SEL-387A Relay

Current Differential

Instruction Manual

20250127

SCHWEITZER ENGINEERING LABORATORIES

 PM387A-01

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Preface

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 Refer to accompanying documents.	**⚠ATTENTION** 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

⚠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.	**⚠ATTENTION** 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.
For use in Pollution Degree 2 environment.	Pour l'utilisation dans un environnement de Degré de Pollution 2.

Other Safety Marks

⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	⚠DANGER Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Removal of relay front panel exposes circuitry which may cause electrical shock that may result in injury or death.	⚠DANGER Le retrait du panneau avant expose à la circuiterie qui pourrait être la source de chocs électriques pouvant entraîner des blessures ou la mort.
⚠WARNING Before working on a CT circuit, first apply a short to the secondary winding of the CT.	⚠AVERTISSEMENT Avant de travailler sur un circuit TC, placez d'abord un court-circuit sur l'enroulement secondaire du TC.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	⚠AVERTISSEMENT Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.
⚠WARNING This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.	⚠AVERTISSEMENT Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accès non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accès non-autorisé.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	⚠AVERTISSEMENT L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	⚠AVERTISSEMENT Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠CAUTION The continuous rating of the current inputs is $3 \cdot I_{NOM}$. 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 La capacité, en régime permanent, des entrées de courant est $3 \cdot I_{NOM}$. Si un courant d'essai dépassait cette valeur, réduire la prise TAPn pour prévenir les dommages aux circuits d'entrée.
⚠CAUTION The continuous rating of the current inputs is $3 \cdot I_{NOM}$. For this test, you may want to choose low values of U87P and TAP*n*, in order to limit the required test current to a safe value.	⚠ATTENTION La limite, en régime permanent, des entrées de courant est $3 \cdot I_{NOM}$. 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.
⚠CAUTION The relay contains devices sensitive to electrostatic discharge (ESD). When working on the relay with front or top cover removed, work surfaces and personnel must be properly grounded or equipment damage may result.	⚠ATTENTION Le relais contient des pièces sensibles aux décharges électrostatiques (DES). Quand on travaille sur le relais avec le panneau avant ou du dessus enlevé, les surfaces de travail et le personnel doivent être mis à la terre convenablement pour éviter les dommages à l'équipement.

Trademarks

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SEL trademarks appearing in this manual are shown in the following table.

ACSELERATOR Architect®	Compass®
ACSELERATOR QuickSet®	SELOGIC®
ACSELERATOR TEAM®	SYNCHROWAVE®

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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Section 1
Introduction and Specifications

Introduction

Use this relay to protect two-winding power transformers, reactors, generators, large motors, or other multiterminal power apparatus. The relay settings permit you to use wye- or delta-connected current transformers with virtually any type of transformer winding connection.

The SEL-387A 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.

Winding 3 and Winding 4 Reporting

The SEL-387A satisfies the requirement for a two-winding differential relay equipped with extensive I/O. To this end, the SEL-387A is a subset of the larger SEL-387 Relay, including most functions of the SEL-387, but suitable for two-winding applications only. Because the SEL-387A retains the reporting structure of the SEL-387, the report formats still include rows and/or columns for Windings 3 and 4. Because current values for Winding 3 no longer apply, they are displayed as zeros and should be ignored. When you order an SEL-387A with the optional restricted earth fault (REF) elements, current channels assigned to Winding 4 in the SEL-387 are reassigned to represent neutral currents IN1, IN2, and IN3 (i.e., IAW4 = IN1, IBW4 = IN2, and ICW4 = IN3). In an SEL-387A without the REF option, the current values for Winding 4 are displayed as zeros.

Instruction Manual Overview

This instruction manual applies to the SEL-387A. 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: Differential, Restricted Earth Fault, and Overcurrent Elements 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: Setting the Relay to understand settings that are not described in *Section 3* or *Section 4*, for default settings, and for settings sheets.

Section 7: Serial Port Communications and Commands 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 Interface 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: Event Reports and SER 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

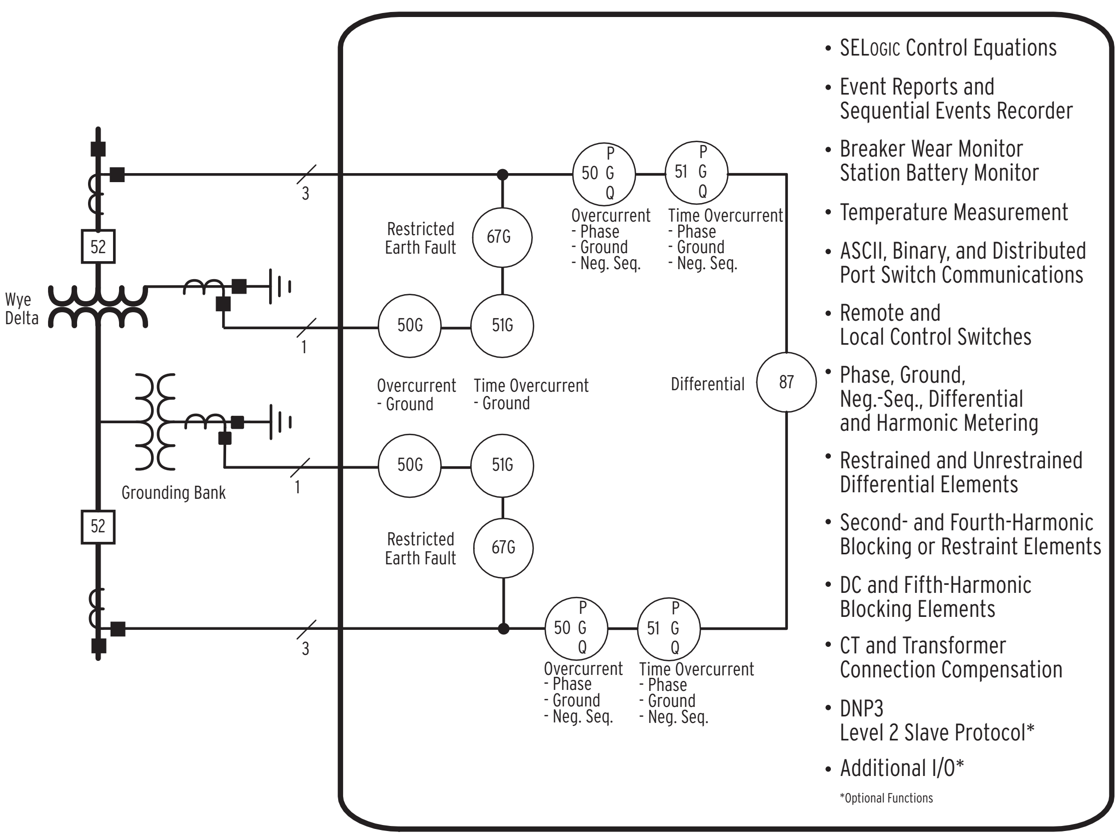

Figure 1.1 Functional Overview

Current Differential Protection

The SEL-387A includes independent restrained and unrestrained current differential elements. The restrained element has a dual-slope, variable-percentage restraint characteristic. A separate unrestrained differential element provides faster clearance of high-magnitude, internal faults. The relay also provides security against conditions that may cause relay misoperation, resulting from both system and transformer events. 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 blocking 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.

Restricted Earth Fault Protection (Option)

As an option, the SEL-387A provides two sensitive elements for the detection of internal ground faults via the restricted earth fault (REF) protection element. Inputs IN1 and IN2 are available for introducing neutral CT polarizing current, i.e., IN1 for REF1 and IN2 for REF2. Operating current is derived from the residual current calculated for the protected winding. Directional elements determine 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 grounded wye-wye transformers or grounded wye-delta transformers with a grounding bank on the delta winding.

Overcurrent Protection

The SEL-387A 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
- Neutral Overcurrent: Three-level instantaneous; definite-time; inverse-time

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

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-387A Relay 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-387A is equipped with enhanced SELOGIC control equations that allow you to design a custom tripping or control scheme. SELOGIC control equation functions include independent timers, tripping, event report triggering, and relay output contact control.

Application Ideas

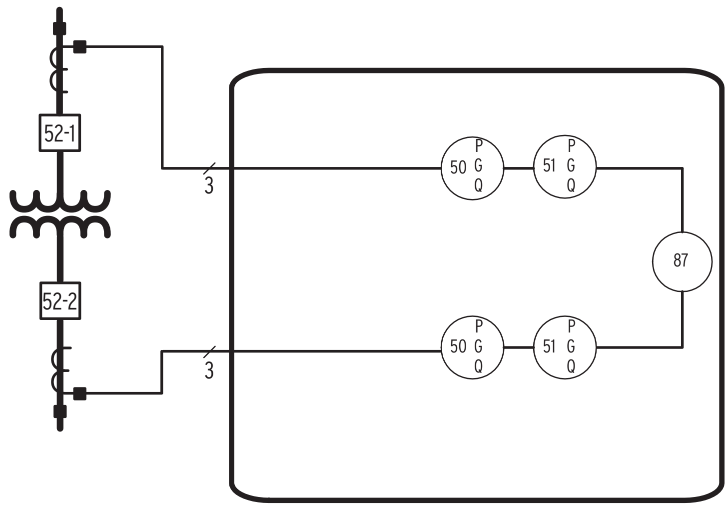

Figure 1.2 Transformer and Overcurrent Protection

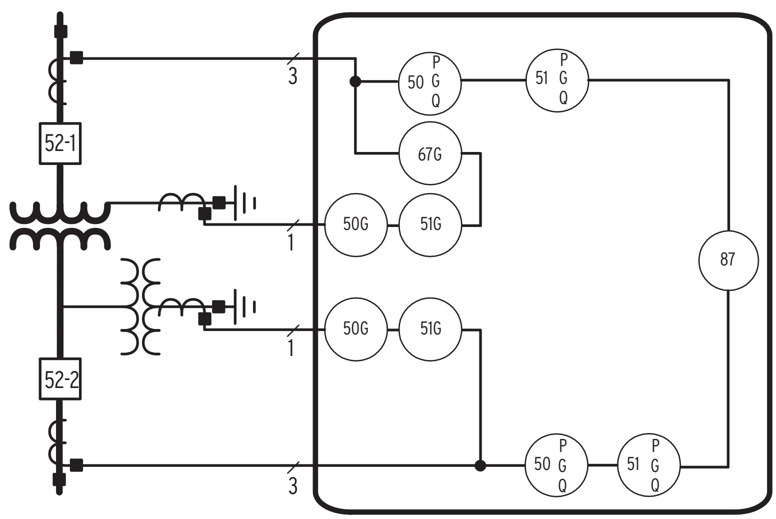

Figure 1.3 Transformer With Ground Bank

Model Options

Distributed Network Protocol (DNP) and two REF and three neutral elements are options for the SEL-387A. Other options include extended I/O, available in the form of interface boards added to the relay.

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)

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

AC Current Inputs

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

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: 24/48 Vdc

Range: 18–60 Vdc polarity dependent

Burden: <25 W

Interruption: 110 ms at 48 Vdc

Ripple: 100%

Note: Interruption and Ripple per IEC 60255-11:1979.

Output Contacts

Standard

Make: 30 A

Carry: 6 A continuous carry at 70°C
4 A continuous carry at 85°C

1 s Rating: 50 A

MOV Protection: 270 Vac/360 Vdc; 40 J

Pickup Time: <5 ms

Dropout Time: <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 Cycles/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
4 A continuous carry at 85°C

1 s Rating: 50 A

MOV Protection: 330 Vdc; 130 J

Pickup Time: <5 ms

Dropout Time: <8 ms, typical

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 (4 Cycles in 1 Second Followed by 2 Minutes Idle for Thermal Dissipation):

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 high current interrupting output contacts to switch ac control signals. These outputs are polarity dependent.
Note: Make per IEEE C37.90-1989; Breaking and Cyclic Capacity per IEC 60255-23:1994.

Optoisolated Inputs

250 Vdc: Pickup 200–300 Vdc; Dropout 150 Vdc

220 Vdc: Pickup 176–264 Vdc; Dropout 132 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

Note: 24, 48, and 125 Vdc optoisolated inputs draw approximately 4 mA of current; 110 Vdc inputs draw approximately 8 mA of current; and 220 and 250 Vdc inputs draw approximately 5 mA of current. All current ratings are at nominal input voltage.

Routine Dielectric Strength

AC current inputs: 2500 Vac for 10 s

Power supply, optoisolated inputs, and output contacts: 3100 Vdc for 10 s

Frequency and Rotation

System Frequency: 50 or 60 Hz

Phase Rotation: ABC or ACB

Communications Ports

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

Operating Temperature

–40° to +85°C (–40° to +185°F)

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.

Weight

2U rack unit height:	6.8 kg (15 lb)
3U rack unit height:	8 kg (17.75 lb)

Type Tests

Emissions

Generic Emissions, Heavy Industrial:	EN 50081-2:1993, Class A
Generic Immunity, Heavy Industrial:	EN 50082-2:1995
Radiated and Conducted Emissions:	EN 55011:1998, Class A Canada ICES-001 (A) / NMB-001 (A)
Conducted Radio Frequency:	EN 61000-4-6:1996, ENV 50141:1993, 10 Vrms
Radiated Radio Frequency (900 MHz With Modulation):	ENV 50204:1995, 10 V/m

Environmental Tests

Cold:	IEC 60068-2-1:1990 [EN 60068-2-1:1993] Test Ad; 16 hr at –40°C
Damp Heat Cyclic:	IEC 60068-2-30:1980 Test Db; 25° to 55°C, 6 cycles, 95% humidity
Dry Heat:	IEC 60068-2-2:1974 [EN 60068-2-2:1993] Test Bd: 16 hr at +85°C

Dielectric Strength and Impulse Tests

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

Electrostatic Discharge Test

ESD:	IEC 60255-22-2:1996 IEC 61000-4-2:1995 Level 4

RFI and Interference Tests

1 MHz Burst Disturbance:	IEC 60255-22-1:1988 Class 3
Fast Transient Disturbance:	IEC 60255-22-4:1992 IEC 61000-4-4:1995 Level 4
Radiated EMI:	IEC 60255-22-3:1989 ENV 50140:1993 IEEE C37.90.2-1995, 35 V/m no keying test
Surge Withstand:	IEEE C37.90.1-1989 3.0 kV oscillatory; 5.0 kV fast transient

Vibration and Shock Tests

Shock and Bump:	IEC 60255-21-2:1988 Class 1 IEC 60255-21-3:1993 Class 2
Sinusoidal Vibration:	IEC 60255-21-1:1988 Class 1

Object Penetration

Object Penetration:	IEC 60529:1989 IP 30, IP 54 from the front panel using the SEL-9103 front-cover dust and splash protection

Processing Specifications

64 samples per power system cycle

Metering Accuracy

5 A Model	
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	
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

Substation Battery Voltage Monitor

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

Relay Elements

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 (A secondary)	
5 A Model:	±5% ±0.10 A
1 A Model:	±5% ±0.02 A
Unrestrained Element Pickup Time:	0.8/1.0/1.9 cycles (Min/Typ/Max)
Restrained Element (With Harmonic Blocking) Pickup Time:	1.5/1.6/2.2 cycles (Min/Typ/Max)
Restrained Element (With Harmonic Restraint) Pickup Time:	2.62/2.72/2.86 cycles (Min/Typ/Max)

Harmonic Element

Pickup Range (% of fundamental): 5–100%

Pickup Accuracy (A secondary)

- 5 A Model: ±5% ±0.10 A
- 1 A Model: ±5% ±0.02 A

Time Delay Accuracy: ±0.1% ±0.25 cycle

Winding Instantaneous/Definite-Time Overcurrent Elements

Pickup Ranges (A secondary)

- 5 A Model: 0.25–100.00 A
- 1 A Model: 0.05–20.00 A

Pickup Accuracies (A secondary)

- 5 A Model
  - Steady State: ±3% ±0.10 A
  - Transient: ±5% ±0.10 A
- 1 A Model
  - Steady State: ±3% ±0.02 A
  - Transient: ±5% ±0.02 A

Note: For transient, ±6% for negative-sequence elements.

