3 | |
| SVGGIO5 | Ind04.stVal | S1V4 | |
| SVGGIO5 | Ind05.stVal | S2V1 | |
| SVGGIO5 | Ind06.stVal | S2V2 | |
| SVGGIO5 | Ind07.stVal | S2V3 | |
| SVGGIO5 | Ind08.stVal | S2V4 | |
| SVGGIO5 | Ind09.stVal | S3V1 | |
| SVGGIO5 | Ind10.stVal | S3V2 | |
| SVGGIO5 | Ind11.stVal | S3V3 | |
| SVGGIO5 | Ind12.stVal | S3V4 | |
| SVGGIO5 | Ind13.stVal | S3V5 | |
| SVGGIO5 | Ind14.stVal | S3V6 | |
| SVGGIO5 | Ind15.stVal | S3V7 | |
| SVGGIO5 | Ind16.stVal | S3V8 | |
| SVTGGIO6 | Ind01.stVal | S1V1T | |
| SVTGGIO6 | Ind02.stVal | S1V2T | |
| SVTGGIO6 | Ind03.stVal | S1V3T | |
| SVTGGIO6 | Ind04.stVal | S1V4T | |
| SVTGGIO6 | Ind05.stVal | S2V1T | |
| SVTGGIO6 | Ind06.stVal | S2V2T | |
| SVTGGIO6 | Ind07.stVal | S2V3T | |
| SVTGGIO6 | Ind08.stVal | S2V4T | |
| SVTGGIO6 | Ind09.stVal | S3V1T | |
| SVTGGIO6 | Ind10.stVal | S3V2T | |
| SVTGGIO6 | Ind11.stVal | S3V3T | |
| SVTGGIO6 | Ind12.stVal | S3V4T | |
| SVTGGIO6 | Ind13.stVal | S3V5T | |
| SVTGGIO6 | Ind14.stVal | S3V6T | |
| SVTGGIO6 | Ind15.stVal | S3V7T | |
| SVTGGIO6 | Ind16.stVal | S3V8T | |
| LTGGIO7 | Ind01.stVal | S1LT1 | |
| LTGGIO7 | Ind02.stVal | S1LT2 | |

**Table H.12 Logical Device: ANN** (Sheet 3 of 3)

| Logical Node | Status | Relay Word Bit | Comment |
|---|---|---|---|
| LTGGIO7 | Ind03.stVal | S1LT3 | |
| LTGGIO7 | Ind04.stVal | S1LT4 | |
| LTGGIO7 | Ind05.stVal | S2LT1 | |
| LTGGIO7 | Ind06.stVal | S2LT2 | |
| LTGGIO7 | Ind07.stVal | S2LT3 | |
| LTGGIO7 | Ind08.stVal | S2LT4 | |
| LTGGIO7 | Ind09.stVal | S3LT1 | |
| LTGGIO7 | Ind10.stVal | S3LT2 | |
| LTGGIO7 | Ind11.stVal | S3LT3 | |
| LTGGIO7 | Ind12.stVal | S3LT4 | |
| LTGGIO7 | Ind13.stVal | S3LT5 | |
| LTGGIO7 | Ind14.stVal | S3LT6 | |
| LTGGIO7 | Ind15.stVal | S3LT7 | |
| LTGGIO7 | Ind16.stVal | S3LT7 | |
| TLEDGGIO8 | Ind01.stVal | EN | Front-panel target LED **EN** |
| TLEDGGIO8 | Ind02.stVal | TRIP | Front-panel target LED **TRIP** |
| TLEDGGIO8 | Ind03.stVal | INST | Front-panel target LED **INST** |
| TLEDGGIO8 | Ind04.stVal | 87-1 | Front-panel target LED **87-1** |
| TLEDGGIO8 | Ind05.stVal | 87-2 | Front-panel target LED **87-2** |
| TLEDGGIO8 | Ind06.stVal | 87-3 | Front-panel target LED **87-3** |
| TLEDGGIO8 | Ind07.stVal | 24 | Front-panel target LED **24** |
| TLEDGGIO8 | Ind08.stVal | 81 | Front-panel target LED **87** |
| TLEDGGIO8 | Ind09.stVal | A | Front-panel target LED **A** |
| TLEDGGIO8 | Ind10.stVal | B | Front-panel target LED **B** |
| TLEDGGIO8 | Ind11.stVal | C | Front-panel target LED **C** |
| TLEDGGIO8 | Ind12.stVal | N | Front-panel target LED **N** |
| TLEDGGIO8 | Ind13.stVal | W1 | Front-panel target LED **W1** |
| TLEDGGIO8 | Ind14.stVal | W2 | Front-panel target LED **W2** |
| TLEDGGIO8 | Ind15.stVal | W3 | Front-panel target LED **W3** |
| TLEDGGIO8 | Ind16.stVal | 50/51 | Front-panel target LED **50/51** |

[a] Active data only if additional I/O card(s) installed.

# Protocol Implementation Conformance Statement

The following tables are as shown in the IEC 61850 standard, Part 8-1, Section 24. Note that because the standard explicitly dictates which services and functions must be implemented to achieve conformance, only the optional services and functions are listed.

**Table H.13 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 H.14 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 in the Reference Manual for information on the supported services.

## MMS Conformance

The Manufacturing Message Specification (MMS) stack provides the basis for many IEC 61850 Protocol services. *Table H.15* defines the service support requirement and restrictions of the MMS services in the SEL-387E 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 H.15 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 | | |
| input | | |

**Table H.15 MMS Service Supported Conformance** (Sheet 2 of 3)

| MMS Service Supported CBB | Client-CR Supported | Server-CR Supported |
|---|---|---|
| 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 | | |
| acknowledgeEventNotification | | |
| getAlarmSummary | | |

**Table H.15 MMS Service Supported Conformance** (Sheet 3 of 3)

| MMS Service Supported CBB | Client-CR Supported | Server-CR Supported |
|---|---|---|
| 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 H.16* lists specific settings for the MMS parameter Conformance Building Block (CBB).

**Table H.16 MMS Parameter CBB**

| MMS Parameter CBB | Client-CR Supported | Server-CR Supported |
|---|---|---|
| STR1 | | Y |
| STR2 | | Y |
| VNAM | | Y |
| VADR | | Y |
| 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 H.17 AlternateAccessSelection Conformance Statement**

| AlternateAccessSelection | Client-CR Supported | Server-CR Supported |
|---|---|---|
| accessSelection | | Y |
| component | | Y |
| index | | |
| indexRange | | |
| allElements | | |
| alternateAccess | | Y |
| selectAccess | | Y |
| component | | Y |
| index | | |
| indexRange | | |
| allElements | | |

**Table H.18 VariableAccessSpecification Conformance Statement**

| VariableAccessSpecification | Client-CR Supported | Server-CR Supported |
|---|---|---|
| listOfVariable | | Y |
| variableSpecification | | Y |
| alternateAccess | | Y |
| variableListName | | Y |

**Table H.19 VariableSpecification Conformance Statement**

| VariableSpecification | Client-CR Supported | Server-CR Supported |
|---|---|---|
| name | | Y |
| address | | |
| variableDescription | | |
| scatteredAccessDescription | | |
| invalidated | | |

**Table H.20 Read Conformance Statement**

| Read | Client-CR Supported | Server-CR Supported |
|---|---|---|
| Request | | |
| specificationWithResult | | |
| variableAccessSpecification | | |
| Response | | |
| variableAccessSpecification | | Y |
| listOfAccessResult | | Y |

**Table H.21 GetVariableAccessAttributes Conformance Statement**

| GetVariableAccessAttributes | Client-CR Supported | Server-CR Supported |
|---|---|---|
| Request | | |
| name | | |
| address | | |
| Response | | |
| mmsDeletable | | Y |
| address | | |
| typeSpecification | | Y |

**Table H.22 DefineNamedVariableList Conformance Statement**

| DefineVariableAccessAttributes | Client-CR Supported | Server-CR Supported |
|---|---|---|
| Request | | |
| variableListName | | |
| listOfVariable | | |
| variableSpecification | | |
| alternateAccess | | |
| Response | | |

**Table H.23 GetNamedVariableListAttributes Conformance Statement**

| GetNamedVariableListAttributes | Client-CR Supported | Server-CR Supported |
|---|---|---|
| Request | | |
| ObjectName | | |
| Response | | |
| mmsDeletable | | Y |
| listOfVariable | | Y |
| variableSpecification | | Y |
| alternateAccess | | Y |

**Table H.24 DeleteNamedVariableList Conformance Statement**

| DeleteNamedVariableList | Client-CR Supported | Server-CR Supported |
|---|---|---|
| Request | | |
| Scope | | |
| listOfVariableListName | | |
| domainName | | |
| Response | | |
| numberMatched | | |
| numberDeleted | | |
| DeleteNamedVariableList-Error | | |

## GOOSE Services Conformance Statement

**Table H.25 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 H.26 ACSI Basic Conformance Statement**

| | | Client/Subscriber | Server/Publisher | Value/Comments |
|---|---|---|---|---|
| Client-Server Roles | | | | |
| B11 | Server side (of Two-Party Application-Association) | | Y[a] | |
| B12 | Client side (of Two-Party Application-Association) | | –[b] | |
| SCMS Supported | | | | |
| B21 | SCSM: IEC 61850-8-1 used | | Y[a] | |
| 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 | –[b] | Y[a] | |
| B32 | Subscriber side | Y[a] | –[b] | |
| Transmission of Sampled Value Model (SVC) | | | | |
| B41 | Published side | –[b] | | |
| B42 | Subscriber side | | –[b] | |