Pickup Time: 0.75/1.20 cycles (Typ/Max)

Time Delay Range: 0–16000 cycles

Time Delay Accuracy: ±0.1% ±0.25 cycle

Winding Time Overcurrent Elements

Pickup Ranges (A secondary)

- 5 A Model: 0.5–16.0 A
- 1 A Model: 0.1–3.2 A

Pickup Accuracies (A secondary)

- 5 A Model
  - Steady State: ±3% ±0.10 A
  - Transient: ±5% ±0.10 A
- 1 A Model
  - Steady State: ±3% ±0.02 A
  - Transient: ±5% ±0.02 A

Note: For transient, ±6% for negative-sequence elements.

Curve

- U1 = U.S. Moderately Inverse
- U2 = U.S. Inverse
- U3 = U.S. Very Inverse
- U4 = U.S. Extremely Inverse
- U5 = U.S. Short-Time Inverse
- C1 = IEC Class A (Standard Inverse)
- C2 = IEC Class B (Very Inverse)
- C3 = IEC Class C (Extremely Inverse)
- C4 = IEC Long-Time Inverse
- C5 = IEC Short-Time Inverse

Time-Dial Range

- US 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.

Reset Characteristic: Induction-disk reset emulation or 1 cycle linear reset

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Section 2
Installation

Design your installation using the mounting and connection information in this section. Options include rack or panel mounting. This section also includes information on configuring the relay for your application.

Relay Mounting

Rack Mount

We offer the SEL-387A Relay in a rack-mount version that bolts easily into a standard 19-inch rack. See *Figure 2.2*. From the front of the relay, insert four bolts (two on each side) through the holes on the relay mounting flanges to secure the relay to the rack. See *Figure 2.1*.

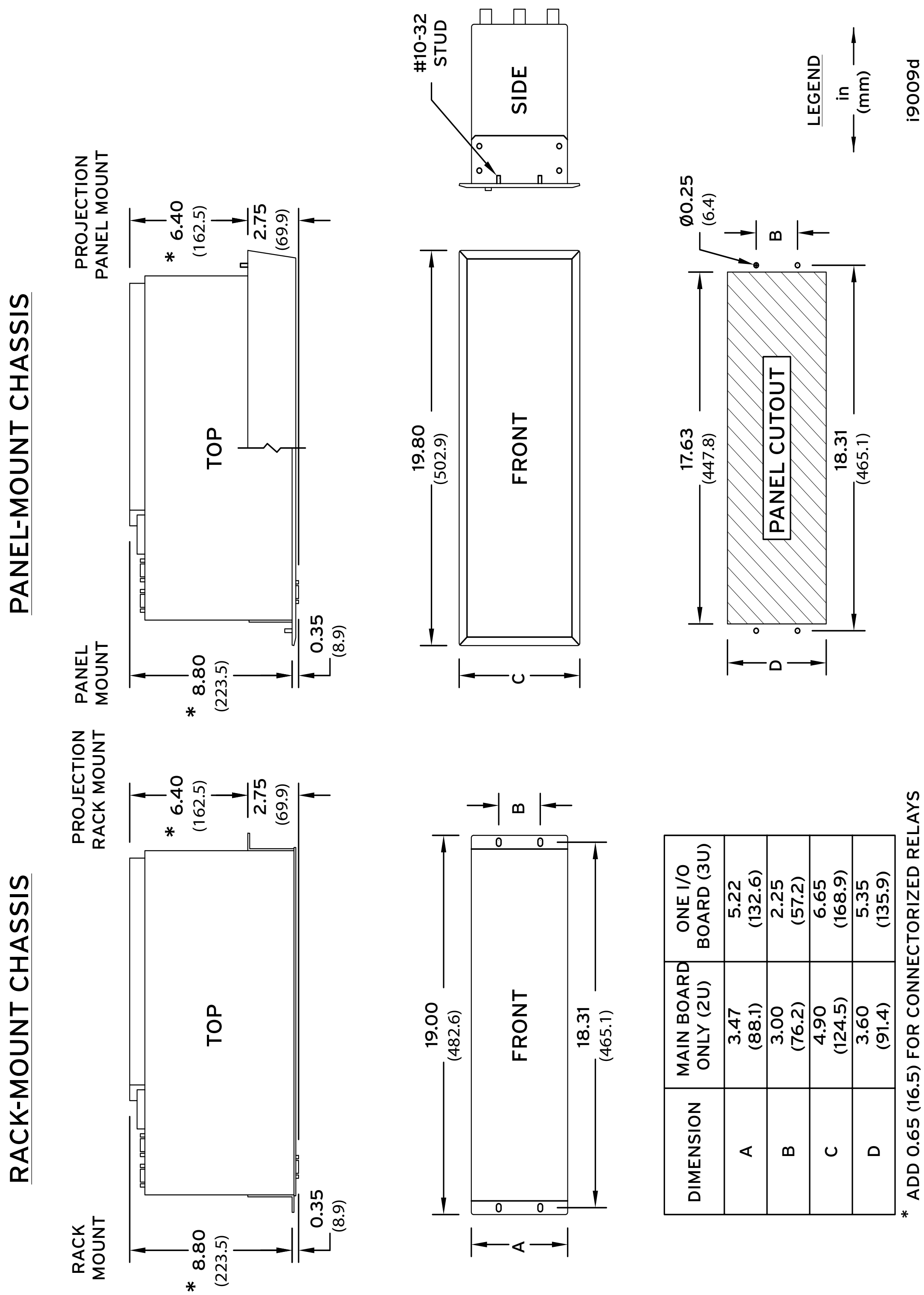
Reverse the relay mounting flanges to cause the relay to project 69.9 millimeters (2.75 inches) from the front of your mounting rack and provide additional space at the rear of the relay for applications where the relay might otherwise be too deep to fit.

Panel Mount

We also offer the SEL-387A in a panel-mount version for a clean look. Panel-mount relays have sculpted front-panel molding that covers all installation holes. See *Figure 2.3*. 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 with the drilled holes in your panel, and use nuts to secure the relay to the 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 millimeters (2.75 inches) from the front of your panel. This ordering option increases space at the rear of the relay for applications where the relay would ordinarily be too deep to fit your cabinet.

Dimensions and Cutout



DIMENSION	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)

Figure 2.1 Relay Dimensions and Panel-Mount Cutout

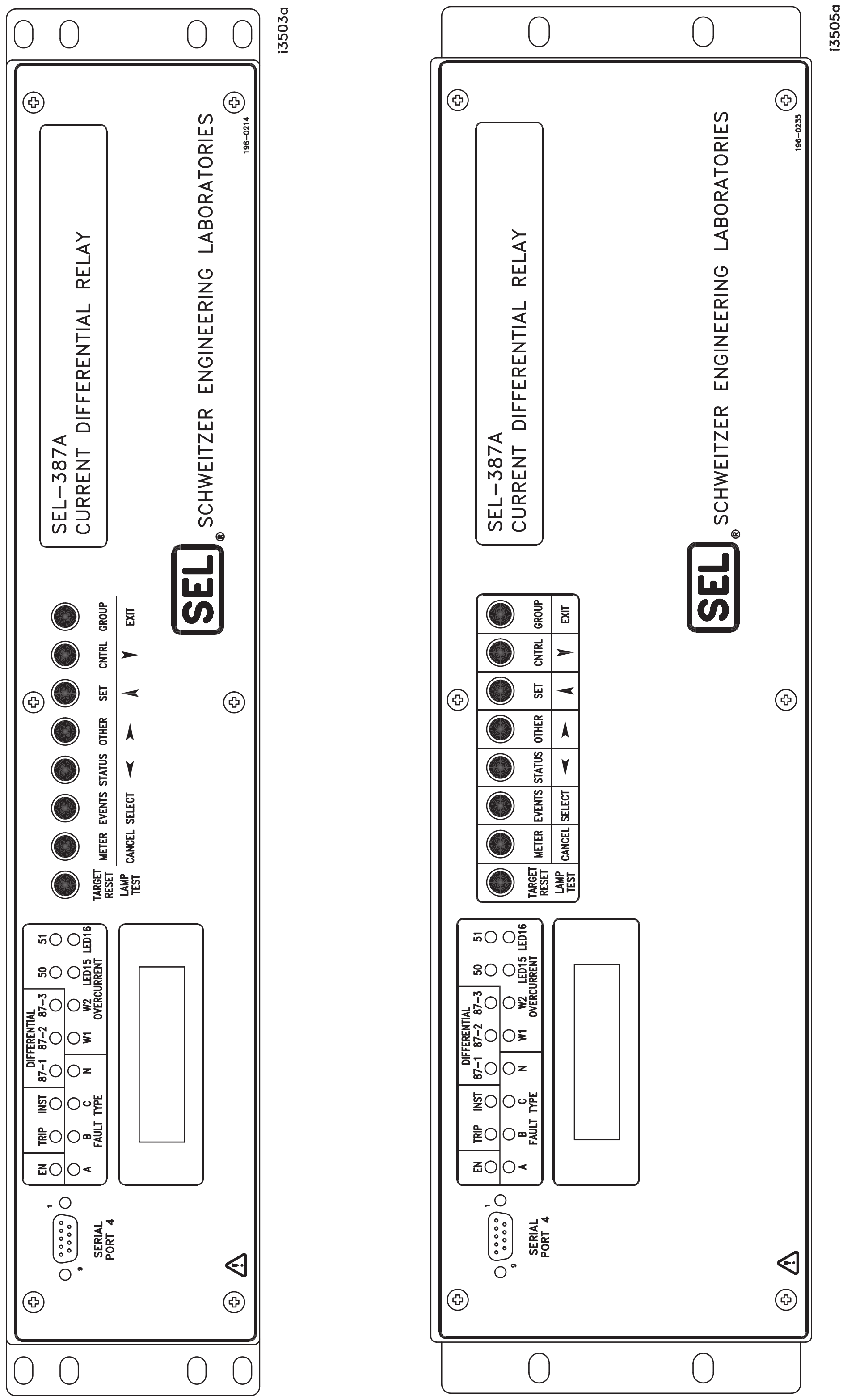


Figure 2.2 Front-Panel Drawings—Models 0387A0xxxH and 0387A1xxxH

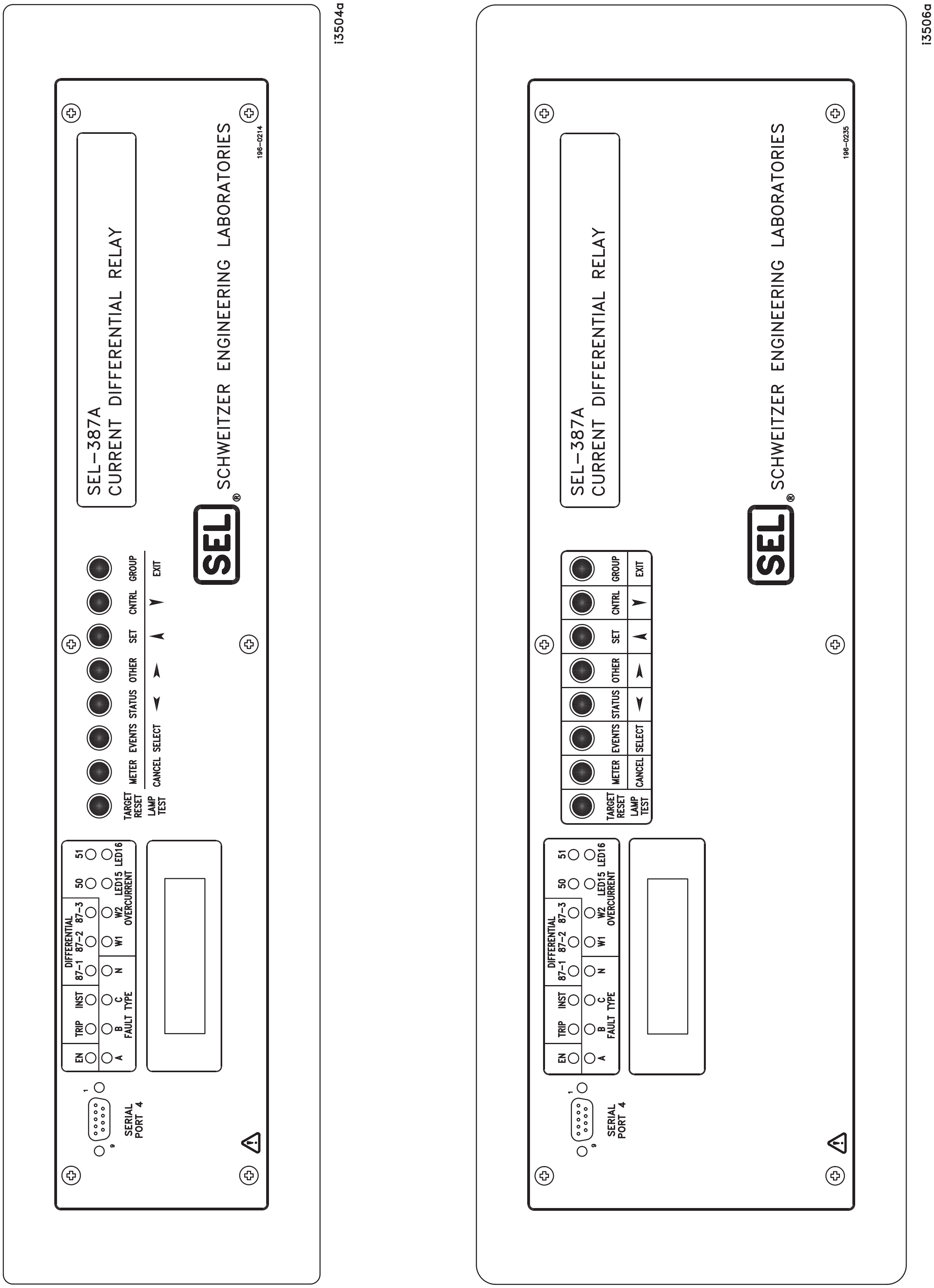


Figure 2.3 Front-Panel Drawings—Models 0387A0xxx3 and 0387A1xxx3

Rear-Panel Connections

The conventional terminal block makes a secure connection of wiring to the relay rear panel. 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 2.4* and *Figure 2.5* to make all terminal block connections.

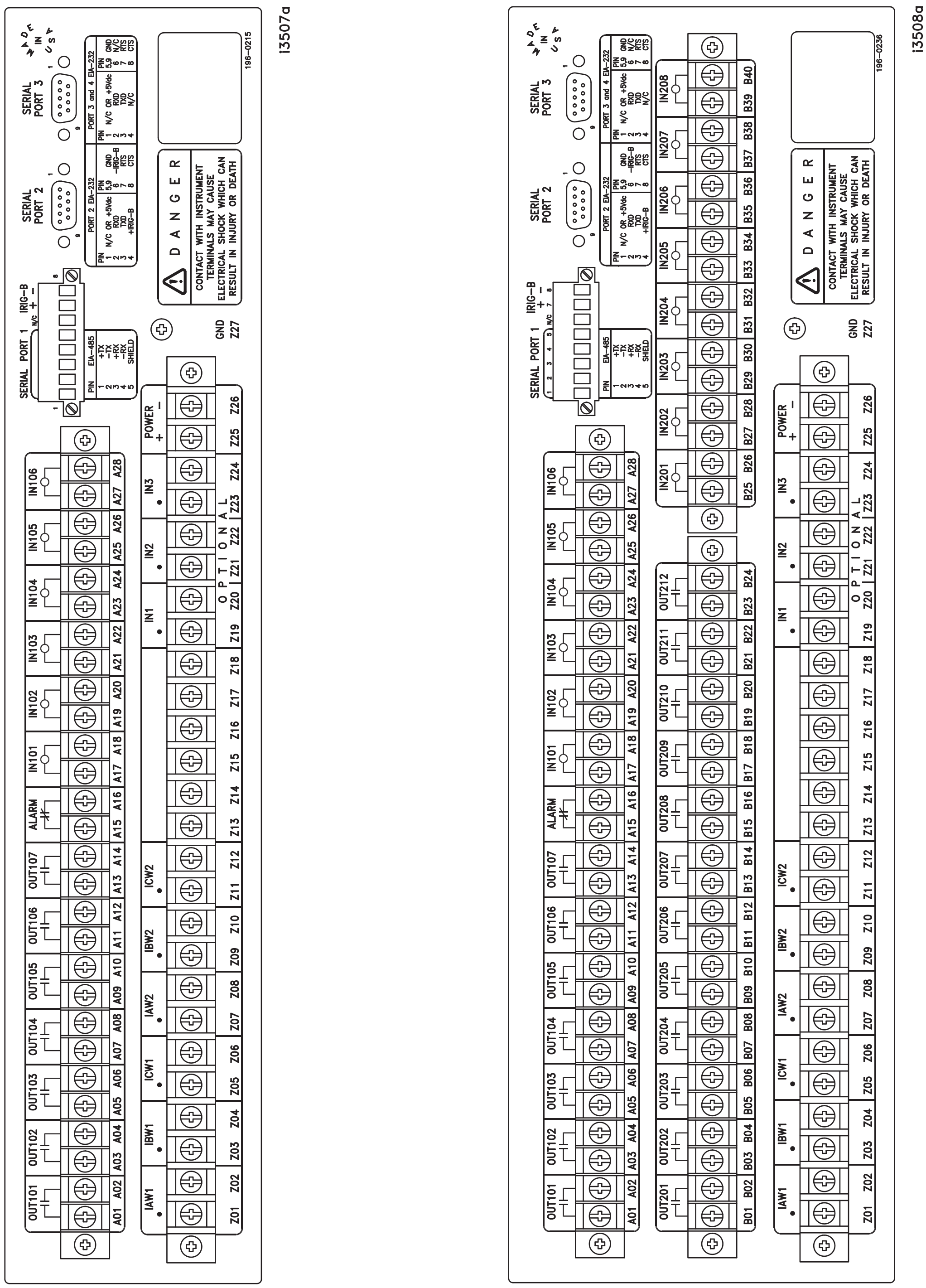


Figure 2.4 Rear-Panel Drawings—Models 0387Axx0xxxxxxx and 0387Axxxx2xxxxx

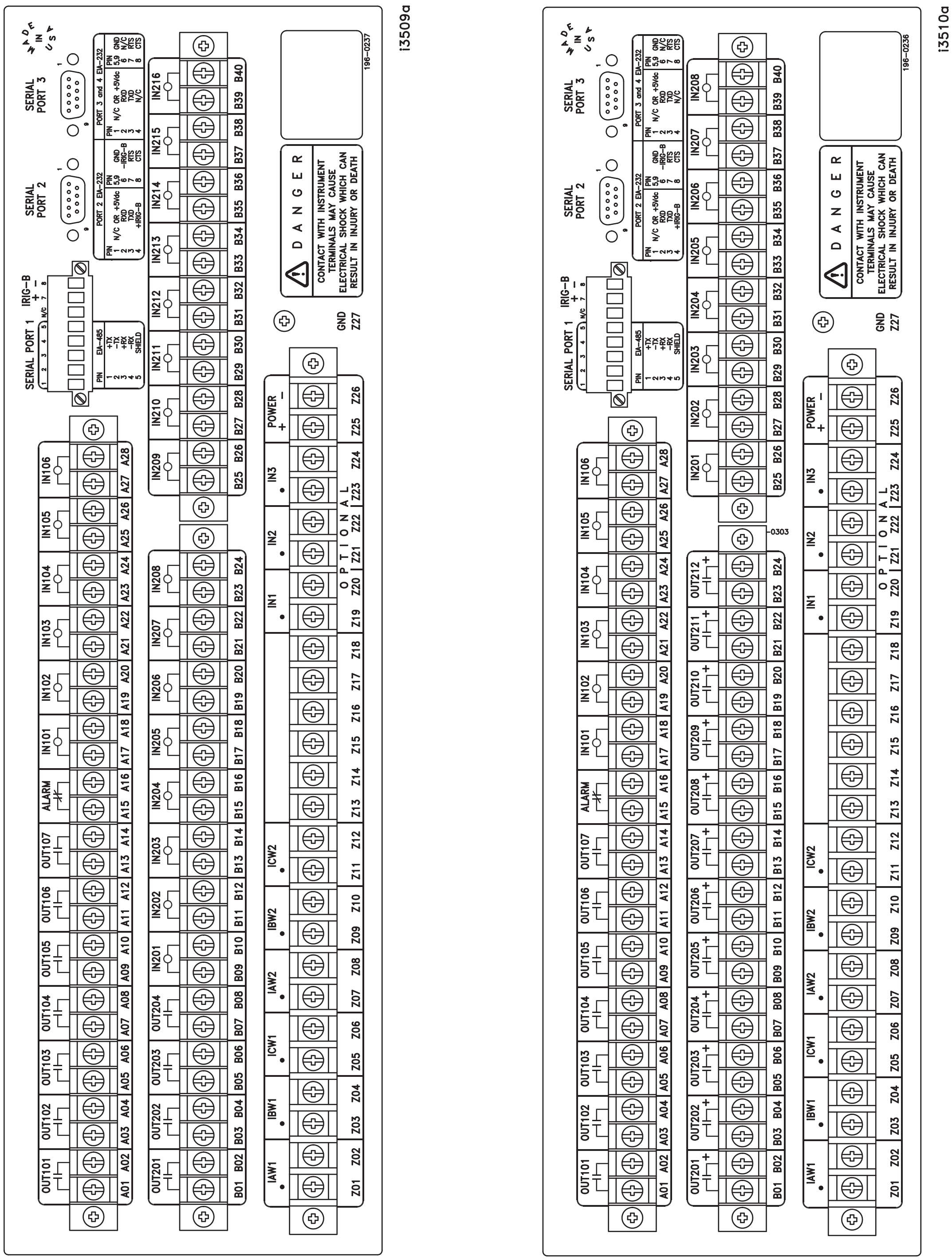


Figure 2.5 Rear-Panel Drawings—Models 0387A1xxxx4 and 0387A1xxxx6

Connections

Frame Ground

For safety and performance, ground the relay chassis at terminal **GND** (Z27). If the tab on the chassis is removed, the chassis ground connection can be made with a size #6-32 screw. The grounding terminal connects directly to the 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.

Connect current inputs to the three sets of current input terminals. Note that the current input terminals on terminal block 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 IN1, IN2, and IN3.

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, 220, 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* in *Section 1: Introduction and Specifications* for optoisolated input ratings. There are no internal connections between inputs. ON and OFF values are normally within one volt of each other, in the indicated range.

Output Contacts

Connect output wiring to the SEL-387A 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 2.6* shows these contacts as they would appear on a terminal block version.

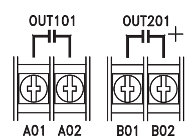


Figure 2.6 Output Contact Representations

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 2.6* 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: Serial Port Communications and Commands* 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: Serial Port Communications and Commands* 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-387A Ports 2, 3, or 4 to the 9-pin male connector on a laptop computer, order cable number C234A and specify the length needed. Standard length is eight feet. To connect the SEL-387A Port 2 to the SEL-2020 or SEL-2030 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 100 feet, 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-387A Communication Cable Numbers

SEL-387 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-2020 or SEL-2030 without IRIG-B	SEL-C272A
2	SEL-2020 or SEL-2030 with IRIG-B	SEL-C273A
2	SEL-IDM, Ports 2 through 11	Requires an SEL-C254 and SEL-C257 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 C220 (see *EIA-232 Serial Port Jumpers* later in this section).

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-387A accepts a demodulated IRIG-B format signal for synchronizing an internal clock to some external source such as the SEL-2020 or SEL-2030 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 Connections

Figure 2.7 and *Figure 2.8* represent the ac and dc connections for a typical two-winding transformer application. The autotransformer has a buried delta, not compensated for in the differential protection. Refer to *Figure 2.7* and note that the current transformers for all windings are wye-connected, with their polarity marks facing away from the transformer. The outputs of the CTs go to the polarity ends of the relay current inputs, with the nonpolarity ends of the inputs connected to the CT neutral and ground. You should use a single safety-ground point, 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.)

As *Figure 2.7* shows, this transformer has a neutral current CT connected to one of the neutral current inputs. The restricted earth fault (REF) protection function uses measured neutral current in conjunction with the residual current calculated from the Winding 1 CTs. You can use the REF function only if CTs for the protected wye winding are themselves wye-connected. Delta-connected CTs remove the zero-sequence components of the winding currents and provide no basis for comparison of residual and neutral currents.

We use this transformer example later for calculating relay settings; see *Section 6: Setting the Relay*. This example forms the basis for most of the factory-default settings SEL stores in the relay before shipment.

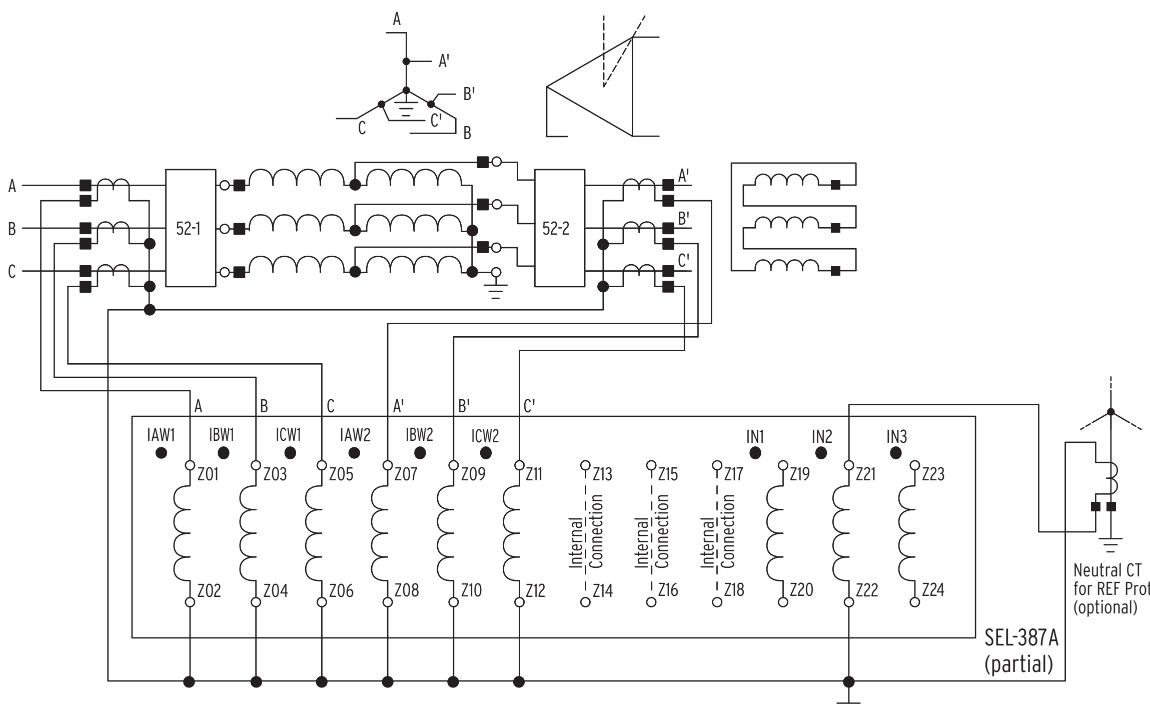


Figure 2.7 Example AC Connections (Three-Winding Transformer)

The dc connection diagram, *Figure 2.8*, illustrates tripping control of the two power circuit breakers. The diagram includes two 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.

The diagram also shows ALARM and annunciation functions. The ALARM contact comes factory wired as a form-B contact, so that it closes under conditions of complete relay power failure. If breaker closing control is desired, use OUT104 and OUT106 as separate output contacts for connection to the breaker closing coils.

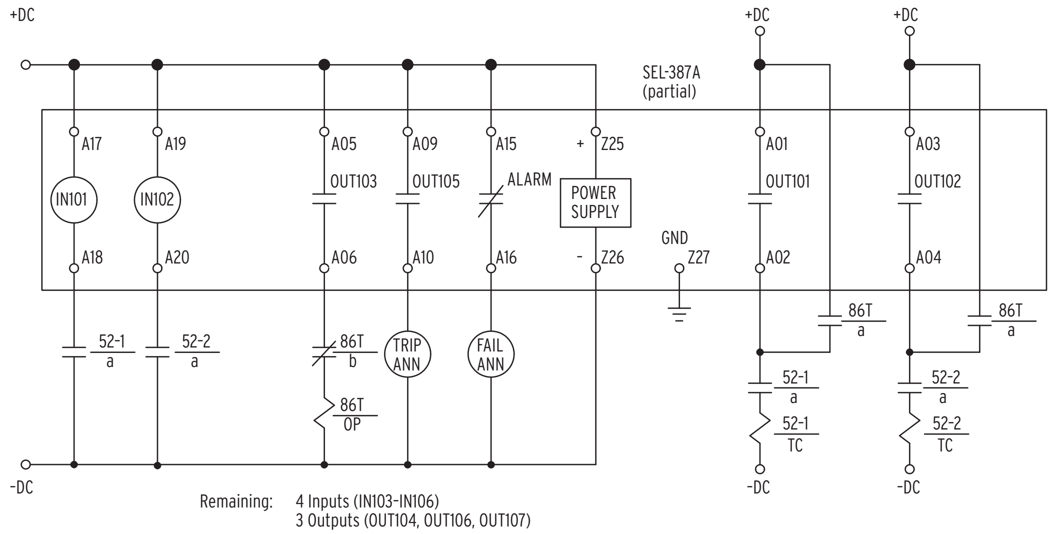


Figure 2.8 Example DC Connections (basic version)

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

⚠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.

1. De-energize the relay by removing the connections to rear-panel terminals + (Z25) and – (Z26).
2. Remove any cables connected to serial ports on the front and rear panels.
3. Loosen the six front-panel screws (they remain attached to the front panel) and remove the relay front panel.
4. Each circuit board corresponds to a row of rear-panel terminal blocks and is affixed to a drawout tray. Identify which drawout tray needs to be removed. An SEL-387A Model 0387A0 has only a main board. A Model 0387A1 relay has an extra interface board below the main board.
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.
6. Grasp the drawout assembly of the board and pull the assembly from the relay chassis.

7. Locate the jumper(s) or battery to be changed. Make the desired changes. Note that the output contact jumpers are soldered in place.
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.
9. Replace any cables previously connected to serial ports.
10. Re-energize the relay by reconnecting wiring to rear-panel terminals **+** (Z25) and **–** (Z26).

Main Board

Output Contact Jumpers

Refer to *Figure 2.9* 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 2.9*, 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-387A 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 2.9* 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 previously in *Accessing the Relay Circuit Boards*.

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: Serial Port Communications and Commands*).

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: Serial Port Communications and Commands*).

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 2.9*. 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-387A. 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-387A 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. Refer to *Figure 2.9*. 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 2.9* 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.

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 2.10* to remove the relay main board.

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Rayovac no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.

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: Serial Port Communications and Commands* or *Section 8: Front-Panel Interface*).

Additional Interface Board

We offer versions of the SEL-387A 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 *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 caused by electrostatic discharge (ESD).

Board Layout

Figure 2.10, *Figure 2.11*, and *Figure 2.12* show the layout of Interface Board 2, Interface Board 4, and Interface Board 6, respectively.