[a] Y = supported
[b] – or empty = not supported

**Table H.27 ASCI Models Conformance Statement** (Sheet 1 of 2)

| | | Client/Subscriber | Server/Publisher[a] | Value/Comments |
|---|---|---|---|---|
| If Server Side (B11) Supported | | | | |
| M1 | Logical device | | Y | |
| M2 | Logical node | | Y | |
| M3 | Data | | Y | |
| M4 | Data set | | Y | |
| M5 | Substation | | | |
| M6 | Setting group control | | | |

**Table H.27 ASCI Models Conformance Statement** (Sheet 2 of 2)

| | | Client/Subscriber | Server/Publisher[a] | Value/Comments |
|---|---|---|---|---|
| Reporting | | | | |
| M7 | Buffered report control | | Y | |
| M7-1 | sequence-number | | Y | |
| M7-2 | report-time-stamp | | Y | |
| M7-3 | reason-for-inclusion | | Y | |
| M7-4 | data-set-name | | Y | |
| M7-5 | data-reference | | Y | |
| M7-6 | buffer-overflow | | Y | |
| M7-7 | entryID | | Y | |
| M7-8 | BufTm | | Y | |
| M7-9 | IntgPd | | Y | |
| M7-10 | G1 | | Y | |
| M8 | Unbuffered report control | | Y | |
| M8-1 | sequence-number | | Y | |
| M8-2 | report-time-stamp | | Y | |
| M8-3 | reason-for-inclusion | | Y | |
| M8-4 | data-set-name | | Y | |
| M8-5 | data-reference | | Y | |
| M8-6 | BufTm | | Y | |
| M8-7 | IntgPd | | Y | |
| M-8-8 | GI | | Y | |
| | **Logging** | | | |
| M9 | Log control | | | |
| M9-1 | IntgPd | | | |
| M10 | Log | | | |
| M11 | Control | | Y | |
| If GSE (B31/32) Is Supported | | | | |
| M12 | GOOSE | | Y | |
| M13 | GSSE | | Y | |
| If SVC (B41/42) Is Supported | | | | |
| M14 | Multicast SVC | | | |
| M15 | Unicast SVC | | | |
| If Server or Client Side (B11/12) Is Supported | | | | |
| M16 | Time | | Y | |
| M17 | File Transfer | | | |

[a] Y = Supported; N or empty = service is not supported

**Table H.28 ASCI Services Conformance Statement** (Sheet 1 of 3)

| Services | | AA: TP/MC | Client (C) | Server (S) | Comments |
|---|---|---|---|---|---|
| Server (Clause 6) | | | | | |
| S1 | ServerDirectory | TP | | Y | |
| Application Association (Clause 7) | | | | | |
| S2 | Associate | | | Y | |
| S3 | Abort | | | Y | |
| S4 | Release | | | Y | |
| Logical Device (Clause 8) | | | | | |
| S5 | LogicalDeviceDirectory | TP | | Y | |
| Logical Node (Clause 9) | | | | | |
| S6 | LogicalNodeDirectory | TP | | Y | |
| S7 | GetAllDataValues | TP | | Y | |
| Data (Clause 10) | | | | | |
| S8 | GetDataValues | TP | | Y | |
| S9 | SetDataValues | TP | | | |
| S10 | GetDataDirectory | TP | | Y | |
| S11 | GetDataDefinition | TP | | Y | |
| Data Set (Clause 11) | | | | | |
| S12 | GetDataSetValues | TP | | Y | |
| S13 | SetDataSetValues | TP | | | |
| S14 | CreateDataSet | TP | | | |
| S15 | DeleteDataSet | TP | | | |
| S16 | GetDataSetDirectory | TP | | Y | |
| Substitution (Clause 12) | | | | | |
| S17 | SetDataValues | TP | | | |
| Setting Group Control (Clause 13) | | | | | |
| S18 | SelectActiveSG | TP | | | |
| S19 | SelectEditSG | TP | | | |
| S20 | SetSGvalues | TP | | | |
| S21 | ConfirmEditSGVal | TP | | | |
| S22 | GetSGValues | TP | | | |
| S23 | GetSGCBValues | TP | | | |
| Reporting | | | | | |
| Buffered Report Control Block (BRCB) | | | | | |
| S24 | Report | TP | | Y | |
| S24-1 | data-change (dchg) | | | Y | |
| S24-2 | qchg-change (qchg) | | | Y | |
| S24-3 | data-update (dupd) | | | | |
| S25 | GetBRCBValues | TP | | Y | |
| S26 | SetBRCBValues | TP | | Y | |

**Table H.28 ASCI Services Conformance Statement** (Sheet 2 of 3)

| Services | | AA: TP/MC | Client (C) | Server (S) | Comments |
|---|---|---|---|---|---|
| Unbuffered Report Control Block (URCB) | | | | | |
| S27 | Report | TP | | Y | |
| S27-1 | data-change (dchg) | | | Y | |
| S27-2 | qchg-change (qchg) | | | Y | |
| S27-3 | data-update (dupd) | | | | |
| S28 | GetURCBValues | TP | | Y | |
| S29 | SetURCBValues | TP | | Y | |
| Logging (Clause 14) | | | | | |
| Log Control Block | | | | | |
| S30 | GetLCBValues | TP | | | |
| S31 | SetLCBValues | TP | | | |
| LOG | | | | | |
| S32 | QueryLogByTime | TP | | | |
| S33 | QueryLogByEntry | TP | | | |
| S34 | GetLogStatusValues | TP | | | |
| Generic Substation Event Model (GSE) (Clause 14.3.5.3.4) | | | | | |
| GOOSE-Control-Block | | | | | |
| S35 | SendGOOSEMessage | MC | | Y | |
| S36 | GetReference | TP | | | |
| S37 | GetGOOSEElement Number | TP | | | |
| S38 | GetGoCBValues | TP | | Y | |
| S39 | SetGoCBValues | TP | | | |
| GSSE-Control-Block | | | | | |
| S40 | SendGSSEMessage | MC | | | |
| S41 | GetReference | TP | | | |
| S42 | GetGSSEElement Number | TP | | | |
| S43 | GetGsCBValues | TP | | | |
| S44 | GetGsCBValues | TP | | | |
| Transmission of Sample Value Model (SVC) (Clause 16) | | | | | |
| Multicast SVC | | | | | |
| S45 | SendMSVMessage | MC | | | |
| S46 | GetMSVCBValues | TP | | | |
| S47 | SetMSVCBValues | TP | | | |
| Unicast SVC | | | | | |
| S48 | SendUSVMessage | TP | | | |
| S49 | GetUSVCBValues | TP | | | |
| S50 | SetUSVCBValues | TP | | | |
| Control (Clause 16.4.8) | | | | | |
| S51 | Select | | | | |
| S52 | SelectWithValue | TP | | Y | |
| S53 | Cancel | TP | | Y | |

**Table H.28 ASCI Services Conformance Statement** (Sheet 3 of 3)

| Services | | AA: TP/MC | Client (C) | Server (S) | Comments |
|---|---|---|---|---|---|
| S54 | Operate | TP | | Y | |
| S55 | Command-Termination | TP | | Y | |
| S56 | TimeActivated-Operate | TP | | | |
| File Transfer (Clause 20) | | | | | |
| S57 | GetFile | TP | | | |
| S58 | SetFile | TP | | | |
| S59 | DeleteFile | TP | | | |
| S60 | GetFileAttributeValues | TP | | | |
| Time (Clause 5.5) | | | | | |
| T1 | Time resolution of internal clock | | | 20 | Nearest negative power of 2 in seconds |
| T2 | Time accuracy of internal clock | | | 31 | T0 |
| | T1 | | | | T1 |
| | T2 | | | | T2 |
| | T3 | | | | T3 |
| | T4 | | | | T4 |
| | T5 | | | | T5 |
| T3 | Supported TimeStamp resolution | | | | Nearest negative power of 2 in seconds |