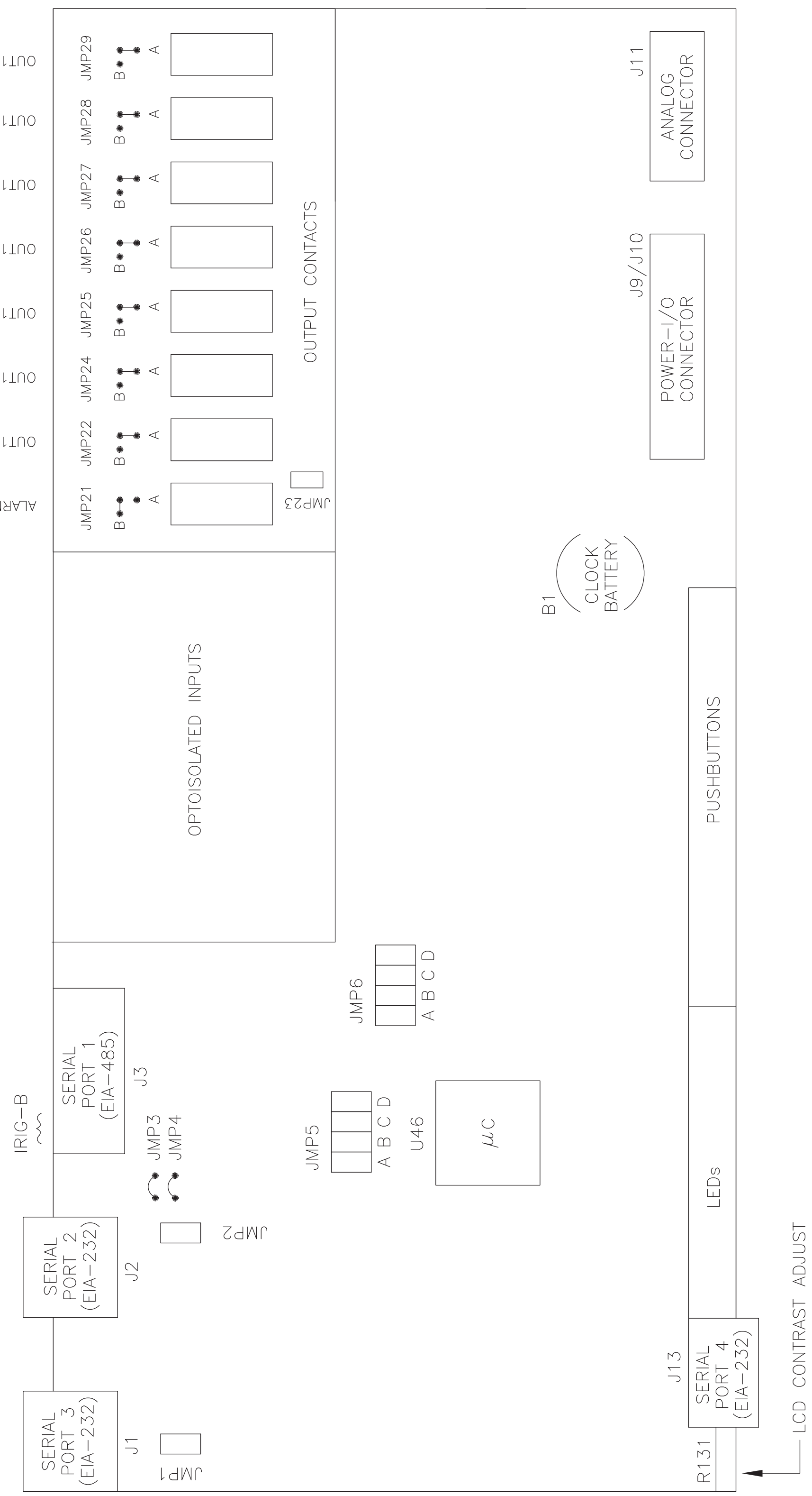


Figure 2.9 Main Board Jumpers, Connections, and Battery Locations

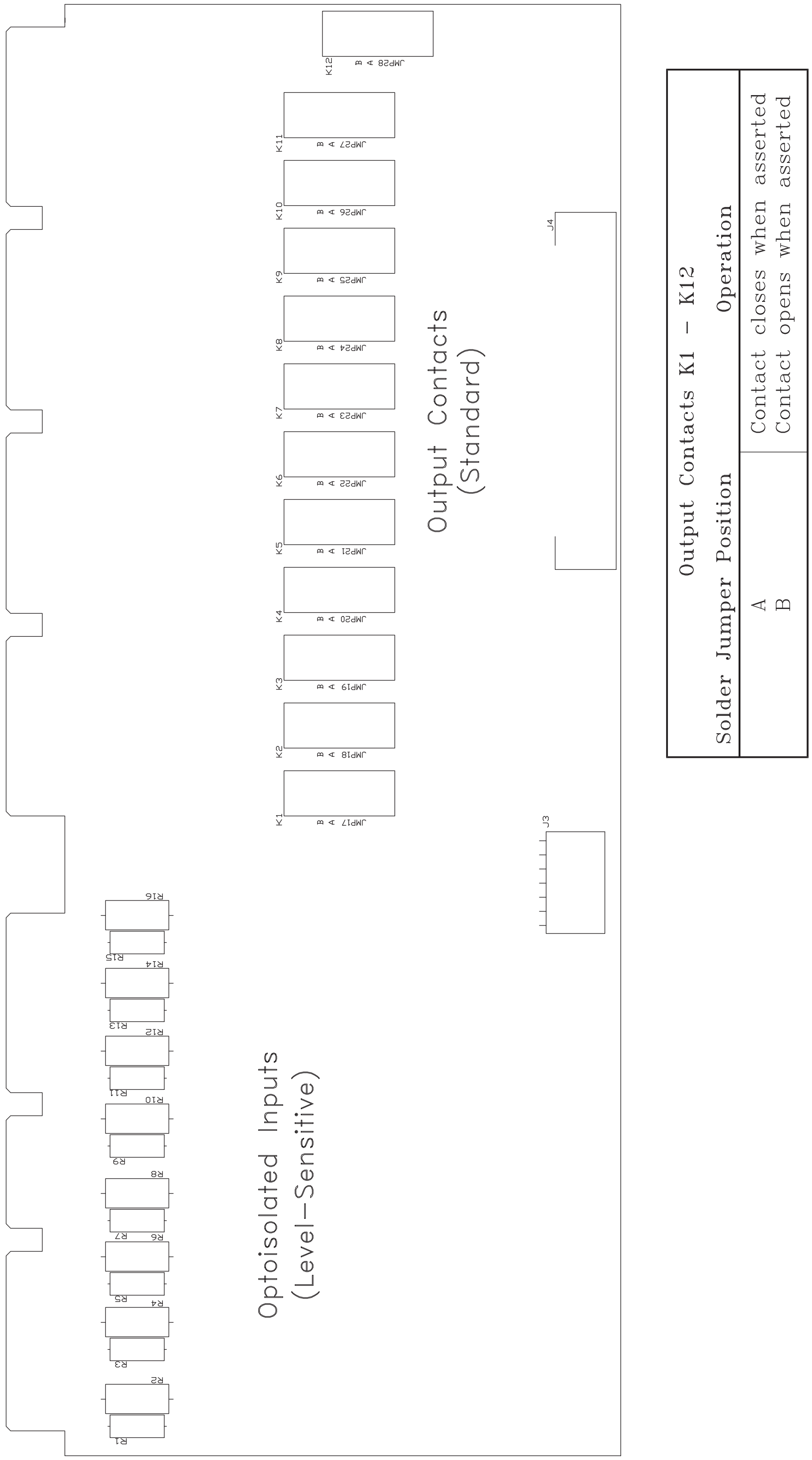
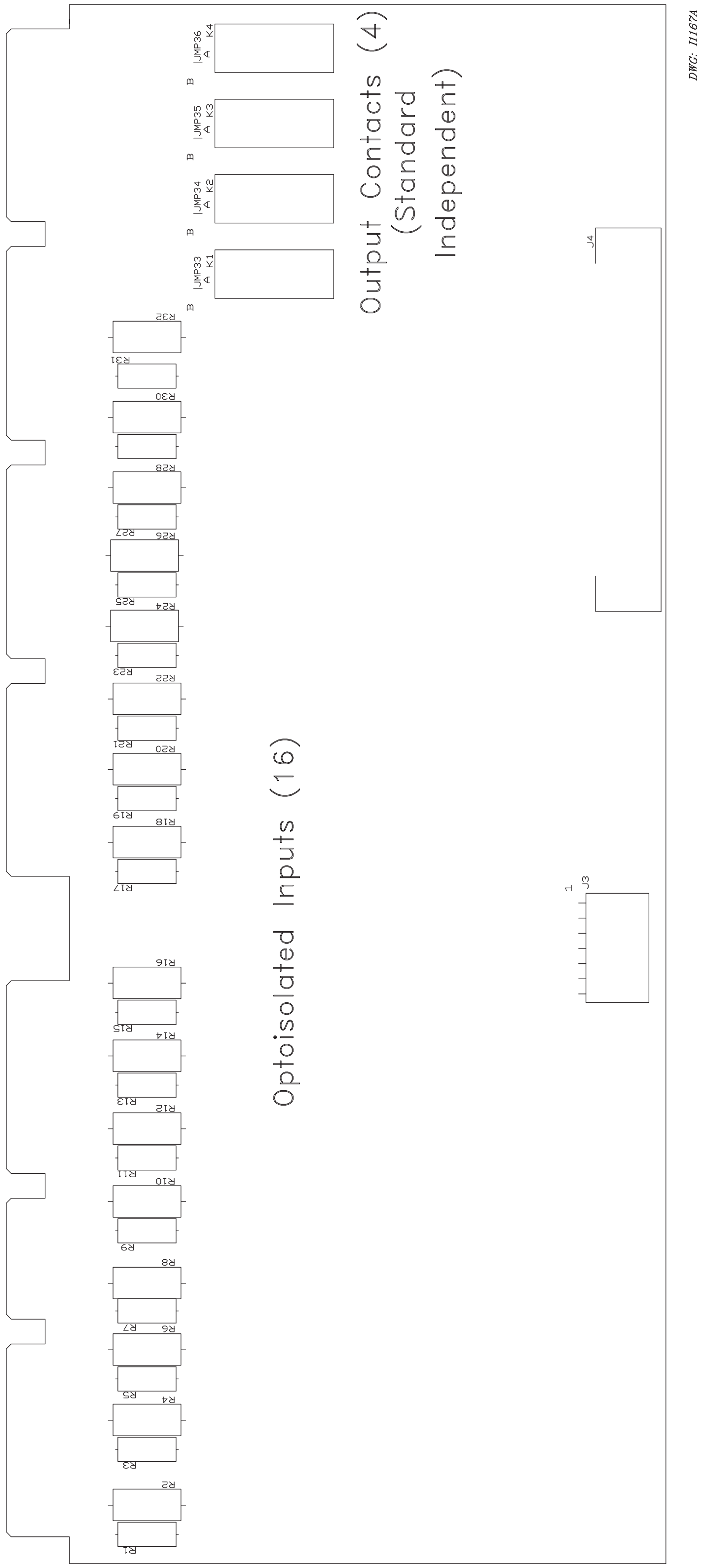


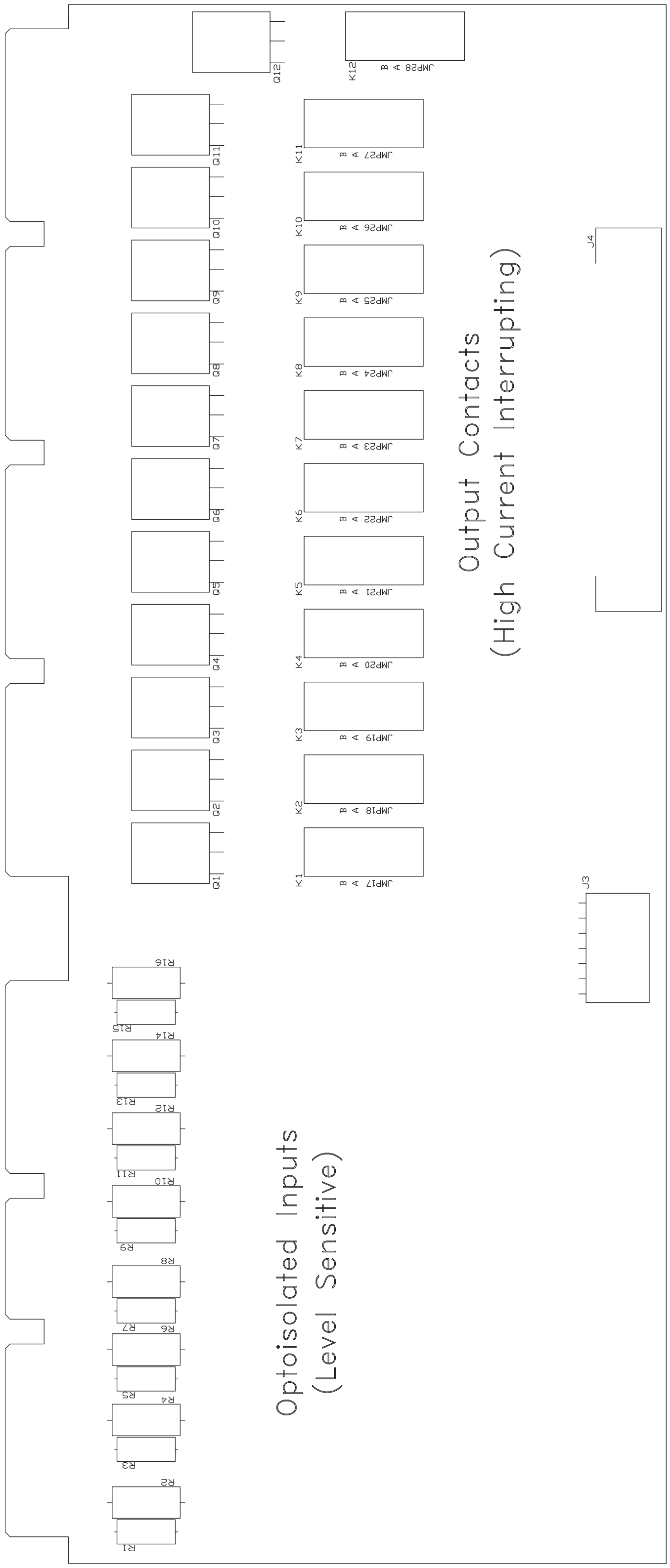
Figure 2.10 Interface Board 2 Component Layout



Output Contacts K1 – K4

Solder Jumper Position	Operation
A	Contact closes when asserted
B	Contact opens when asserted

Figure 2.11 Interface Board 4 Component Layout



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

Figure 2.12 Interface Board 6 Component Layout

Section 3
Differential, Restricted Earth Fault, and Overcurrent Elements

Introduction

This section describes general applications and operating characteristics for the current differential, restricted earth fault (REF), and overcurrent protection elements. The section also contains application guidelines for the differential 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 caused by tap changing.

The SEL-387A Relay offers the choice between harmonic blocking and harmonic restraint to secure relay 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 Characteristics

The SEL-387A 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. The relay uses a characteristic such as that in *Figure 3.1*. You can set the characteristic as either a single-slope, percentage differential characteristic or 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 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.

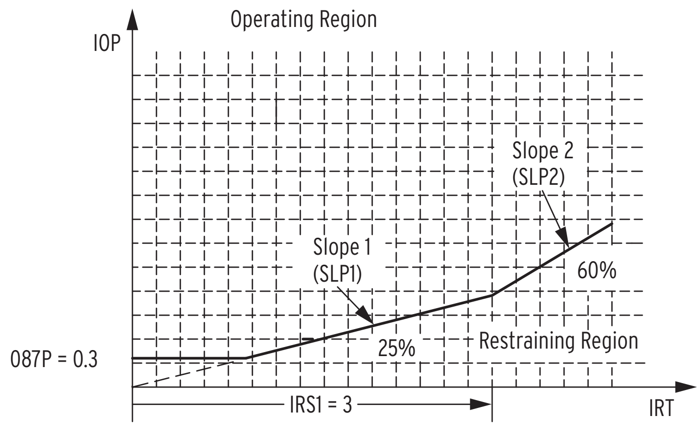


Figure 3.1 Percentage Restraint Differential Characteristic

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 two 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 both windings, whereas “TAP*n*” refers to the ampere value of a particular winding(s); TAPmin and TAPmax refer to the lesser and greater of the two 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 and W2CTC determine the mathematical corrections to the three-phase currents for Winding 1 and Winding 2, 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.