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# Appendix I

## Relay Power Calculations

## SEL-387E Power Meter Calculations

| | |
|---|---|
| **Case** | 1 |
| **Setting WmCT** | D |
| **Setting DELTA_Y** | D |
| **Setting TPVI** | Y |
| **Quantities Removed From Meter Display** | MWA, MWB, MWC, MVRA, MVRB, MVRC, MVAA, MVAB, MVAC |
| **Power Calculations** | $P_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \cos(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$Q_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \sin(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$S_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert/1000$<br>$V_A = V_{A_SEC} \bullet PTR/\sqrt{3}$<br>$I_A = I_{A_SEC} \bullet CTR/\sqrt{3}$ |

| | |
|---|---|
| **Case** | 2 |
| **Setting WmCT** | D |
| **Setting DELTA_Y** | D |
| **Setting TPVI** | N |
| **Quantities Removed From Meter Display** | VBWX,VCWX, 3V1WX, 3V2WX,VRWX<br>MWA, MWB, MWC, MVRA, MVRB, MVRC, MVAA, MVAB, MVAC |
| **Power Calculations** | $P_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \cos(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$Q_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \sin(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$S_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert/1000$<br>$V_A = V_{A_SEC} \bullet PTR/\sqrt{3}$<br>$I_A = I_{A_SEC} \bullet CTR/\sqrt{3}$ |

| | |
|---|---|
| **Case** | 3 |
| **Setting WmCT** | D |
| **Setting DELTA_Y** | Y |
| **Setting TPVI** | Y |
| **Quantities Removed From Meter Display** | MWA, MWB, MWC, MVRA, MVRB, MVRC, MVAA, MVAB, MVAC |
| **Power Calculations** | $P_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \cos(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$Q_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \sin(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$S_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert/1000$<br>$V_A = V_{A_SEC} \bullet PTR/\sqrt{3}$<br>$I_A = I_{A_SEC} \bullet CTR/\sqrt{3}$ |

| | |
|---|---|
| **Case** | 4 |
| **Setting WmCT** | D |
| **Setting DELTA_Y** | Y |
| **Setting TPVI** | N |
| **Quantities Removed From Meter Display** | VBWX,VCWX, 3V1WX, 3V2WX,VRWX<br>MWA, MWB, MWC, MVRA, MVRB, MVRC, MVAA, MVAB, MVAC |
| **Power Calculations** | $P_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \cos(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$Q_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \sin(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$S_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert/1000$<br>$V_A = V_{A_SEC} \bullet PTR$<br>$I_A = I_{A_SEC} \bullet CTR/\sqrt{3}$ |

| | |
|---|---|
| **Case** | 5 |
| **Setting WmCT** | Y |
| **Setting DELTA_Y** | D |
| **Setting TPVI** | Y |
| **Quantities Removed From Meter Display** | MWA, MWB, MWC, MVRA, MVRB, MVRC, MVAA, MVAB, MVAC |
| **Power Calculations** | $P_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \cos(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$Q_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \sin(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$S_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert/1000$<br>$V_A = V_{A_SEC} \bullet PTR/\sqrt{3}$<br>$I_A = I_{A_SEC} \bullet CTR$ |

| | |
|---|---|
| **Case** | 6 |
| **Setting WmCT** | Y |
| **Setting DELTA_Y** | D |
| **Setting TPVI** | N |
| **Quantities Removed From Meter Display** | VBWX,VCWX, 3V1WX, 3V2WX,VRWX<br>MWA,MWB,MWC, MVRA,MVRB,MVRC, MVAA,MVAB,MVAC |
| **Power Calculations** | $P_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \cos(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$Q_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert \bullet \sin(\angle V_A - \angle I_A - COMPANG \bullet \pi/180)/1000$<br>$S_{Total} = 3 \bullet \lvert V_A \rvert \bullet \lvert I_A \rvert/1000$<br>$V_A = V_{A_SEC} \bullet PTR/\sqrt{3}$<br>$I_A = I_{A_SEC} \bullet CTR$ |

| | |
|---|---|
| **Case** | 7 |
| **Setting WmCT** | Y |
| **Setting DELTA_Y** | Y |
| **Setting TPVI** | Y |
| **Quantities Removed From Meter Display** | N/A |
| **Power Calculations** | $P_\phi = \lvert V_\phi \rvert \bullet \lvert I_\phi \rvert \bullet \cos(\angle V_\phi - \angle I_\phi - COMPANG \bullet \pi/180)/1000$<br>$Q_\phi = \lvert V_\phi \rvert \bullet \lvert I_\phi \rvert \bullet \sin(\angle V_\phi - \angle I_\phi - COMPANG \bullet \pi/180)/1000$<br>$S_\phi = \lvert V_\phi \rvert \bullet \lvert I_\phi \rvert/1000$<br>$P_{Total} = P_A + P_B + P_C$<br>$Q_{Total} = Q_A + Q_B + Q_C$<br>$S_{Total} = S_A + S_B + S_C$<br>$V_\phi = V_{\phi_SEC} \bullet PTR$<br>$I_\phi = I_{\phi_SEC} \bullet CTR$<br>$\phi = A, B, C$ |

| | |
|---|---|
| **Case** | 8 |
| **Setting WmCT** | Y |
| **Setting DELTA_Y** | Y |
| **Setting TPVI** | N |
| **Quantities Removed From Meter Display** | VBWX,VCWX, 3V1WX, 3V2WX,VRWX<br>MWA, MWB, MWC, MVRA, MVRB, MVRC, MVAA, MVAB,MVAC |
| **Power Calculations** | $P_\phi = \lvert V_\phi \rvert \bullet \lvert I_\phi \rvert \bullet \cos(\angle V_\phi - \angle I_\phi - COMPANG \bullet \pi/180)/1000$<br>$Q_\phi = \lvert V_\phi \rvert \bullet \lvert I_\phi \rvert \bullet \sin(\angle V_\phi - \angle I_\phi - COMPANG \bullet \pi/180)/1000$<br>$S_\phi = \lvert V_\phi \rvert \bullet \lvert I_\phi \rvert /1000$<br>$P_{Total} = P_A + P_B + P_C$<br>$Q_{Total} = Q_A + Q_B + Q_C$<br>$S_{Total} = S_A + S_B + S_C$<br>$V_\phi = V_{\phi_SEC} \bullet PTR$<br>$I_\phi = I_{\phi_SEC} \bullet CTR$<br>$\phi = A, B, C$<br>Read $V_A$ and assume balanced conditions (see Note 1). |

Notes:

1. When TPVI = N, the relay calculates the $V_B$ and $V_C$ voltages as follows:

$$V_B = V_A \bullet e^{j \bullet (-120°)}$$

$$V_C = V_A \bullet e^{j \bullet (120°)}$$

2. When VIWDG = 12, the relay uses Winding 1 and 2 combined currents for power calculations, as follows:

$$I_{A_COMBINED_PRI} = I_{A_WDG1_PRI} + I_{A_WDG2_PRI}$$

$$I_{B_COMBINED_PRI} = I_{B_WDG1_PRI} + I_{B_WDG2_PRI}$$

$$I_{C_COMBINED_PRI} = I_{C_WDG1_PRI} + I_{C_WDG2_PRI}$$

$$I_{3iO_COMBINED_PRI} = I_{3iO_WDG1_PRI} + I_{3iO_WDG2_PRI}$$

3. The relay uses VAX as the phase angle reference if the |VAWX| > 13 V secondary, otherwise it uses IAW1.
4. IAW*m*, IBW*m*, ICW*m*, 3I1W*m*, 3I2W*m*, IRW*m*, IAW12, IBW12, ICW12, and IRW12 are always calculated and displayed.
5. The displayed phase voltages are phase-to-ground. When TPVI = N, the relay only displays A-Phase Voltage and sets 3V1WX = 3V2WX = VRWX = 0.

6. When DELTA_Y = D, the relay only uses the VAWX measurement in its metering calculations.
7. The relay calculates positive- and negative-sequence quantities according to PHROT.

# Instantaneous Meter Displays

## Case 1 (VIWDG = 1)

```
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)          0         0         0              0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0              0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0              0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0              0
                 Phase Voltages                     Sequence Voltages
WdgX            VAWX      VBWX      VCWX          3V1WX     3V2WX      VRWX
V (KV,pri)      0.00      0.00      0.00           0.00      0.00      0.00
                 Power Quantities
                MW
P (MW,pri)      0.00
               MVAR
Q (MVar,pri)    0.00
                MVA
S (MVa,pri)     0.00
```

## Case 2 (VIWDG = 1)

```
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)          0         0         0              0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0              0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0              0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0              0
                 Phase Voltage
WdgX            VAWX
V (KV,pri)      0.00
                 Power Quantities
                MW
P (MW,pri)      0.00
               MVAR
Q (MVar,pri)    0.00
                MVA
S (MVa,pri)     0.00
```

## Case 3 (VIWDG = 1)

```
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)          0         0         0              0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0              0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0              0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0              0
                 Phase Voltages                     Sequence Voltages
WdgX            VAWX      VBWX      VCWX          3V1WX     3V2WX      VRWX
V (KV,pri)      0.00      0.00      0.00           0.00      0.00      0.00
                 Power Quantities
                MW
P (MW,pri)      0.00
               MVAR
Q (MVar,pri)    0.00
                MVA
S (MVa,pri)     0.00
```

## Case 4 (VIWDG = 1)

```
I (A,pri)          0         0         0             0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0             0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0             0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0             0
                 Phase Voltage
WdgX            VAWX
V (KV,pri)      0.00
                 Power Quantities
                MW
P (MW,pri)      0.00
               MVAR
Q (MVar,pri)    0.00
                MVA
S (MVa,pri)     0.00
```

## Case 5 (VIWDG = 1)

```
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)          0         0         0             0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0             0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0             0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0             0
                 Phase Voltages                    Sequence Voltages
WdgX            VAWX      VBWX      VCWX          3V1WX     3V2WX      VRWX
V (KV,pri)      0.00      0.00      0.00           0.00      0.00      0.00
                 Power Quantities
                MW
P (MW,pri)      0.00
               MVAR
Q (MVar,pri)    0.00
                MVA
S (MVa,pri)     0.00
```

## Case 6 (VIWDG = 1)

```
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)          0         0         0             0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0             0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0             0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0             0
                 Phase Voltage
WdgX            VAWX
V (KV,pri)      0.00
                 Power Quantities
                MW
P (MW,pri)      0.00
               MVAR
Q (MVar,pri)    0.00
                MVA
S (MVa,pri)     0.00
```