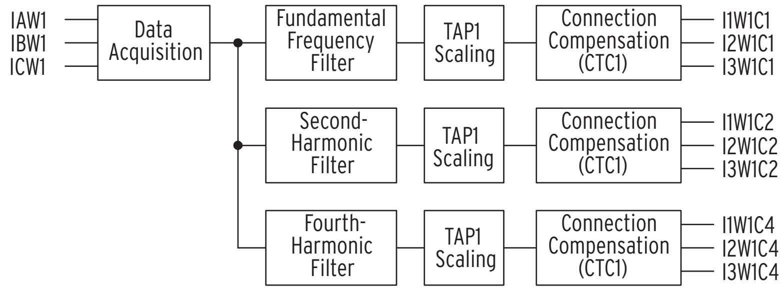


Figure 3.2 Winding 1 Compensated Currents

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 winding 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.

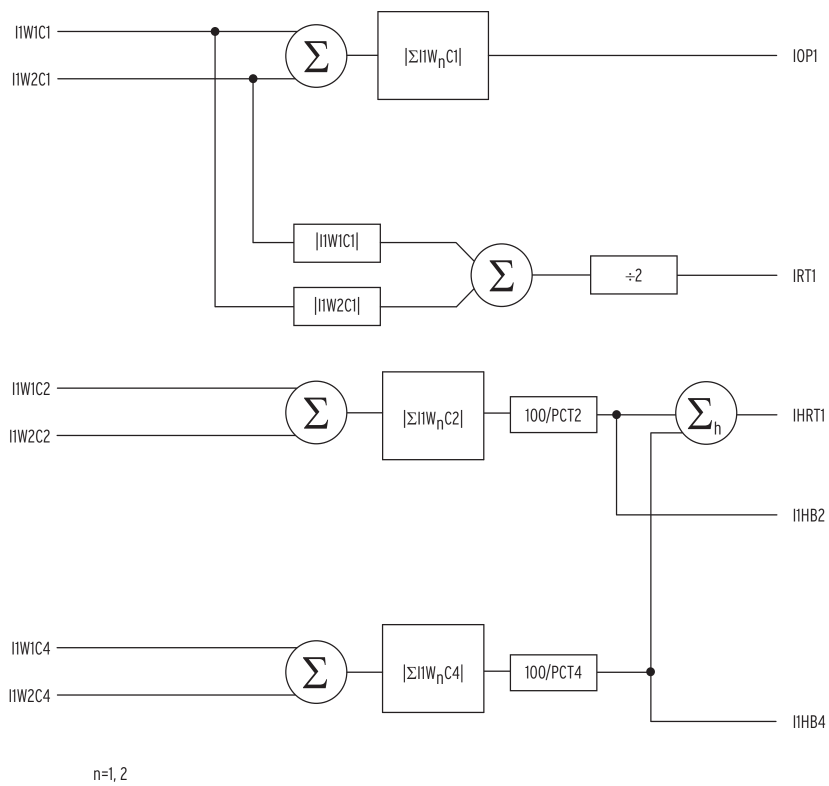


Figure 3.3 Differential Element (87-1) Quantities

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 threshold 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 87On 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.

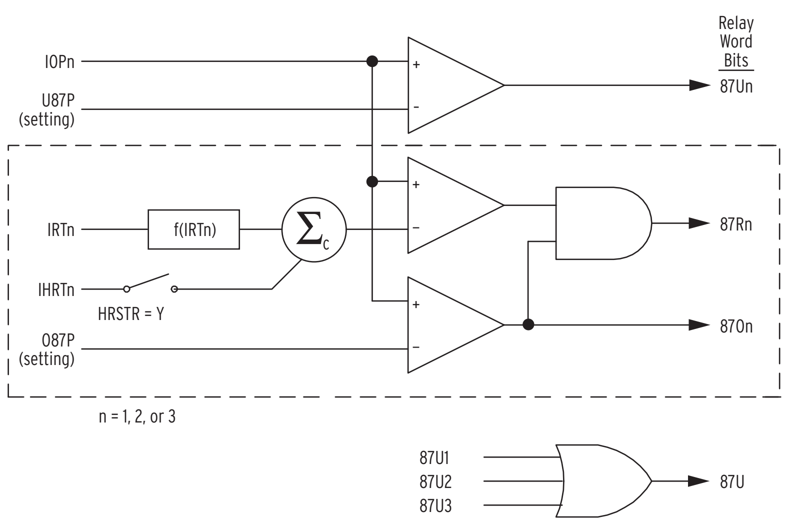


Figure 3.4 Differential Element Decision Logic

Harmonic Restraint

Consider the harmonic restraint feature (HRSTR = Y) if your practices require independent harmonic restraint. This feature disables common harmonic blocking (IHBL = Y). It also disables second- and fourth-harmonic blocking since 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-387A:

$$IOP = SLP1 \bullet IRT + c$$

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* normally is 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* (A) 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.

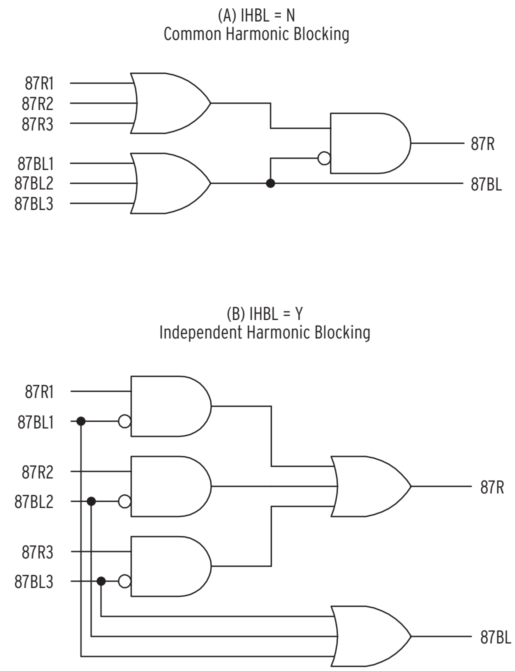


Figure 3.5 Differential Element Harmonic Blocking Logic

If IHBL is set to Y (Yes), the logic shown in the lower half of *Figure 3.5*, 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 TR3. If either bit asserts, this variable asserts bit TRIP3, which drives contact OUT103. OUT103 connects to an 86 lockout device, which trips all breakers via multiple sets of contacts.

Harmonic Blocking

Blocking prevents improper tripping during transformer inrush or allowable overexcitation conditions. *Figure 3.6* shows the differential element blocking logic (87BL1). The 87BL1 blocking element picks up if the second-, fourth-, or fifth-harmonic operating current, as a percentage of fundamental operating current, is above the 2PCT, 4PCT, or 5PCT setting threshold, respectively. The blocking element also picks up if the ratio of positive and negative dc exceeds a threshold.

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

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

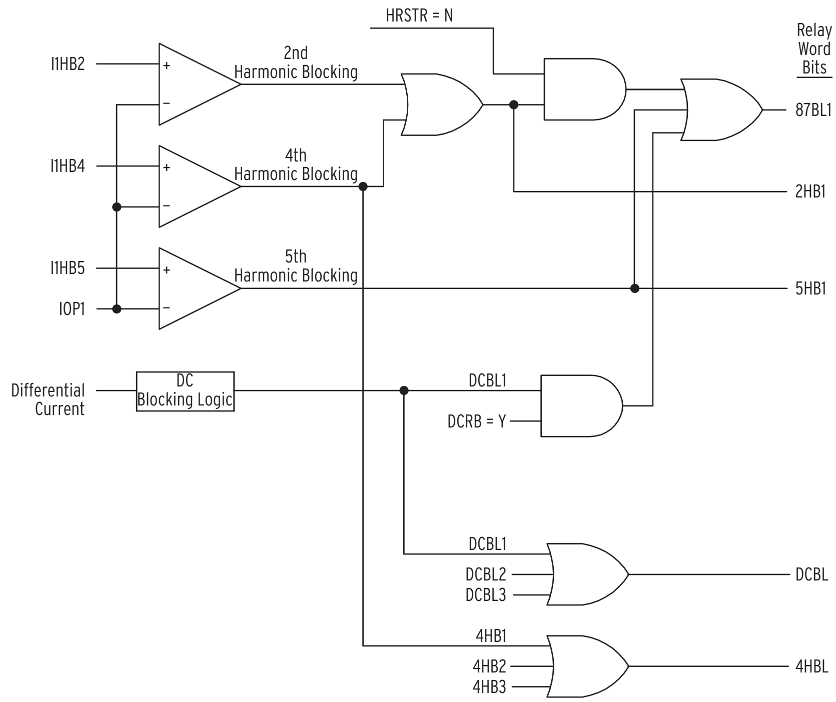


Figure 3.6 Differential Element (87BL1) Blocking Logic

DC Ratio Blocking

Figure 3.7 shows the dc blocking logic for Differential Element 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.

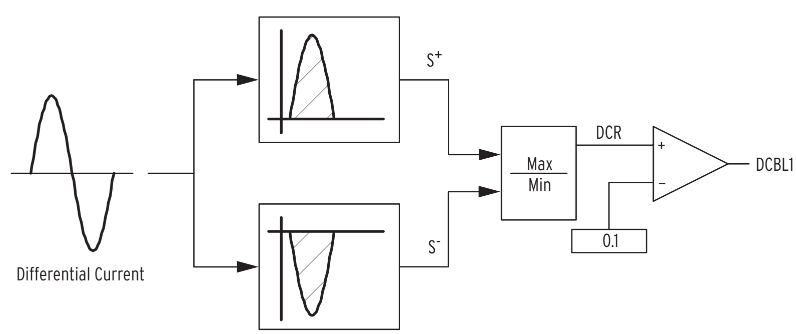


Figure 3.7 DC Blocking (DCBL1) Logic

Setting Descriptions

Differential Element Enable (E87)

Range: Y, N

The SEL-387A has two sets of three-phase current inputs, both enabled with the E87 setting. An independent setting, EOC*n*, exists to enable the overcurrent and demand metering elements. Selecting Y for E87 enables differential element settings. Selecting N for E87 disables differential element settings; the relay hides the settings, and they are unavailable for use.

CT Connection (W1CT and W2CT)

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*n* 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-387 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-387 current inputs are phase-to-phase difference currents (e.g., phase-to-phase difference current $I_A – I_B$ 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 and CTR2)

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 and W2CTC)

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 and VWDG2)

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 and TAP2)

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 and TAP2 values directly, along with the other pertinent settings.

Restrained Element Operating Current Pickup (O87P)

Range: 0.10–1.0 • TAP

Note: 1 A: $TAP_{MIN} \bullet O87P \geq 0.1 \bullet I_n$
5 A: $TAP_{MIN} \bullet O87P \geq 0.1 \bullet I_n$

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: $TAP_{MAX} \bullet IRS1 \leq 31.0$
5 A: $TAP_{MAX} \bullet IRS1 \leq 155.0$

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 that it does not 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 even-harmonic current can be used to identify the inrush phenomenon and to prevent relay misoperation. The SEL-387A 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

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-387A 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} • TH5P ≥ 0.05
TAP_{MAX} • TH5P ≤ 31.0

5 A: TAP_{MIN} • TH5P ≥ 0.25
TAP_{MAX} • TH5P ≤ 155.0

NOTE: The relay permits the setting of values smaller than TH5P • TAP_{MIN} ≥ 0.05 • I_{NOM}, but alerts the user with the message "Settings times minimum TAP should be >= 0.25." If the setting is not changed to a value within the limits, the relay performance may be outside the element specification.

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)

Range: Y, N

Some magnetizing inrush cases contain very little harmonic content but contain a dc offset. The SEL-387A can detect the dc offset and use it in the blocking (not restraint) logic. Enable this function by setting DCRB = Y.

Harmonic Restraint (HRSTR)

Range: Y, N

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 since 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-387A 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 or 2), 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
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

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
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 or 2.

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 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 H: 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).

$$\mathrm{TAP}n = \frac{\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet \mathrm{VWDG}n \bullet \mathrm{CTR}n} \bullet \mathrm{C}$$

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 smaller of TAP1 or TAP2. 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:

$$\mathrm{Idmax} = (1 + e) \bullet \sum_{''\mathrm{IN}''} \mathrm{IW}n - \frac{(1 - e)}{(1 + a)} \bullet \sum_{''\mathrm{OUT}''} \mathrm{IWn}$$

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:

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

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 $31 \bullet I_{NOM}/TAP_{max}$, 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 that it does not 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 (PCT2) 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 caused by point-on-wave switching. Inrush conditions typically are detected using even harmonics and are used to prevent misoperations caused by inrush. The largest even-harmonic current component is usually second harmonic followed by 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:

- $\mathrm{TH5P} \cdot \mathrm{TAP}_{\mathrm{MIN}} \geq 0.05 \cdot \mathrm{I}_{\mathrm{NOM}}$, and
- $\mathrm{TH5P} \cdot \mathrm{TAP}_{\mathrm{MAX}} \leq 31 \cdot \mathrm{I}_{\mathrm{NOM}}$

where $\mathrm{TAP}_{\mathrm{MIN}}$ and $\mathrm{TAP}_{\mathrm{MAX}}$ 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-387A can perform harmonic blocking two ways:

- Independent Harmonic Blocking (IHBL = Y) blocks the percentage differential element for a particular phase if the harmonic in that phase is above 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 above the blocking threshold.

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

Example of Setting the SEL-387A for a Two-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 two-winding transformer application and demonstrates the use of CT compensation settings and tap calculations.

Consider a wye-wye connected transformer with both windings grounded. The transformer primary and secondary have a maximum rating of 100 MVA, and both windings have wye-connected current transformers, with ratios of 600/5 A at 230 kV and 1200/5 A at 138 kV.

1. Set the appropriate enable. Because we need to enable the differential element, make the first setting as follows:

   E87 = Y

   This setting enables Windings 1 and 2.

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
W1CT = Y	W2CT = Y
CTR1 = 120	CTR2 = 240

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

   MVA = 100

4. Decide whether to use internal CT compensation and determine compensation settings. Because there are only wye transformer windings and only wye CTs, we need not adjust for the delta phase angle shifts. In the "traditional" differential relay connection, the wye transformer windings would have their CTs connected in delta (DAC/DAC, for example) to remove the zero-sequence current component by physically subtracting the appropriate phase currents via the delta connection (refer to *Steps to Determine the Compensation Settings (WnCTC) on page H.5* for transformer connection and compensation settings). We achieve the same effect within the relay by using the selected compensation. The settings are:

   ICOM = Y (choose to define the CT compensation)

   W1CTC = 11 W2CTC = 11

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

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

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

$$\mathrm{TAP}n = \frac{\mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet \mathrm{VWDGn} \bullet \mathrm{CTRn}} \bullet \mathrm{C} \quad (\mathrm{C} = 1 \text{ for wye CTs})$$

Thus, we have the following:

$$\mathrm{TAP1} = \frac{100\ \mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet 230\ \mathrm{kV} \bullet 120} \bullet 1 \quad \mathrm{TAP1} = 2.09\ \mathrm{A}$$

$$\mathrm{TAP2} = \frac{100\ \mathrm{MVA} \bullet 1000}{\sqrt{3} \bullet 138\ \mathrm{kV} \bullet 240} \bullet 1 \quad \mathrm{TAP2} = 1.74\ \mathrm{A}$$

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 2.09, by the least TAP*n*, here 1.74, to get a ratio of 1.2. Because this is below 7.5, adjustment of the CT ratio is unnecessary.

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)
PCT2 =	15	(block operation if second harmonic is above 15 percent)
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)
IHBL =	N	(no independent element blocking; any unit detecting second, fourth, or fifth harmonic above PCT2, PCT4, or PCT5 will block all units)

Remember that the O87P setting must yield an operating current value of at least $0.1 \bullet I_N$, at the least tap. In this case $\mathrm{O87P}_{MIN} = (0.1 \bullet I_N)/\mathrm{TAP}_{MIN} = 0.5/1.74 = 0.287$. 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 Guideline

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-387A you may apply two 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 $\sqrt{3} \cdot I_{HS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \cdot I_N$ and $1.0 \cdot I_N$ A secondary, where I_N is the relay nominal secondary current, 1 A or 5 A.

Step 3. Select CTR2 by considering the maximum continuous secondary current, I_{LS}, for Winding 2. 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-387A (see *Step 4* and *Step 5*). As before, for wye-connected CTs I_{REL} equals I_{LS}. For delta-connected CTs I_{REL} equals $\sqrt{3} \cdot I_{LS}$. Select the nearest standard ratio such that I_{REL} is between $0.1 \cdot I_N$ and $1.0 \cdot I_N$ A secondary.

Step 4. The SEL-387A calculates settings TAP1 and TAP2 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 smaller 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 Elements

Application Description

The SEL-387A provides two separate restricted earth fault (REF) elements. Use the 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

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 the 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-387A 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. Because the SEL-387A has two REF elements, you can apply separate elements to each of the wye windings of a wye-wye-connected transformer. The neutral CT connects to one of the relay inputs (wye-delta no grounding bank), or two relay inputs (wye-wye or wye-delta with grounding bank). The three current inputs are labeled IN1, IN2, and IN3.

Figure 3.8 shows the REF simplified enable/block logic. 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 the respective winding. Such a winding residual current value might occur with "false I0" or if zero-sequence current for that winding exceeds 50GP*n*. False I0 can occur in cases of CT saturation during heavy three-phase faults. If the blocking logic asserts, the CTS*n* Relay Word bit asserts. To prevent 32IE*n* assertion when CTS*n* asserts, set the E32I setting = !CTS.

The middle 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 (IN*n*) greater than the pickup setting, 50GP*n*. 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*n* pickup value. If the sum is greater than the pickup level, Relay Word bit 50GC*n* asserts. This bit indicates that the winding currents are present in sufficient magnitude.

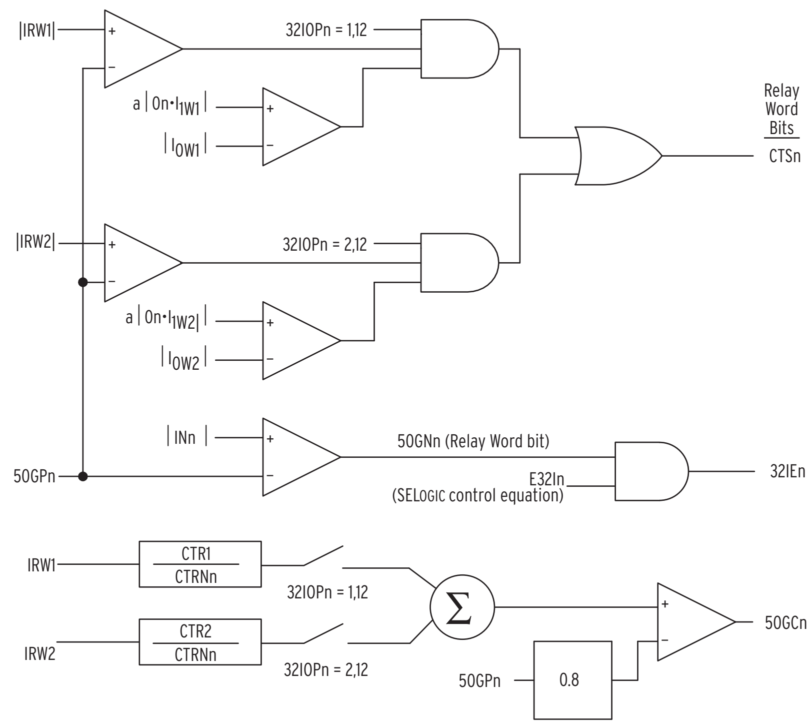


Figure 3.8 REF Enable/Block Logic

Figure 3.9 illustrates the logic of the REF directional element.

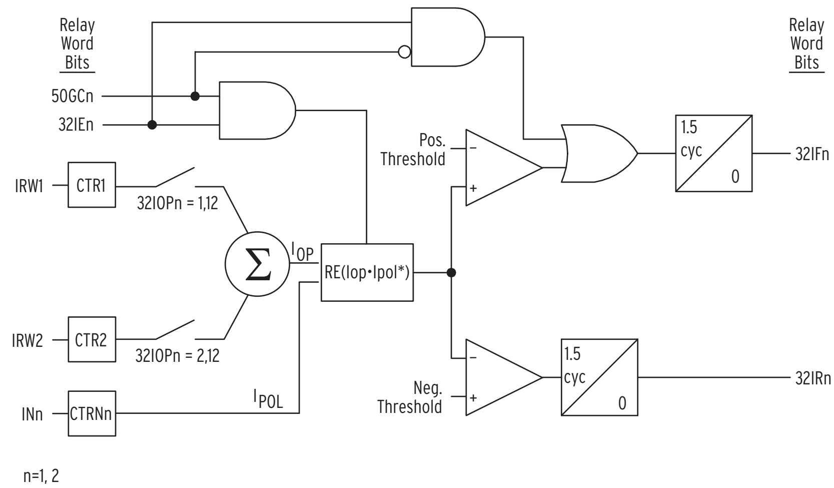


Figure 3.9 REF Directional Element

The relay enables the 32I directional element, RE(Iop • Ipol*), if the output of the AND gate at left-center in *Figure 3.9* asserts. This will occur if the two Relay Word bits 32IE and 50GC*n* assert.

The directional element compares the polarizing current (from IN*n*) to the operating current (from IRW1 or IRW2) 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.

The polarizing current, IPOL, is simply the neutral CT current multiplied by the neutral CT ratio, CTRN*n*, 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*n* setting determines the appropriate IRW*n*, which the relay multiplies by the associated CTR*n*. The relay then sums the products. The 32I*n* 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*n* (forward) or 32IR*n* (reverse) asserts. Assertion of 32IF*n* constitutes a decision to trip by the REF function.

A second path can also assert the 32IF*n* bit. This path comes from the AND gate at the top-right of *Figure 3.9*. The gate asserts if 32IE*n* is asserted. This assertion indicates that neutral current is above pickup but 50GC*n* 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*n* into one or more of the trip variables, TR1 to TR5, as appropriate. If you want additional security, the relay is programmed to use 32IF*n* to torque control an inverse-time curve for delayed tripping, as discussed below. *Figure 3.10* 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*n* as the pickup setting.

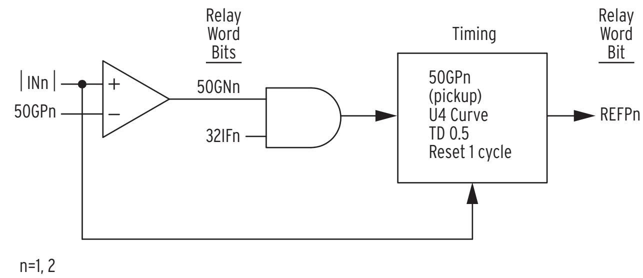


Figure 3.10 REF Protection Output (Extremely Inverse-Time O/C)

Relay Word bit 32IF*n* (forward fault) torque controls the timing curve, and |IN*n*| operates the timing function. The curve resets in one cycle if current drops below pickup or if 32IF*n* deasserts. When the curve times out, Relay Word bit REFP*n* 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 (E32I1, E32I2)

Range: SELOGIC control equation

The setting E32I*n* 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 (32IOP1, 32IOP2)

Range: 1, 2, 12

The setting 32IOP*n* 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 (a01, a02)

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 |I0W*n*| > a0*n* • |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 (50GP1, 50GP2)

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 • I_{NOM} (0.25 A for 5 A nominal CT current), the minimum residual current sensitivity of the relay. However, the minimum acceptable value of 50GP*n* must meet two criteria:

1. 50GP*n* must be greater than any natural 3I0 unbalance caused by load conditions.
2. 50GP*n* 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*n*, 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 and Polarizing Quantities

The polarizing quantities are assigned in the following manner: IN1 for REF1, IN2 for REF2. IN3 is never assigned to an REF element, but all overcurrent functions are available.

The operating quantities are selected as a function of the transformer vector group and can be 1, 2, or 12.

Figure 3.11 depicts how to determine the Operate quantity, 32IOP*n*, setting.

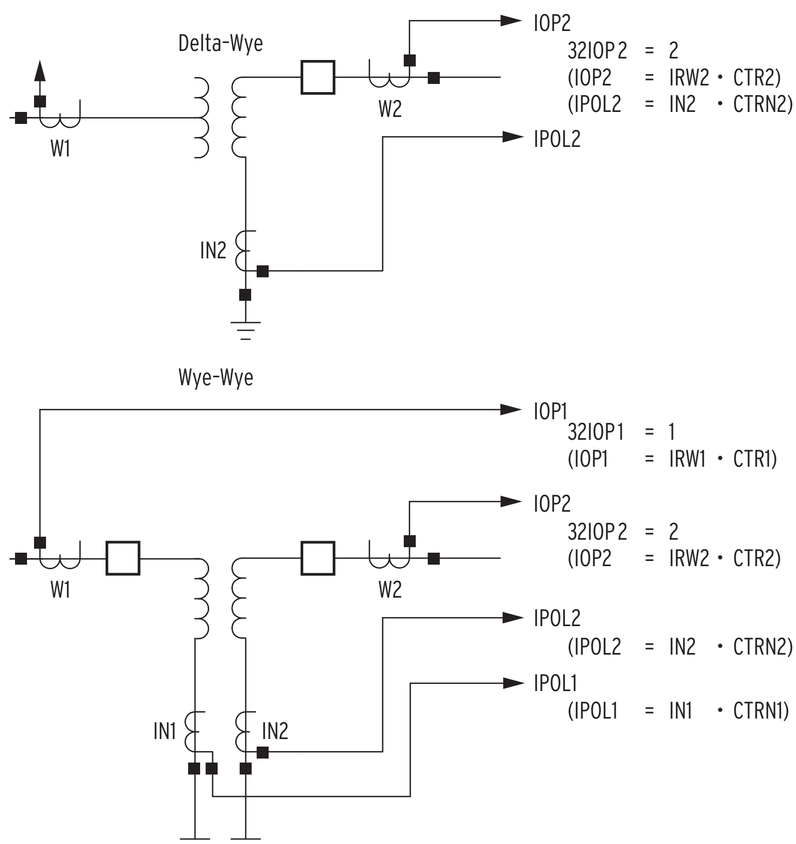


Figure 3.11 REF Function, 32IOP Setting Guide

If you want to protect a single wye winding in, for example, a delta-wye transformer, set 32IOP*n* at 1 or 2, 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 3.11* shows neutral CT input connected to IN*n* 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:

$$IRWn = IAWn + IBWn + ICWn \quad (n = 1 \text{ or } 2)$$

For the neutral CT connection, the relay uses one dedicated input (e.g., IN2) and not the sum of the three neutral inputs.

Residual Current Sensitivity Threshold

The second criterion of 50GP*n* 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*n*:

$$50GP_{min} \geq 0.05 \bullet I_{NOM} \bullet \frac{CTR_{max}}{CTRNn}$$

where CTRN*n* is the neutral CT ratio and CTRmax is the line CT ratio.

The 32IOP setting defines which line CTs the relay uses for REF. For example, if 32IOP = 1, the CTR1 value applies.

An example 50GP1 calculation is as follows, assuming that CTRN1 = 40, CTRmax = 160, I_{NOM} = 5 A, and load unbalance is 10 percent:

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

$$50\ GP_{min} \geq 0.25A \bullet 4$$

$$50\ GP_{min} \geq 1.0A$$

Criterion 2 minimum setting of 50GP*n* 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*n* 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*n* setting that is too low, the relay will respond `Out of Range`. The relay then will prompt you for a new setting.

The relay stores a default setting for the Residual Current Sensitivity Threshold of 50GP*n* = 0.5 A.

Temperature Measurement

For temperature measurement purposes, the SEL-387 accepts RTD inputs from the SEL-2600 RTD Module via any one of the serial ports. Set the RTD enable and the RTD alarm and trip settings under group settings. Set the RTD configuration under the port settings. A discussion of these settings follows.

RTD Enable (E49A, E49B)

Range: Y, N

The relay can accept 12 RTD inputs from each of two SEL-2600 RTD modules (total of 24 RTD inputs). The two groups of RTD inputs are labeled "49A" and "49B," respectively.

RTD Alarm and Trip Settings (49A01A–49T12A and 49A01B–49T12B)

Range: OFF, 32–482°F; OFF, 0–250°C

Set the temperature value for alarm and trip operations.

The relay can accept 12 RTD inputs from each of two SEL-2600 RTD modules (total of 24 RTD inputs). Configure the SEL-387A and SEL-2600 communication with the port setting SET P *n* (*n* = 1, 2, 3, or 4).

Temperature Preference (TMPREFA, TMPREFB)

NOTE: The SEL-387A can report a different RTD alarm or trip temperature than the temperature you entered for settings 49A01A–49T12A and 49A01B–49T12B. The relay rounds digits after the decimal point, processes the rounded values, and reports temperature in unit-precision (e.g., 25, 72). The rounded result can differ from the temperature setting especially when settings TMPREFA or TMPREFB are F (Fahrenheit). The relay converts Fahrenheit scale settings to the Celsius scale for processing, and then reconverts these temperatures to the Fahrenheit scale for reporting. For example, if setting 49A01A is 101°F, the relay reports 100°F.

Range: C, F

Located under the Global settings, TMPREFA, TMPREFB select the preferred temperature units: C for Celsius or F for Fahrenheit. The relay automatically recalculates all 49-element temperature values.

$$\frac{\text{Setting 49 A 01 A}°\text{F} - 32°}{1.8} = \frac{101°\text{F} - 32°}{1.8} = 38.3°\text{C}$$

internal relay processing temperature, rounded to 38°C.

38°C • 1.8 + 32° = 100.4°F = 100°F reported temperature, rounded to 100°F.

Protocol Setting (PROTO)

Range: SEL, LMD, RTDA, RTDB, DNP

Select the RTDA or RTDB protocol under the Port settings (SET P *n*, *n* = 1–4), to enable communication with the SEL-2600 RTD module.

Number of RTDs in Use (RTDNUMA, RTDNUMB)

Range: 0. . .12

Enter the number of RTDs to be used for Group A. Group B has a similar setting.

Type of RTDs (RTD1TA–RTD12TA)

Range: NA, PT100, NI100, NI120, CU10

Enter the type of metal: platinum, nickel, or copper. Based on the RTD*n*TA setting (where *n* is the RTD number), the data for the specified RTD type will be used to update the associated RTD temperature value.

Type of RTDs (RTD1TB–RTD12TB)

Range: NA, PT100, NI100, NI120, CU10

Enter the type of metal: platinum, nickel, or copper. Based on the RTD*n*TB setting (where *n* is the RTD number), the data for the specified RTD type will be used to update the associated RTD temperature value.

Overcurrent Element

Application Description

The SEL-387A provides numerous overcurrent elements, as many as 11 per winding and 5 per neutral input. Four levels of phase-instantaneous/definite-time elements are available for overcurrent 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 element are available for system backup protection. The SEL-387A also has neutral instantaneous/definite-time elements available.

Operating Characteristic

Each winding input of the SEL-387A 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.

Each neutral input has five overcurrent elements. Three of these five are torque-controlled elements: one definite-time element, one instantaneous element, and one inverse-time element. Two of the five overcurrent elements (50NN*n*3 and 50NN*n*4) 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
Negative-Sequence ($IQ = 3 \cdot I_2$)			
Winding 1	50Q11	50Q12	51Q1
Winding 2	50Q21	50Q22	51Q2
Residual (IR = Ia + Ib +Ic)			
Winding 1	50N11	50N12	51N1
Winding 2	50N21	50N22	51N2
Neutral Elements			
Element 1	50NN11	50NN12, 50NN13, 50NN14	51NN1
Element 2	50NN21	50NN22, 50NN23, 50NN24	51NN2
Element 3	50NN31	50NN32, 50NN33, 50NN34	51NN3

50P*n*1 – Phase Definite-Time Element

Figure 3.12 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.