## Case 7 (VIWDG = 1)

```
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)          0         0         0              0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0              0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0              0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0              0
                 Phase Voltages                     Sequence Voltages
WdgX            VAWX      VBWX      VCWX          3V1WX     3V2WX      VRWX
V (KV,pri)      0.00      0.00      0.00           0.00      0.00      0.00
                 Power Quantities
                 MW        MWA       MWB        MWC
P (MW,pri)      0.00      0.00      0.00       0.00
                MVAR      MVRA      MVRB       MVRC
Q (MVar,pri)    0.00      0.00      0.00       0.00
                 MVA      MVAA      MVAB       MVAC
S (MVa,pri)     0.00      0.00      0.00       0.00
```

## Case 8 (VIWDG = 1)

```
Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)          0         0         0              0         0         0
Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)          0         0         0              0         0         0
Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)          0         0         0              0         0         0
Wdg1&2         IAW12     IBW12     ICW12          IRW12
I (A,pri)          0         0         0              0
                 Phase Voltage
WdgX            VAWX
V (KV,pri)      0.00
                 Power Quantities
                 MW
P (MW,pri)      0.00
               MVAR
Q (MVar,pri)    0.00
                MVA
S (MVa,pri)     0.00
```

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# Appendix J

# Protection Application Examples

## Overview

This section provides instructions for setting the SEL-387E Relay protection functions. Use these application examples to help familiarize yourself with the relay and assist you with your own protection settings calculations. This section is not intended to provide a complete settings guide for the relay.

## Transformer Winding and CT Connection Compensation Settings Examples

In electromechanical and solid-state transformer differential relays, the standard current transformer (CT) configuration was wye-connected on the delta winding of the transformer and delta-connected on the wye winding of the transformer. The CT delta connection was constructed based on the power transformer delta to compensate for the phase shift that occurred on the system primary currents because of the power transformer connection. The CT configuration allowed the currents entering the relay for through-load or external faults to be 180 degrees out-of-phase so that the phasor sum of the currents added to zero (no differential current) in an electromechanical differential relay. Taps on the relay current inputs compensated for magnitude differences. Modern digital relays perform both the connection (or phase) and magnitude compensation mathematically so all CTs can be connected in wye.

NOTE: In this settings guideline, the term "phase rotation" is synonymous with "phase sequence." This settings guideline uses "phase rotation" to be consistent with the relay Global setting, PHROT.

This section provides a procedure for SEL-387E Relays to determine and set the Terminal *n* CT connection compensation settings, W*n*CTC (where *n* = 1, 2, 3, or 4), to compensate for the phase shift across the transformer. Each of the connection compensation settings offer thirteen 3x3 matrices, CTC(0)–CTC(12), permitting CT connection compensation from 0 degrees to 360 degrees, in increments of 30 degrees, respectively. Refer to *Section 3: Protection Functions* (*Table 3.1*) for each of the compensation matrices. When applied on a system with an ABC phase rotation, these matrices perform phase angle correction in a counterclockwise (CCW) direction in multiples of 30 degrees, as shown in *Table J.1*. For a system with an ACB phase rotation, the direction of correction is clockwise (CW). See *Special Cases* for a compensation settings example on a system with an ACB phase rotation.

**Table J.1 WnCTC Setting: Corresponding Phase and Direction of Correction**

| WnCTC Setting[a] | Matrix | Amount and Direction of Correction | |
|---|---|---|---|
| | | ABC Phase Rotation | ACB Phase Rotation |
| 0 | CTC(0) | 0° | 0° |
| 1 | CTC(1) | 30° CCW | 30° CW |
| 2 | CTC(2) | 60° CCW | 60° CW |
| 3 | CTC(3) | 90° CCW | 90° CW |
| 4 | CTC(4) | 120° CCW | 120° CW |
| 5 | CTC(5) | 150° CCW | 150° CW |
| 6 | CTC(6) | 180° CCW | 180° CW |
| 7 | CTC(7) | 210° CCW | 210° CW |
| 8 | CTC(8) | 240° CCW | 240° CW |
| 9 | CTC(9) | 270° CCW | 270° CW |
| 10 | CTC(10) | 300° CCW | 300° CW |
| 11 | CTC(11) | 330° CCW | 330° CW |
| 12 | CTC(12) | 0° (360°) CCW | 0° (360°) CW |

[a] n = 1, 2, 3, 4.

As shown in *Section 3: Protection Functions* (*Table 3.1*), compensation matrix CTC(0) multiplies the currents by the identity matrix and creates no change in the currents. 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, CTC(12) removes zero-sequence components from the measured current, as do all of the matrices with non-zero values.

## Transformer Nameplates and System Connections

To determine the phase shift seen by the relay, the following information is required:

- Transformer phasor (vector) diagram (transformer nameplate)
- Three-line connection diagram showing:
  - System phase-to-transformer bushing connections
  - CT connections
  - CT-to-relay connections

*Figure J.1* shows the key information from a typical nameplate for a two-winding transformer. The winding connection diagram and the phasor (vector) diagram are needed to determine the winding compensation settings in the relay.

**Figure J.1 Transformer Nameplate**

Note that there is no phase designation nor any phase rotation designation on the nameplate. However, the phasor diagram is representative of an H1-H2-H3 sequence. The phase shift on the power system depends on the transformer winding connections, the system phase-to-transformer bushing connections, and the system phase rotation.

*Figure J.2* shows a three-line connection diagram with the transformer shown in *Figure J.1* with what this guideline refers to as standard connections. Standard phase-to-bushing connections are A-phase to H1, B-phase to H2, C-phase to H3, a-phase to X1, b-phase to X2, and c-phase to X3. Standard CT connections include wye-connected CTs with polarity marks of both CTs away from or toward the transformer. *Figure J.2* shows both H-side and X-side CTs connected in wye and the polarity marks away from the transformer. A CT-to-relay connection is considered to be standard when the polarity of the CT is connected to the polarity of the relay analog current input and the primary system phase current is connected to the same phase input on the relay (e.g., IA system to IAW1). Unless otherwise noted, an ABC phase rotation is assumed for the following discussion.

**Figure J.2 Three-Line Diagram Showing System Phase-to-Transformer Bushing, CT, and CT-to-Relay Connections**

If all the connections are standard as shown in *Figure J.2*, under a through-load condition the phase relationship between the system primary currents (Ia system and IA system) and corresponding secondary currents as seen by the relay (IAW2 and IAW1) will look like as shown in *Figure J.3* (Ia lags IA by 30 degrees) and *Figure J.4* (IAW2 lags IAW1 by 210 degrees), respectively. The goal of the compensation settings is to compensate IAW2 so as to bring IAW2_compensated 180 degrees out-of-phase with IAW1 for proper application of the differential function.

**Figure J.3 Primary Current Phasors**

**Figure J.4 Current at the Relay Terminals**

Many applications do not conform to the standard connections, but compensation settings are adaptable to fit any application. The subsequent sections outline the procedure to determine the phase shift and current transformer compensation settings, and also discuss what to do with non-standard phase-to-bushing, CT, and CT-to-relay connections.

## Steps to Determine the Compensation Settings (WnCTC)

Use the following guidelines to determine compensation settings for your application(s).

Step 1. Determine the phase shift as seen by the relay.

a. Determine the phase shift in the primary load current.

b. Determine if there are non-standard CT connections.

Step 2. Select the reference winding and associated relay terminal.

a. If a delta winding exists and is wired into the relay, choose it as the reference winding. Select matrix CTC(0) for the compensation of the delta winding. If a zigzag grounding transformer exists on the delta side of the transformer and is within the zone of protection, then select matrix CTC(12).

b. If a delta winding does not exist, select one of the wye windings as the reference and choose matrix CTC(11) for the compensation.

Step 3. Determine the required compensation setting for all other windings. Select matrix CTC(0) for delta windings. Use odd matrices for compensating wye windings. Avoid the use of even matrices when possible.

There may be applications that require the guidelines to be violated, but they should be followed when possible.

The rest of this section discusses each of the guidelines in detail. Examples and special cases are provided to illustrate the application of the guidelines in determining the compensation settings.

### Step 1. Determine the Phase Shift as Seen by the Relay

#### Determine the Phase Shift in the Primary Load Current

The first step in selecting the compensation setting in the relay is to determine the phase shift in the primary load current.

#### Standard System Phase-to-Transformer Bushing Connections.

**NOTE:** Unless otherwise stated, this discussion assumes an ABC system phase rotation.

Consider the transformer in *Figure J.1* and the phase-to-bushing connections in *Figure J.2*. Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic, as shown in *Figure J.5*. The currents on the H-side (delta-winding) of the transformer are Ia/N, Ib/N, and Ic/N where N is the turns ratio of the transformer. Because the discussion focuses on the phase shift and not the magnitude, you can assume N = 1 for this discussion.

**Figure J.5 Standard System Phase-to-Transformer Bushing Connections**

Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

IA = Ia – Ib

IB = Ib – Ic

IC = Ic – Ia

The following examples start with the currents on the wye side of the transformer to graphically derive the currents on the delta side of the transformer. *Figure J.6* shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees.

**Figure J.6 X- and H-Side Current Phasors for Figure J.5**

The primary load phase shift determined in *Figure J.6* applies for the phase-to-bushing connections shown in *Table J.2*. In each of these phase-to-bushing connections, the order of the phases (A, B, C) matches the order of the bushings (H1, H2, H3).

**Table J.2 (A, B, C) to (H1, H2, H3) Phase-to-Bushing Connections**

| | Bushing | | | | | |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | X1 | X2 | X3 |
| System Phase | A | B | C | a | b | c |
| | B | C | A | b | c | a |
| | C | A | B | c | a | b |

**Non-Standard Phase-to-Bushing Connections.** Consider the transformer connections in *Figure J.7*. This is the same transformer discussed in *Figure J.5*, but with different phase-to-bushing connections: A-phase to H3, B-phase to H2, C-phase to H1, a-phase to X3, b-phase to X2, and c-phase to X1.

**Figure J.7 Non-Standard System Phase-to-Transformer Bushing Connections**

Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic. Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

$$IA = Ia - Ic$$

$$IB = Ib - Ia$$

$$IC = Ic - Ib$$

*Figure J.8* shows that system primary current Ia (X-side) leads the system primary current IA (H-side) by 30 degrees.

**Figure J.8 X- and H-Side Current Phasors for Figure J.7**

The primary load phase shift determined in *Figure J.8* applies for the phase-to-bushing connections shown in *Table J.3*. In each of these phase-to-bushing connections, the order of the phase connections (A, C, B) is opposite the order of the bushings (H1, H2, H3).

**Table J.3 (A, C, B) to (H1, H2, H3) Phase-to-Bushing Connections**

| | Bushing | | | | | |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | X1 | X2 | X3 |
| System Phase | C | B | A | c | b | a |
| | B | A | C | b | a | c |
| | A | C | B | a | c | b |

The system phase-to-transformer bushing connection diagrams in *Figure J.5* and *Figure J.7* are on the same transformer, but with a different order of the phases connected to the transformer bushings. As a result, the X-side primary current shifts 30 degrees in opposite directions in the two systems.

**Combination of Standard and Non-Standard Phase-to-Bushing Connections.** Consider the transformer connections shown in *Figure J.9*. The transformer is the same as in previous examples. However, in this example, the H-side phase-to-bushing connections are standard: A-phase to H1, B-phase to H2, and C-phase to H3. The X-side connections are non-standard: a-phase to X2, b-phase to X3, and c-phase to X1.

**Figure J.9 Combination of Standard and Non-Standard Phase-to-Bushing Connection Diagram**

Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic. Kirchhoff's Current Law is used at each H-node to determine the primary phase currents on the H-side of the system:

$$IA = Ic - Ia$$

$$IB = Ia - Ib$$

$$IC = Ib - Ic$$

*Figure J.10* shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 150 degrees.

**Figure J.10 X- and H-Side Current Phasors for Figure J.9**

These three examples show that the same transformer winding connections can produce different phase shifts in the system primary load current based on the phase-to-bushing connections.

## Determine if There Are Non-Standard CT Connections

*Figure J.11* shows the transformer of *Figure J.2* with a standard current transformer configuration; that is, both the H-side and X-side CTs are connected in wye and the polarity marks are away from the power transformer.

**Figure J.11 Standard CT Connections**

**Standard CT Connections.** In *Figure J.11*, the polarity of the CT connects to the polarity of the relay current input, and the primary system phase current connects to the same phase input on the relay (e.g., IA system to IAW1 relay input). While the H-side currents connect to the W1-terminal and the X-side currents connect to W2-terminal, they could be connected to any two sets of current inputs on the relay. *Figure J.11* represents the standard connections for the transformer, CTs, and relay.

*Figure J.11* also shows the primary system currents (IA system, Ia system) and the CT secondary currents seen by the relay (IA relay, Ia relay) based on the currents of *Figure J.6*. For these connections, with power flow from the H-side to the X-side of the transformer, currents enter the relay at the polarity mark on the H-side, and leave the relay at the polarity mark on the X-side. Thus, on the primary system, Ia lags IA by 30 degrees, but at the relay, IAW2 leads IAW1 by 150 degrees, as shown in *Figure J.12*. B- and C-phases follow this relationship. Only A-phase is discussed for simplicity, but the concept is the same.

**Figure J.12 Primary System Currents and Currents as Seen by the Relay**

**Non-Standard CT Connections: Reversed CT Polarity.** *Figure J.13* shows the X-side CT polarity marks toward the transformer. However, because the connections to the relay remain the same, the relay currents flow the same, as in *Figure J.12*. No additional adjustments need to be made because of this type of non-standard CT connection.

**Figure J.13 Current Flow With Reversed X-Side CT Polarity**

**Non-Standard CT Connections: Reversed CT Polarity and Reversed Connections.** In *Figure J.14*, the polarity marks of the X-side CTs are toward the transformer, as in *Figure J.13*, but the neutral sides of the CTs are away from the transformer. With these connections, the H-side and X-side currents are both entering the relay at the relay polarity mark.

**Figure J.14 Current Flow With Reversed X-Side CT Polarity and Reversed Connections**

As shown in *Figure J.15*, the resulting IAW2 current measured by the relay is now shifted 180 degrees, as compared to *Figure J.12*.

**Figure J.15 Results of Reversed X-Side CT Polarity and Reversed Connections**

One method to correct this is to reverse the current connections at the relay. Connect the nonpolarity terminal of the CT to the polarity terminal of the relay current input and the polarity terminal of the CT to the nonpolarity terminal of the relay current input. These changes result in the connections shown in *Figure J.13*.

An alternate method to correct the phase shift is to use the CT compensation setting, W*n*CTC. As shown in *Table J.1*, each CTC setting results in a counter-clockwise phase shift that is a multiple of 30 degrees for an ABC system phase rotation. Selecting a compensation setting of 6 effectively shifts the current by 180 degrees (6 • 30° = 180°). Further explanation for selecting the final settings for non-standard CT connections is provided in *Example J.3*.

## Step 2. Select the Reference Winding and Associated Relay Terminal

If there is a delta winding on the power transformer, the delta winding should be selected as the reference winding regardless of whether it is the high- or low-voltage winding. The reference winding can be associated with any analog current measurement terminal on the relay. For example, if the delta winding current is measured by the W1-terminal inputs on the relay, W1CTC is the setting that corresponds to the reference winding.

The compensation for the delta winding should be set to matrix CTC(0) (W*n*CTC = 0) unless there is a grounding bank on the delta winding within the differential zone. Grounding banks are a source of zero-sequence current and this current needs to be filtered to avoid operation of the differential element for external ground faults. If there is a grounding bank within the differential zone, use W*n*CTC = 12. Both W*n*CTC = 0 and W*n*CTC = 12 result in no phase shift, but W*n*CTC = 12 additionally removes zero-sequence current from the differential calculation.

If there is no delta winding, select one of the wye windings as the reference and set the compensation setting to 11 (W*n*CTC = 11) for the reference winding.

## Step 3. Determine the Required Compensation Settings for All Other Windings

Use the following guidelines for choosing the remaining CT compensation settings.

1. Compensate delta windings with matrix CTC(0)
2. Compensate wye windings with odd matrices
3. Avoid the use of even matrices

There may be applications that require one or more of the guidelines to be violated, but they should be followed when possible. The following examples illustrate the steps required to determine the compensation setting(s) for the remaining winding(s).

### Application Examples

**EXAMPLE J.1 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation**

Consider the system shown in Figure J.16. The primary current phase shift for these connections was determined in Figure J.6. Figure J.17 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay. The system primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 leading IAW1 by 150 degrees.

**Figure J.16 Delta-Wye Transformer With Standard Phase-to-Bushing Connections**

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-387E Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2 of the SEL-387E Relay, so W2CTC must be determined.

**Figure J.17 Primary Currents and Secondary Currents as Measured by the Relay**

IAW2 must be rotated 30 degrees (1 multiple of 30 degrees) in the counterclockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 1. The resulting compensation settings for this system are W1CTC = 0 and W2CTC = 1.

### EXAMPLE J.2 Delta-Wye Transformer With Non-Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

This example uses the transformer and relay connections of Figure J.18. This is the same transformer as in Example J.1, but with non-standard phase-to-bushing connections. Figure J.19 shows that for this connection, the system current Ia (X-side) leads the system current IA (H-side) by 30 degrees, or lags by 330 degrees. The CT connections are standard, which results in IAW2 lagging IAW1 by

150 degrees. Figure J.19 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

**Figure J.18 Delta-Wye Transformer With Non-Standard Phase-to-Bushing Connections**

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-387E Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2, so W2CTC must be determined.

**Figure J.19 Primary Currents and Secondary Currents as Measured by the Relay**

IAW2 must be rotated 330 degrees (11 multiples of 30 degrees) in the counterclockwise direction for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 11. The resulting compensation settings are W1CTC = 0 and W2CTC = 11. Although the same transformer is used in Example J.1 and Example J.2, notice that the non-standard phase-to-bushing connections affect the compensation settings in both examples.

**EXAMPLE J.3 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, X-Side Non-Standard CT Connections, and an ABC System Phase Rotation**

This example uses standard phase-to-bushing connections as shown in Figure J.20. Notice the X-side CT connections are non-standard. This example differs from the previous examples because the wye winding is now on the high side. The method to solve for the compensation settings is the same.