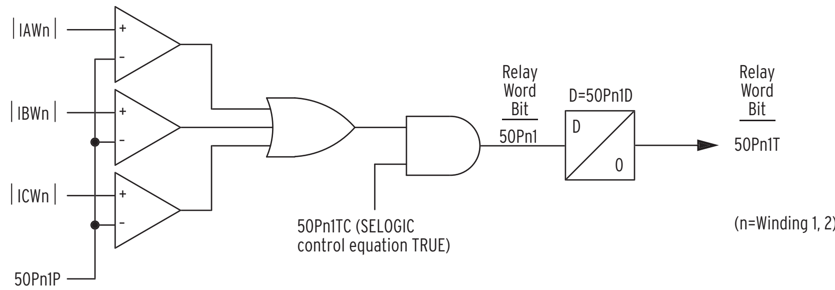


Figure 3.12 50Pn1 Phase Definite-Time O/C Element, Torque Controlled

50P*n*2 – Phase-Instantaneous Element

Figure 3.13 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.

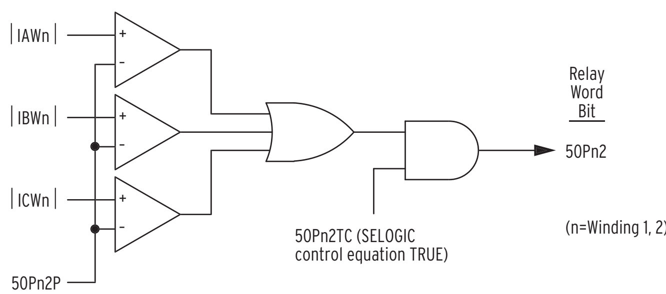


Figure 3.13 50Pn2 Phase-Instantaneous O/C Element, Torque Controlled

50P*n*3 and 50P*n*4 — Phase-Instantaneous Element

Figure 3.14 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.

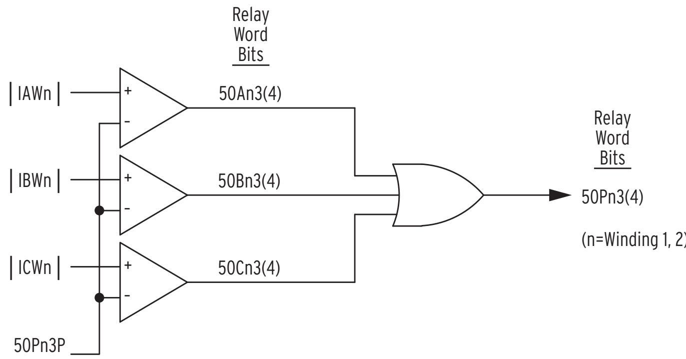


Figure 3.14 50Pn3 and 50Pn4 Phase-Instantaneous O/C Element, Nontorque-Controlled

51P*n* – Phase Inverse-Time Element

Figure 3.15 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.

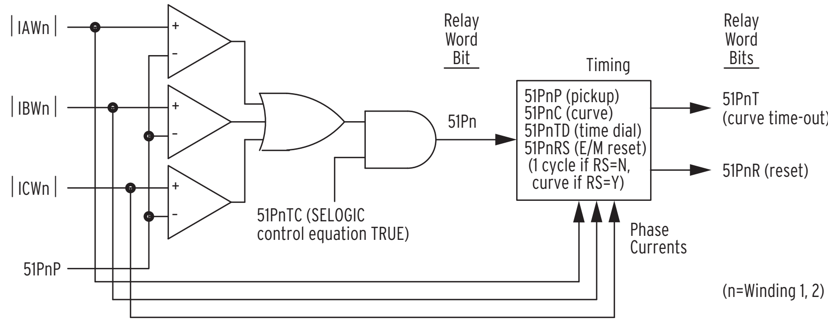


Figure 3.15 51Pn Phase Inverse-Time O/C Element, Torque Controlled

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.

50Q*n*1 and 50N*n*1 – Sequence Current Definite-Time Element Logic

Figure 3.16 shows the logic for the definite-time 50Q*n*1 negative-sequence element and the definite-time 50N*n*1 residual element.

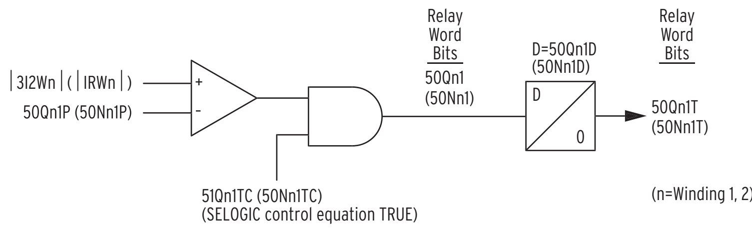


Figure 3.16 50Qn1 and 50Nn1 Sequence Definite-Time O/C Element, Torque Controlled

50Q*n*1 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.

50N*n*1 Residual Definite-Time Element

The 50N*n*1 element logic compares the magnitude of the calculated residual current, IRWn, 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.

50Q*n*2 and 50N*n*2 – Sequence Instantaneous Element Logic

Figure 3.17 shows the logic for the instantaneous 50Q*n*2 negative-sequence element and the instantaneous 50N*n*2 residual element.

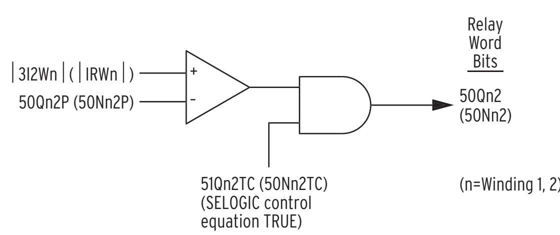


Figure 3.17 50Qn2 and 50Nn2 Sequence Instantaneous O/C Element, Torque Controlled

50Q*n*2 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.

50N*n*2 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.

51Q*n* and 51N*n* – Sequence Inverse-Time Elements

Figure 3.18 shows the logic for the inverse-time 51Q*n* negative-sequence element and the instantaneous 51N*n* residual element.

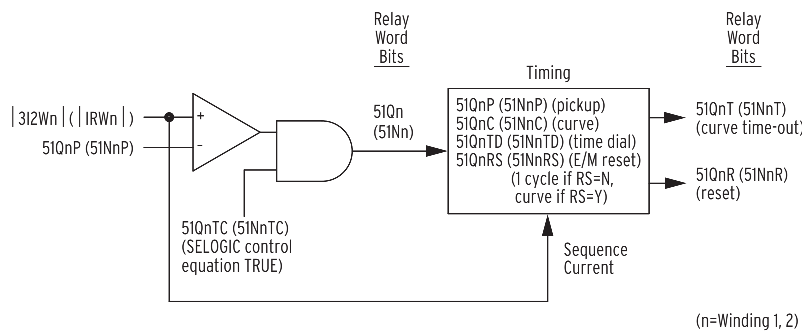


Figure 3.18 51Qn and 51Nn Sequence Inverse-Time O/C Element, Torque-Controlled

51Q*n* 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.

51N*n* 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.

50NN*n*1 – Neutral Definite-Time Element (Torque Controlled)

The 50NN*n*1 element logic compares the magnitude of the neutral current, IN*n*, to the pickup setting, 50NN*n*1P.

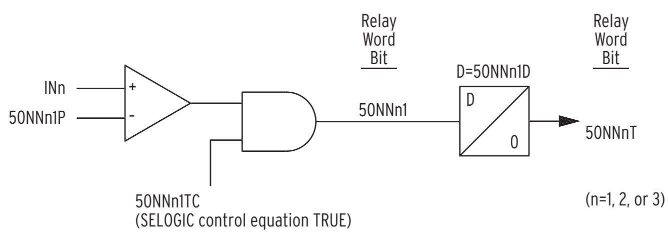


Figure 3.19 50NNn1 Neutral Definite-Time O/C Element, Torque-Controlled

If the neutral 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 50NN*n*1TC, determines the other AND input. If 50NN*n*1TC is true, Relay Word bit 50NN*n*1 asserts and the timer starts. After the time specified by delay setting 50NN*n*1D has expired, a second Relay Word bit, 50NN*n*1T, asserts. The 50NN*n*T bit asserts only if the 50NN*n*1 bit remains asserted for the duration of 50NN*n*1D. When 50NN*n*1 deasserts, the timer resets without delay, along with 50NN*n*1T if it has asserted.

50NN*n*2 – Neutral Instantaneous Element (Torque Controlled)

The logic compares magnitudes of neutral currents IN*n* to pickup setting 50NN*n*2P. The torque-control SELOGIC control equation 50NN*n*2TC determines the other AND input. If 50NN*n*2TC is true, Relay Word bit 50NN*n*2 asserts. When IN*n* falls below the 50NN*n*2P setting, Relay Word bit 50NN*n*2 resets without delay.

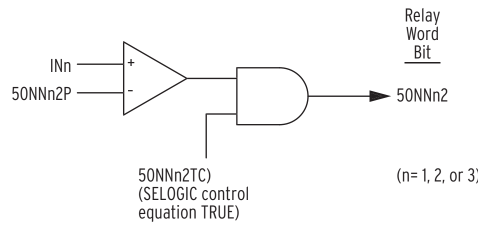


Figure 3.20 50NNn2 Neutral Instantaneous O/C Element, Torque-Controlled

50NN*nm* – Neutral Instantaneous Element

Figure 3.21 shows the logic for the two nontorque-controlled neutral instantaneous elements. The two elements find application primarily in level detection. The logic compares magnitudes of phase input currents IN*n* to pickup setting 50NN*nm*. These bits are independent, assert Relay Word bits 50NN*nm*, and can be used as indication of neutral current flow.

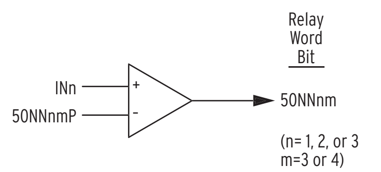


Figure 3.21 50NNnm Neutral Instantaneous O/C Element

51NN*n* Neutral Inverse-Time Elements (Torque Controlled)

Figure 3.22 shows the logic for the inverse-time 51NN*n* neutral element.

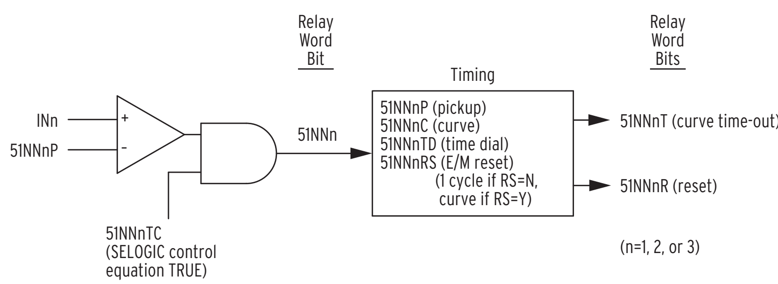


Figure 3.22 51NNn Neutral Inverse-Time O/C Element, Torque-Controlled

The 51NN*n* element logic compares the magnitude of the neutral current, IN*n*, to the pickup setting, 51NN*n*P. If the calculated 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 51NN*n*TC determines the other AND input. If 51NN*n*TC is true, Relay Word bit 51NN*n* asserts and the inverse curve begins timing.

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

Curve time-out causes Relay Word bit 51NN*n*T to assert. When the current drops below pickup, 51NN*n* deasserts and the element resets according to the setting for 51NN*n*RS. At the completion of the reset, Relay Word bit 51NN*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.

Setting Descriptions

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

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

Winding *n* Overcurrent Element and Demand Threshold Enables (EOC*n*)

Range: Y, N

Set EOC1 = Y to enable overcurrent elements and demand thresholds for Winding 1. The operation is identical for Winding 2. The relay default is for both winding overcurrent elements and demand thresholds to be enabled.

Neutral Overcurrent Elements Enable (EOCN)

Range: Y, N

Set EOCN = Y to enable the neutral overcurrent elements for all three inputs.

Instantaneous and Definite-Time Element Pickups (50P*nm*P, 50Q*nm*P, 50N*nm*P, 50NN*am*P)

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

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 (50P*n*1D, 50Q*n*1D, 50N*n*1D, 50N*na*1D)

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 (51P*n*P, 51Q*n*P, 51N*n*P, 51NN*a*P)

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 (51P*n*C, 51Q*n*C, 51N*n*C, 51NN*a*C)

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 (51P*n*TD, 51Q*n*TD, 51N*n*TD, 51NN*a*TD)

Range: US 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 (51P*n*RS, 51Q*n*RS, 51N*n*RS, 51NN*a*RS)

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 full reset of the time-overcurrent element one cycle after current drops below the element pickup setting.

Torque-Control Settings (50P*nm*TC, 50Q*nm*TC, 50N*nm*TC, 51P*n*TC, 51Q*n*TC, 51N*n*TC, 50NN*ma*TC, 51NN*a*TC)

Range: SELOGIC control equation

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 because of 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-387A 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 current and often contains a significant dc component. Unlike conventional electromechanical overcurrent elements, the SEL-387A 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-387A instantaneous, definite-time, and time-overcurrent elements need only be set with regard to expected load and fault conditions.

Where the SEL-387A 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-387A 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-387A phase-overcurrent elements respond to the maximum phase current magnitude, I_p, where I_p is the largest value of $|I_a|$, $|I_b|$, and $|I_c|$. Set phase overcurrent element pickup settings above the highest expected load current to avoid tripping on normal load current. You may set the pickup lower if you use torque control.

Since 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 $3I_2 = I_a + I_b \bullet (1\angle 240) + I_c \bullet (1\angle 120)$. For ABC rotation systems, 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 an unbalanced load. For this reason, select an element pickup setting above the maximum $3I_2$ current expected because of 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 $3I_0 = I_a + I_b + I_c$. 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 above the maximum $3I_0$ current expected because of 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-387A 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.

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 element. Make this setting when the SEL-387A 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-387A includes instantaneous and definite-time overcurrent elements for phase, negative-sequence, residual current, and neutral elements. 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-387A 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 2 is open, set 51PTC = IN104*!IN106 (i.e., IN104 AND NOT IN106, where IN106 was previously defined as representing the 52a-2 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 2.8*) were defined earlier. Overcurrent settings were chosen to complete the protection settings package.

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

For the 230 kV primary winding (Winding 1), three elements are set for overcurrent tripping of the 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. 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.