**Figure J.20 Wye-Delta Transformer With Non-Standard CT Connections on the X-Side**

Assume balanced three-phase currents on the wye side of the transformer. In this example, the wye side is associated with the H-side of the transformer. The phase currents on the X-side are:

Ia = IA – IC

Ib = IB – IA

Ic = IC – IB

In Figure J.21, IA on the wye side of the transformer is chosen as the reference to derive the phasor diagram of the delta-side currents. The system primary current Ia (X-side) lags IA (H-side) by 30 degrees or leads IA by 330 degrees.

**Figure J.21 X- and H-Side Current Phasors for Figure J.20**

With the reversed CT polarity on the X-side, the current is leaving Terminal W2 at the polarity mark instead of entering the polarity mark, which makes the current seen by the relay 180 degrees out-of-phase compared to a standard CT connection. In Non-Standard CT Connections: Reversed CT Polarity and Reversed Connections, two methods are proposed to correct the phase shift for reverse polarity CTs. The first method is to rewire the current inputs on the relay so

that they match the standard connections. The second method is to use the compensation settings; by adding or subtracting 6 from the setting. This example explores the latter method.

Following the settings guidelines, select the delta side as the reference. The delta side of the transformer is connected to relay Terminal W2, therefore, W2CTC = 0 and is used as the reference. Figure J.22 compares the current phasors if the X-side CT connections use standard connections rather than non-standard connections. On the left side of Figure J.22, standard CT connections and an ABC phase rotation require IAW1 to be rotated by 330 degrees (11 multiples of 30 degrees) counterclockwise to be 180 degrees out-of-phase with IAW2. Therefore, if the X-side CTs have standard connections, set W1CTC = 11. The resulting compensation settings with standard CT connections are W2CTC = 0 and W1CTC = 11.

**Figure J.22 Comparison of Standard and Non-Standard CT Connections on the X-Side of the Transformer**

However, in this example, non-standard CT connections are used on the delta winding, which results in IAW1 leading IAW2 by 30 degrees. IAW1 needs to rotate 150 degrees (5 multiples of 30 degrees) counterclockwise for a system with an ABC phase rotation to be 180 degrees out-of-phase with IAW2. Therefore, set W1CTC = 5. The resulting compensation settings with non-standard CT connections on the X-side are W2CTC = 0 and W1CTC = 5.

### EXAMPLE J.4 Autotransformer, Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

Consider the autotransformer shown in Figure J.23. The delta tertiary exists, but is buried and not brought out to the relay. The primary current phase shift for these connections is shown in Figure J.24. The system primary current Ia (X-side) is in phase with the system primary current IA (H-side). The CT connections are standard, which results in IAW2 180 degrees out-of-phase with IAW1.

Per the guidelines, since there is no delta winding connected to the relay, choose any one of the wye windings, say H-side, as the reference winding and choose matrix CTC(11) for the compensation. The H-side currents are connected to Terminal W1 of the SEL-387E Relay. Therefore, set W1CTC = 11. The X-side currents are connected to Terminal W2, so W2CTC must be determined. Figure J.24 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay. Since Matrix 11 is applied to Winding 1, this will shift IAW1 11 multiples of 30 degrees in the counterclockwise direction. To keep Winding 2 current, IAW2 180 degrees out-of-phase with IAW1, you must also shift IAW2 by 11 multiples of 30 degrees in the counterclockwise direction. The resulting compensation settings are W1CTC = 11 and W2CTC = 11.

**Figure J.23 Autotransformer With Standard Phase-to-Bushing Connections**

**Figure J.24 Primary Currents and Secondary Currents as Measured by the Relay**

## Special Cases

**EXAMPLE J.5 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ACB System Phase Rotation**

Consider the application in Figure J.25 with standard phase-to-bushing connections, standard CT connections, and an ACB system phase rotation.

**Figure J.25 Delta-Wye Transformer With Standard Phase-to-Bushing Connections With an ACB Phase Rotation**

The H-side currents are:

IA = Ia – Ib

IB = Ib – Ic

IC = Ic – Ia

Figure J.26 uses a balanced set of three-phase currents with an ACB phase sequence on the wye winding as a reference to derive the delta winding (H-side) currents. When compared to Example J.1, even with the same transformer and the same connections, Figure J.26 shows that Ia (X-side) now leads IA (H-side) by 30 degrees because of the system phase rotation. Note that in Example J.1, Ia (X-side) lags IA (H-side) by 30 degrees. The CT connections are standard, which results in IAW2 lagging IAW1 by 150 degrees. Figure J.28 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

**Figure J.26 X- and H-Side Current Phasors for Figure J.25**

A common misconception is that a different compensation setting pair is required depending on the system phase rotation. However, closer inspection of the compensation matrices and the direction of correction in Table J.1 (also shown in Figure J.27) indicate that the matrix causes the compensated currents to rotate in the opposite direction depending on the system phase rotation.

**Figure J.27 Direction of Compensation Based on System Phase Rotation**

Thus, the compensation settings required for Example J.1 and Example J.5 are the same. Following the settings guideline, the delta side of the transformer is selected as the reference, so W1CTC = 0. Figure J.28 shows IAW2 needs to be rotated 30 degrees (1 multiple of 30 degrees) clockwise for a system with an ACB phase rotation to be 180 degrees out-of-phase with IAW1. Therefore, set W2CTC = 1. The resulting compensation settings are W1CTC = 0 and W2CTC = 1.

**Figure J.28 Primary Currents and Secondary Currents as Measured by the Relay**

If the relay is set assuming an ABC phase rotation, but the actual system phase sequence is ACB, the relay compensation settings do not need to be changed. However, the calculated positive- and negative-sequence currents will be incorrect unless the Global setting for phase rotation, PHROT, matches the system phase sequence. PHROT does not affect the compensation settings or the differential protection.

### EXAMPLE J.6 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation With a Zigzag Grounding Transformer Within the Differential Zone on the Delta Side

This example uses the same transformer and CT connections as in Example J.1, except that it includes a zigzag grounding transformer within the differential zone on the delta side of the transformer. Zigzag transformers are typically used for grounding purposes and act as a source of zero-sequence current. If the zigzag transformer is located outside of the differential zone on the delta side, it can be ignored, and the compensation settings will remain the same as in Example J.1. The same is true if the zigzag transformer is present on the wye side, be it inside or outside the differential zone. If the zigzag grounding transformer is within the differential zone on the delta side, then it has to be accounted for when determining the compensation settings.

The compensation settings in Example J.1 are W1CTC = 0 for the delta winding (reference winding) and W2CTC = 1 for the wye winding. When a ground current source is within the differential zone on the delta side, the recommended compensation setting of W1CTC = 0 cannot be used. The zero-sequence current needs to be filtered to avoid an operation of the differential element for external ground faults. Therefore, set W1CTC = 12. Matrix CTC(12) has no phase shift, but CTC(12) removes zero-sequence current from the differential calculation.

## Quick Settings Guide for Standard Connections

*Figure J.29* shows examples of common transformer connections. *Table J.4* is a quick reference guide to be used when all standard phase-to-bushing, CT, and relay connections are present. *Table J.4* is applicable to both ABC and ACB system phase rotations.

**Figure J.29 Common Transformer Connections**

**Table J.4 Quick Settings Guide for Common Transformer Configurations and Standard Connections** (Sheet 1 of 2)

| XFMR Connection | W1CTC (Winding 1) | W2CTC (Winding 2) |
|---|---|---|
| DABY/Dy1 | 0 | 1 |
| DACY/Dy11 | 0 | 11 |

**Table J.4 Quick Settings Guide for Common Transformer Configurations and Standard Connections** (Sheet 2 of 2)

| XFMR Connection | W1CTC (Winding 1) | W2CTC (Winding 2) |
|---|---|---|
| YDAC/Yd1 | 11 | 0 |
| YDAB/Yd11 | 1 | 0 |
| DABDAB/Dd0<br>DACDAC/Dd0 | 0 | 0 |
| YY/Yy0 | 11 | 11 |

The compensation settings of *Table J.4* assume that the Winding 1 side of the transformer is connected to relay Terminal W1 and the Winding 2 side of the transformer is connected to relay Terminal W2. These settings apply for all standard phase-to-bushing connections shown in *Table J.2*. In each of these phase-to-bushing connections, the order of the phase connections (A, B, C) matches the order of the bushings (H1, H2, H3).

## References

Further discussion on selecting transformer compensations settings can be found in the technical paper, *Beyond the Nameplate – Selecting Transformer Compensation Settings for Secure Differential Protection* by Barker Edwards, David G. Williams, Ariana Hargrave, Matthew Watkins, and Vinod K. Yedidi.

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# Appendix K

# PC Software

## Overview

**NOTE:** PC software is updated more frequently than relay firmware. As a result, the descriptions in this section may differ slightly from the software. Select **Help** in the PC software for information.

SEL provides many PC software solutions (applications) that support SEL devices. These software solutions are listed in *Table K.1*.

Visit selinc.com to obtain the latest versions of the software listed in *Table K.1*.

**Table K.1 SEL Software Solutions**

| Product Name | Description |
|---|---|
| SEL Compass® | This application provides an interface for web-based notification of product updates and automatic software updating. |
| ACSELERATOR QuickSet® SEL-5030 Software | QuickSet is a powerful setting, event analysis, and measurement tool that aids in applying and using the relay.<br>See the *ACSELERATOR QuickSet SEL-5030 Software Instruction Manual* for information about the various QuickSet applications.[a] |
| ACSELERATOR Architect® SEL-5032 Software | Use this application to design and commission SEL IEDs in IEC 61850 substations, create and map GOOSE messages, use predefined reports, create and edit data sets, and read in SCD, ICD, and CID files. |
| ACSELERATOR TEAM® SEL-5045 Software | The TEAM system provides custom data collection and movement of a wide variety of device information. The system provides tools for device communication, automatic collection of data, and creation of reports, warnings, and alarms. See *ACSELERATOR Team SEL-5045 Software Instruction Manual* for information about the various TEAM applications. |
| SEL-5601-2 SYNCHROWAVE® Event Software | Converts SEL Compressed ASCII and COMTRADE event report files to oscillography. |
| Cable Selector SEL-5801 Software | Selects the proper SEL cables for your application. |

[a] The SEL-387E does not support the freeform logic described in the QuickSet instruction manual.

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# SEL-387E Command Summary

| Command | Description |
|---|---|
| Access Level 0 Commands | |
| **ACC** | Enter **ACC** at a serial port or over Telnet on an optional Ethernet port to move to Access Level 1 on that port. If you are using a serial port and the password jumper (`JMP24A`) is not in place, the relay will require the entry of the Access Level 1 password prior to moving to the new access level. Ethernet ports do not support the password jumper. |
| **EXI** | Terminate a Telnet session (applies to the optional Ethernet port). |
| **ID** | Enter **ID** at a serial port to obtain relay identification and configuration information. Enter **ID** over Telnet on an optional Ethernet port to obtain Ethernet card identification and configuration information. |
| **QUI** | Enter **QUIT** at a serial port with PROTO = SEL or over Telnet on an optional Ethernet port to return the relay to Access Level 0 on that port.<br>Enter **QUIT** at a serial port with PROTO = LMD to terminate the SEL Distributed Port Switch Protocol (LMD) connection and return the relay to Access Level 0 on that port.<br>Returns front-panel LEDs to the default targets. |
| Access Level 1 Commands | |
| **2AC** | Enter **2AC** at a serial port or over Telnet on an optional Ethernet port to move to Access Level 2. If you are using a serial port and the password jumper (`JMP24A`) is not in place, the relay will require the entry of the Access Level 2 password prior to moving to the new access level. Ethernet ports do not support the password jumper. |
| **BAC** | Enter Access Level B. If the main board password jumper (`JMP24A`) is not in place, the relay prompts for the entry of the Access Level B password in order to enter Access Level B. |
| **CEV *n*** | Show compressed winding event report number *n*, at 1/4-cycle resolution.<br>Attach DIF for compressed differential element report, at 1/4-cycle resolution.<br>Attach R for compressed raw winding data report, at 1/16-cycle resolution.<br>Attach S*m* for 1/m-cycle resolution. (*m* = 4 or 8 for filtered data; *m* = 4, 8, 16, 32, or 64 for raw data) |
| **DAT** | Show date |
| **DAT m/d/y** | Enter date in this manner if Date Format setting DATE_F = MDY. |
| **DAT y/m/d** | Enter date in this manner if Date Format setting DATE_F = YMD. |
| **EVE *n*** | Show standard event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE D *n*** | Show digital data event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE DIF1 *n*** | Show differential element 1 event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE DIF2 *n*** | Show differential element 2 event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE DIF3 *n*** | Show differential element 3 event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE R *n*** | Show raw analog data event report number *n*, with 1/16-cycle resolution.<br>Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64) |
| **GOO** | Display transmit and receive GOOSE messaging information. Enter number *k* to scroll the GOOSE data *k* times on the screen. |
| **GRO** | Display active setting group number. |
| **HIS *n*** | Show brief summary of the *n* latest event reports. |
| **HIS C** | Clear the brief summary and corresponding standard event reports. |

| Command | Description |
|---|---|
| **INI** | Reports the number and type of interface boards in the relay. |
| **IRI** | Force synchronization attempt of internal relay clock to IRIG-B time-code input. |
| **MET *k*** | Display metering data, in primary values. Enter number *k* to scroll metering *k* times on screen. |
| **MET D *k*** | Display demand metering data, in primary values. Enter number *k* to scroll metering *k* times on screen. |
| **MET DIF *k*** | Display peak demand times, in multiples of tap. Enter number *k* to scroll metering *k* times on screen. |
| **MET E** | Display energy metering data. |
| **MET H** | Generate harmonic spectrum report for all input currents, showing first to 15th harmonic levels in secondary amperes. |
| **MET P *k*** | Display peak demand metering data, in primary values. Enter number *k* to scroll metering *k* times on screen. |
| **MET RD *n*** | Reset demand metering values. (*n* = 1, 2, 3, A) |
| **MET RE** | Resets the Energy data. |
| **MET RP *n*** | Reset peak demand metering values. (*n* = 1, 2, 3, A) |
| **MET SEC *k*** | Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen. |
| **SER *n*** | Show the latest *n* rows in the Sequential Events Recorder (SER) event report. |
| **SER *m n*** | Show rows *m* through *n* in the Sequential Events Recorder (SER) event report. |
| **SER d1** | Show rows in the Sequential Events Recorder (SER) event report for date d1. |
| **SER d1 d2** | Show rows in the Sequential Events Recorder (SER) event report from date d1 to d2. Entry of dates is dependent on the Date Format setting DATE_F (= MDY or YMD). |
| **SER C** | Clear sequence of event records from memory. |
| **SHO *n*** | Show relay group *n* settings. Shows active group if *n* is not specified. |
| **SHO G** | Show relay Global settings. |
| **SHO P** | Show port settings and identification of port to which user is connected. |
| **SHO P *n*** | Show port settings for Port *n* (*n* = 1, 2, 3, 4). |
| **SHO R** | Show Sequential Events Recorder (SER) settings. |
| **STA** | Enter **STA** at a serial port to obtain a status report for the relay. Enter **STA** over Telnet on an optional Ethernet port to obtain a status report for the Ethernet port. |
| **TAR *n k*** | Show Relay Word row *n* status (*n* = 0 through 41). Enter number *k* to scroll Relay Word row *n* status *k* times on screen.<br>Append F to display targets on the front panel, second row of LEDs. |
| **TAR R** | Return front-panel LED targets to regular operation and reset the tripping front-panel targets. |
| **TFE** | Displays cumulative and individual through-fault event data. The 20 most recent individual events are displayed. |
| **TFE *n*** | Displays cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 1200. |
| **TFE A** | Displays cumulative and individual through-fault event data. All the most recent individual events are displayed (as many as 1200). |
| **TFE C** | Clears/resets cumulative and individual through-fault event data. |
| **TFE P** | Preloads cumulative through-fault event data. |
| **TFE R** | Clears/resets cumulative and individual through-fault event data. |
| **TIM** | Show or set time (24-hour time). Show time presently in the relay by entering just **TIM**. Example time 22:47:36 is entered with command **TIM 22:47:36**. |
| **TRI** | Trigger an event report. |
| **VER** | Relay configuration information. |

| Command | Description |
|---|---|
| Access Level B Commands | |
| **BRE** | Breaker report shows trip counters, trip currents, and wear data for as many as four breakers. |
| **BRE R *n*** | Reset trip counters, trip currents, and wear data for Breaker *n* (*n* = 1, 2, 3, A). |
| **BRE W *n*** | Pre-set the percent contact wear for each pole of Breaker *n* (*n* = 1, 2, 3). |
| **CLO *n*** | Assert the CC*n* Relay Word bit. Used to close Breaker *n* if CC*n* is assigned to an output contact. `JMP6B` has to be in place to enable this command. |
| **GRO** | Display active setting group number. |
| **GRO *n*** | Switch to Setting Group *n*. (Will not function if any SS*n* Relay Word bit is asserted.) |
| **OPE *n*** | Assert the OC*n* Relay Word bit. Used to open breaker *n* if OC*n* is assigned to an output contact. `JMP6B` has to be in place to enable this command. |
| **PUL *y k*** | Pulse output contact *y* (*y* = OUT101,…,OUT107, OUT2XX, and OUT3XX). Enter number *k* to pulse for *k* seconds [*k* = 1 to 30 (seconds)], otherwise pulse time is 1 second. `JMP6B` has to be in place to enable this command. |
| **STA C** | Enter **STA C** at a serial port to restart the relay. Enter **STA C** over Telnet on an optional Ethernet port to restart the Ethernet card. |
| **TEST DB *name01* [*name02… name10*][*s*]** | Pulse as many as 10 binaries (Relay Word bits) for *s* seconds. Available in Ethernet communications capable relays only. |
| Access Level 2 Commands | |
| **CON *n*** | Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1 through 16). Execute CON *n* and the relay responds: `CONTROL RBn`. Reply with one of the following:<br>SRB *n*: Set Remote Bit *n* (assert RB*n*)<br>CRB *n*: Clear Remote Bit *n* (deassert RB*n*)<br>PRB *n*: Pulse Remote Bit *n* [assert RBn for one processing interval (1/8 cycle)] |
| **COP *m n*** | Copy settings and logic from setting Group *m* to Group *n*. |
| **PAS 1 *xxxxxx*** | Chance Access Level 1 password to *xxxxxx*. |
| **PAS B *xxxxxx*** | Chance Access Level B password to *xxxxxx*. |
| **PAS 2 *xxxxxx*** | Chance Access Level 2 password to *xxxxxx*. |
| **RES** | The **RESET51** command resets all inverse-time O/C elements for the four windings, including the combined overcurrent elements. |
| **SET *n*** | Change relay group settings (overcurrent, differential, etc.).<br>For the **SET** commands, parameter *n* is the setting name at which to begin editing settings. If parameter *n* is not entered, setting editing starts at the first setting. |
| **SET G** | Change Global settings. |
| **SET P *n*** | Change port settings. |
| **SET R** | Change Sequential Events Recorder (SER) settings. |

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# SEL-387E Command Summary

| Command | Description |
|---|---|
| Access Level 0 Commands | |
| **ACC** | Enter **ACC** at a serial port or over Telnet on an optional Ethernet port to move to Access Level 1 on that port. If you are using a serial port and the password jumper (`JMP24A`) is not in place, the relay will require the entry of the Access Level 1 password prior to moving to the new access level. Ethernet ports do not support the password jumper. |
| **EXI** | Terminate a Telnet session (applies to the optional Ethernet port). |
| **ID** | Enter **ID** at a serial port to obtain relay identification and configuration information. Enter **ID** over Telnet on an optional Ethernet port to obtain Ethernet card identification and configuration information. |
| **QUI** | Enter **QUIT** at a serial port with PROTO = SEL or over Telnet on an optional Ethernet port to return the relay to Access Level 0 on that port.<br>Enter **QUIT** at a serial port with PROTO = LMD to terminate the SEL Distributed Port Switch Protocol (LMD) connection and return the relay to Access Level 0 on that port.<br>Returns front-panel LEDs to the default targets. |
| Access Level 1 Commands | |
| **2AC** | Enter **2AC** at a serial port or over Telnet on an optional Ethernet port to move to Access Level 2. If you are using a serial port and the password jumper (`JMP24A`) is not in place, the relay will require the entry of the Access Level 2 password prior to moving to the new access level. Ethernet ports do not support the password jumper. |
| **BAC** | Enter Access Level B. If the main board password jumper (`JMP24A`) is not in place, the relay prompts for the entry of the Access Level B password in order to enter Access Level B. |
| **CEV *n*** | Show compressed winding event report number *n*, at 1/4-cycle resolution.<br>Attach DIF for compressed differential element report, at 1/4-cycle resolution.<br>Attach R for compressed raw winding data report, at 1/16-cycle resolution.<br>Attach S*m* for 1/m-cycle resolution. (*m* = 4 or 8 for filtered data; *m* = 4, 8, 16, 32, or 64 for raw data) |
| **DAT** | Show date |
| **DAT m/d/y** | Enter date in this manner if Date Format setting DATE_F = MDY. |
| **DAT y/m/d** | Enter date in this manner if Date Format setting DATE_F = YMD. |
| **EVE *n*** | Show standard event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE D *n*** | Show digital data event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE DIF1 *n*** | Show differential element 1 event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE DIF2 *n*** | Show differential element 2 event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE DIF3 *n*** | Show differential element 3 event report number *n*, with 1/4-cycle resolution.<br>Attach S8 for 1/8-cycle resolution. |
| **EVE R *n*** | Show raw analog data event report number *n*, with 1/16-cycle resolution.<br>Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64) |
| **GOO** | Display transmit and receive GOOSE messaging information. Enter number *k* to scroll the GOOSE data *k* times on the screen. |
| **GRO** | Display active setting group number. |
| **HIS *n*** | Show brief summary of the *n* latest event reports. |
| **HIS C** | Clear the brief summary and corresponding standard event reports. |

| Command | Description |
|---|---|
| **INI** | Reports the number and type of interface boards in the relay. |
| **IRI** | Force synchronization attempt of internal relay clock to IRIG-B time-code input. |
| **MET *k*** | Display metering data, in primary values. Enter number *k* to scroll metering *k* times on screen. |
| **MET D *k*** | Display demand metering data, in primary values. Enter number *k* to scroll metering *k* times on screen. |
| **MET DIF *k*** | Display peak demand times, in multiples of tap. Enter number *k* to scroll metering *k* times on screen. |
| **MET E** | Display energy metering data. |
| **MET H** | Generate harmonic spectrum report for all input currents, showing first to 15th harmonic levels in secondary amperes. |
| **MET P *k*** | Display peak demand metering data, in primary values. Enter number *k* to scroll metering *k* times on screen. |
| **MET RD *n*** | Reset demand metering values. (*n* = 1, 2, 3, A) |
| **MET RE** | Resets the Energy data. |
| **MET RP *n*** | Reset peak demand metering values. (*n* = 1, 2, 3, A) |
| **MET SEC *k*** | Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen. |
| **SER *n*** | Show the latest *n* rows in the Sequential Events Recorder (SER) event report. |
| **SER *m n*** | Show rows *m* through *n* in the Sequential Events Recorder (SER) event report. |
| **SER d1** | Show rows in the Sequential Events Recorder (SER) event report for date d1. |
| **SER d1 d2** | Show rows in the Sequential Events Recorder (SER) event report from date d1 to d2. Entry of dates is dependent on the Date Format setting DATE_F (= MDY or YMD). |
| **SER C** | Clear sequence of event records from memory. |
| **SHO *n*** | Show relay group *n* settings. Shows active group if *n* is not specified. |
| **SHO G** | Show relay Global settings. |
| **SHO P** | Show port settings and identification of port to which user is connected. |
| **SHO P *n*** | Show port settings for Port *n* (*n* = 1, 2, 3, 4). |
| **SHO R** | Show Sequential Events Recorder (SER) settings. |
| **STA** | Enter **STA** at a serial port to obtain a status report for the relay. Enter **STA** over Telnet on an optional Ethernet port to obtain a status report for the Ethernet port. |
| **TAR *n k*** | Show Relay Word row *n* status (*n* = 0 through 41). Enter number *k* to scroll Relay Word row *n* status *k* times on screen.<br>Append F to display targets on the front panel, second row of LEDs. |
| **TAR R** | Return front-panel LED targets to regular operation and reset the tripping front-panel targets. |
| **TFE** | Displays cumulative and individual through-fault event data. The 20 most recent individual events are displayed. |
| **TFE *n*** | Displays cumulative and individual through-fault event data. The *n* most recent individual events are displayed, where *n* = 1 to 1200. |
| **TFE A** | Displays cumulative and individual through-fault event data. All the most recent individual events are displayed (as many as 1200). |
| **TFE C** | Clears/resets cumulative and individual through-fault event data. |
| **TFE P** | Preloads cumulative through-fault event data. |
| **TFE R** | Clears/resets cumulative and individual through-fault event data. |
| **TIM** | Show or set time (24-hour time). Show time presently in the relay by entering just **TIM**. Example time 22:47:36 is entered with command **TIM 22:47:36**. |
| **TRI** | Trigger an event report. |
| **VER** | Relay configuration information. |

| Command | Description |
|---|---|
| Access Level B Commands | |
| **BRE** | Breaker report shows trip counters, trip currents, and wear data for as many as four breakers. |
| **BRE R *n*** | Reset trip counters, trip currents, and wear data for Breaker *n* (*n* = 1, 2, 3, A). |
| **BRE W *n*** | Pre-set the percent contact wear for each pole of Breaker *n* (*n* = 1, 2, 3). |
| **CLO *n*** | Assert the CC*n* Relay Word bit. Used to close Breaker *n* if CC*n* is assigned to an output contact. `JMP6B` has to be in place to enable this command. |
| **GRO** | Display active setting group number. |
| **GRO *n*** | Switch to Setting Group *n*. (Will not function if any SS*n* Relay Word bit is asserted.) |
| **OPE *n*** | Assert the OC*n* Relay Word bit. Used to open breaker *n* if OC*n* is assigned to an output contact. `JMP6B` has to be in place to enable this command. |
| **PUL *y k*** | Pulse output contact *y* (*y* = OUT101,…,OUT107, OUT2XX, and OUT3XX). Enter number *k* to pulse for *k* seconds [*k* = 1 to 30 (seconds)], otherwise pulse time is 1 second. `JMP6B` has to be in place to enable this command. |
| **STA C** | Enter **STA C** at a serial port to restart the relay. Enter **STA C** over Telnet on an optional Ethernet port to restart the Ethernet card. |
| **TEST DB *name01* [*name02… name10*][*s*]** | Pulse as many as 10 binaries (Relay Word bits) for *s* seconds. Available in Ethernet communications capable relays only. |
| Access Level 2 Commands | |
| **CON *n*** | Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1 through 16). Execute CON *n* and the relay responds: `CONTROL RBn`. Reply with one of the following:<br>SRB *n*: Set Remote Bit *n* (assert RB*n*)<br>CRB *n*: Clear Remote Bit *n* (deassert RB*n*)<br>PRB *n*: Pulse Remote Bit *n* [assert RBn for one processing interval (1/8 cycle)] |
| **COP *m n*** | Copy settings and logic from setting Group *m* to Group *n*. |
| **PAS 1 *xxxxxx*** | Chance Access Level 1 password to *xxxxxx*. |
| **PAS B *xxxxxx*** | Chance Access Level B password to *xxxxxx*. |
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| **RES** | The **RESET51** command resets all inverse-time O/C elements for the four windings, including the combined overcurrent elements. |
| **SET *n*** | Change relay group settings (overcurrent, differential, etc.).<br>For the **SET** commands, parameter *n* is the setting name at which to begin editing settings. If parameter *n* is not entered, setting editing starts at the first setting. |
| **SET G** | Change Global settings. |
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