Time-Overcurrent Curve Reference Information

Definitions:

t_p = operating time in seconds

t_r = electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)

TD = time-dial setting

M = applied multiples of pickup current (for operating time (t_p), M > 1; for reset time (t_r), M ≤ 1)

Table 3.3 Equations Associated With U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$t_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 3.23*
U2 (Inverse)	$t_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 3.24*
U3 (Very Inverse)	$t_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 3.25*
U4 (Extremely Inverse)	$t_p = TD \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.67}{1 - M^2}\right)$	*Figure 3.26*
U5 (Short-Time Inverse)	$t_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 3.27*

Table 3.4 Equations Associated With IEC Curves

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$t_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 3.28*
C2 (Very Inverse)	$t_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 3.29*
C3 (Extremely Inverse)	$t_p = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 3.30*
C4 (Long-Time Inverse)	$t_p = TD \bullet \left(\frac{120}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 3.31*
C5 (Short-Time Inverse)	$t_p = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$t_r = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 3.32*

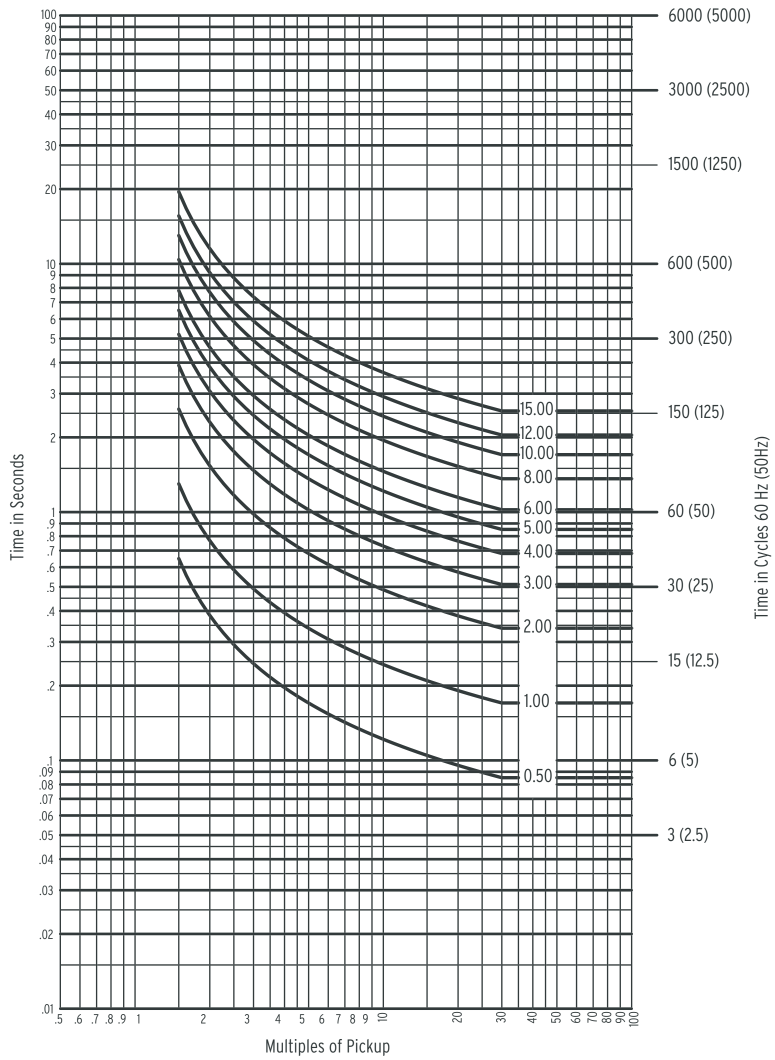


Figure 3.23 U.S. Moderately Inverse Curve: U1

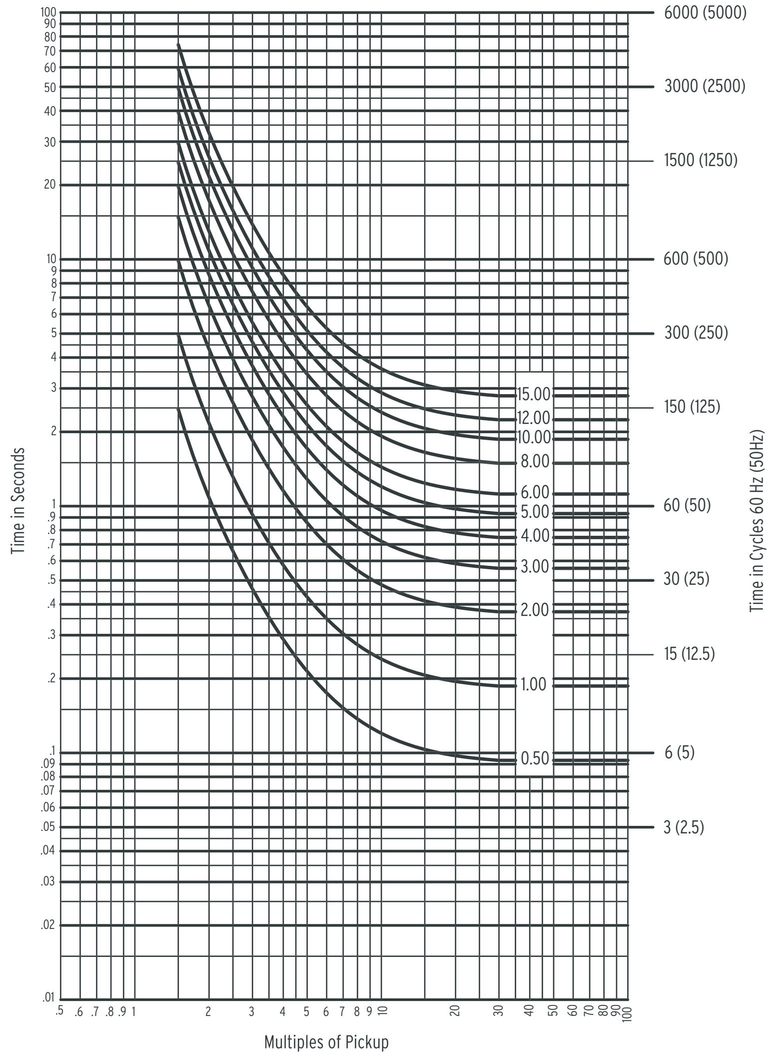


Figure 3.24 U.S. Inverse Curve: U2

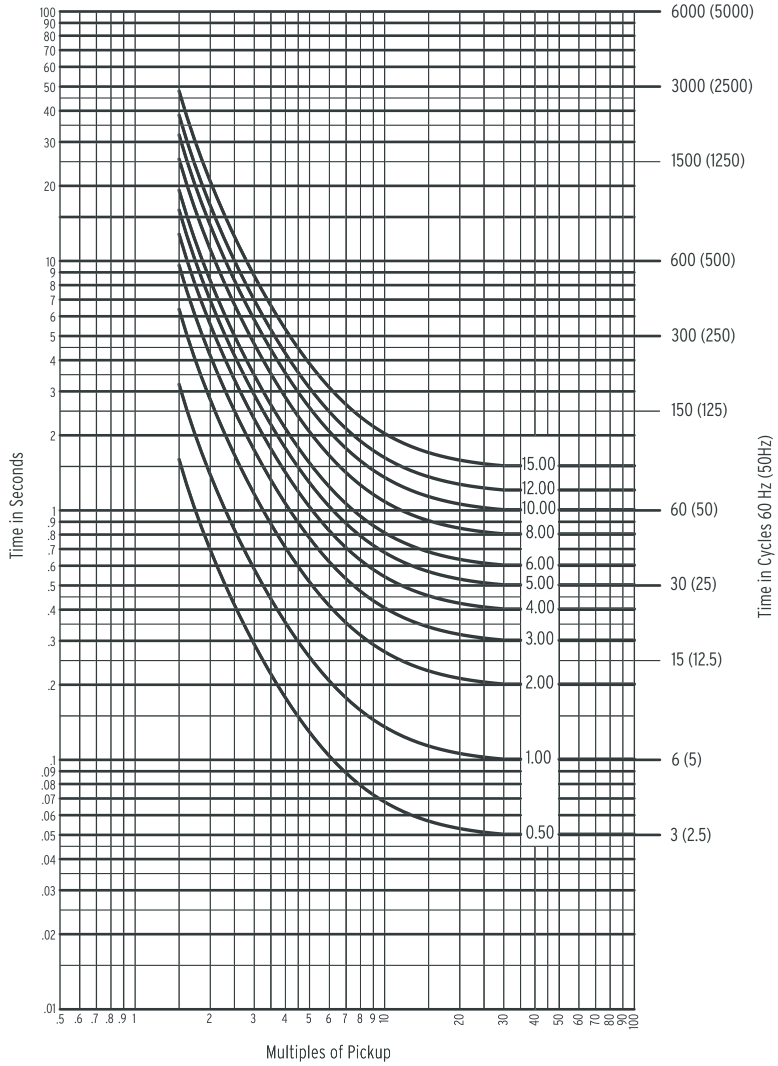


Figure 3.25 U.S. Very Inverse Curve: U3

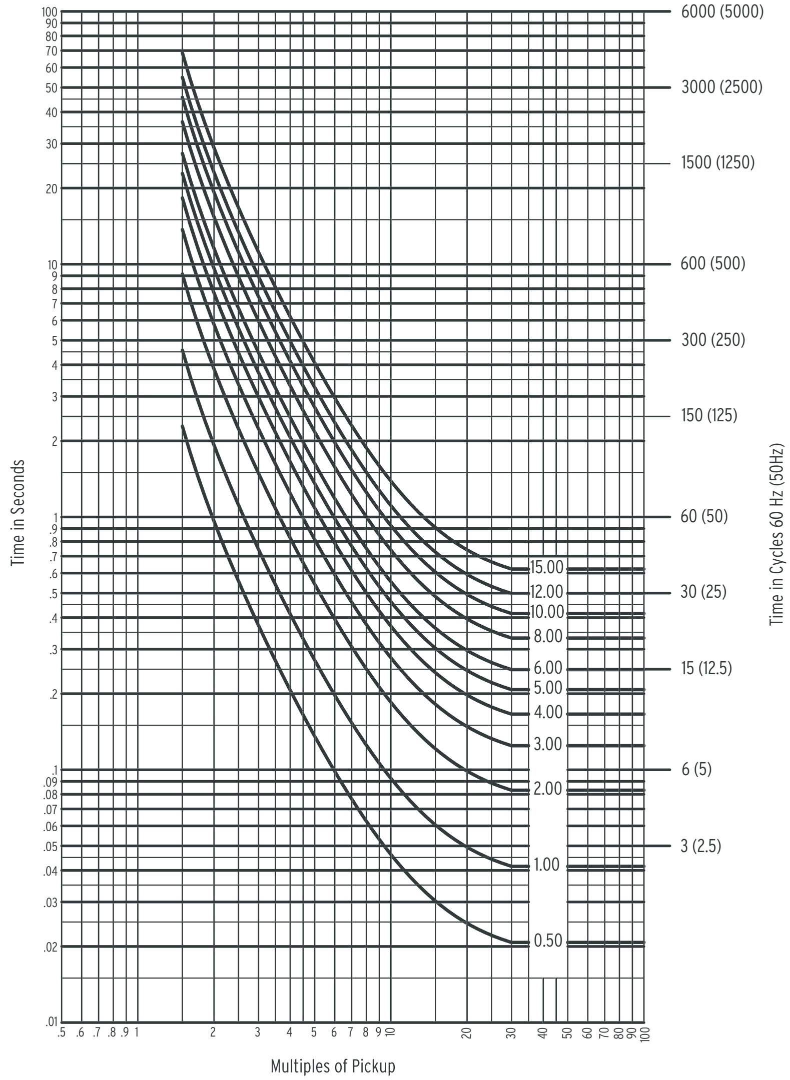


Figure 3.26 U.S. Extremely Inverse Curve: U4

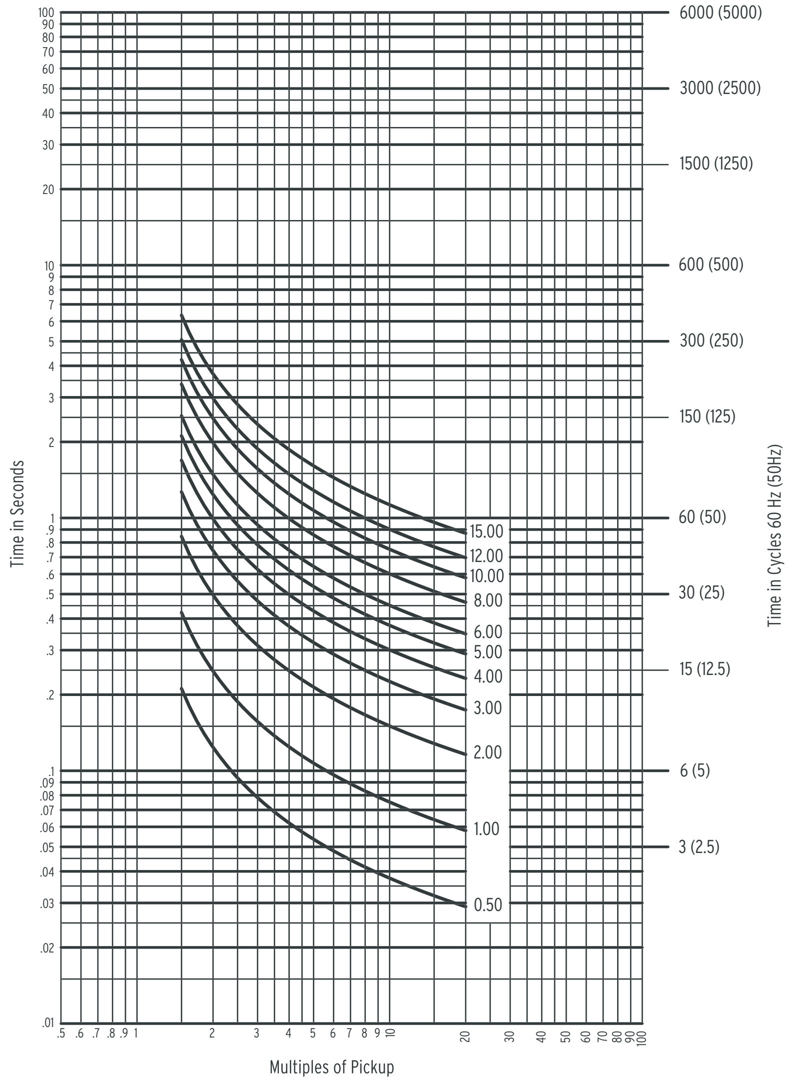


Figure 3.27 U.S. Short-Time Inverse Curve: U5

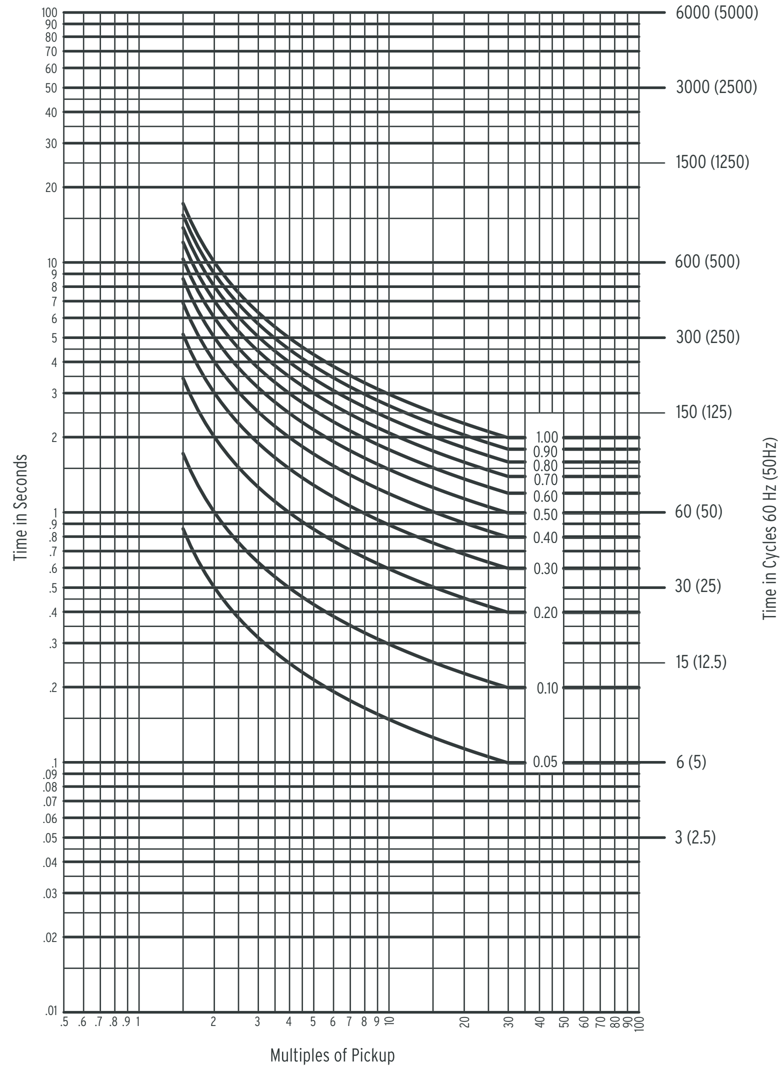


Figure 3.28 IEC Class A Curve (Standard Inverse): C1

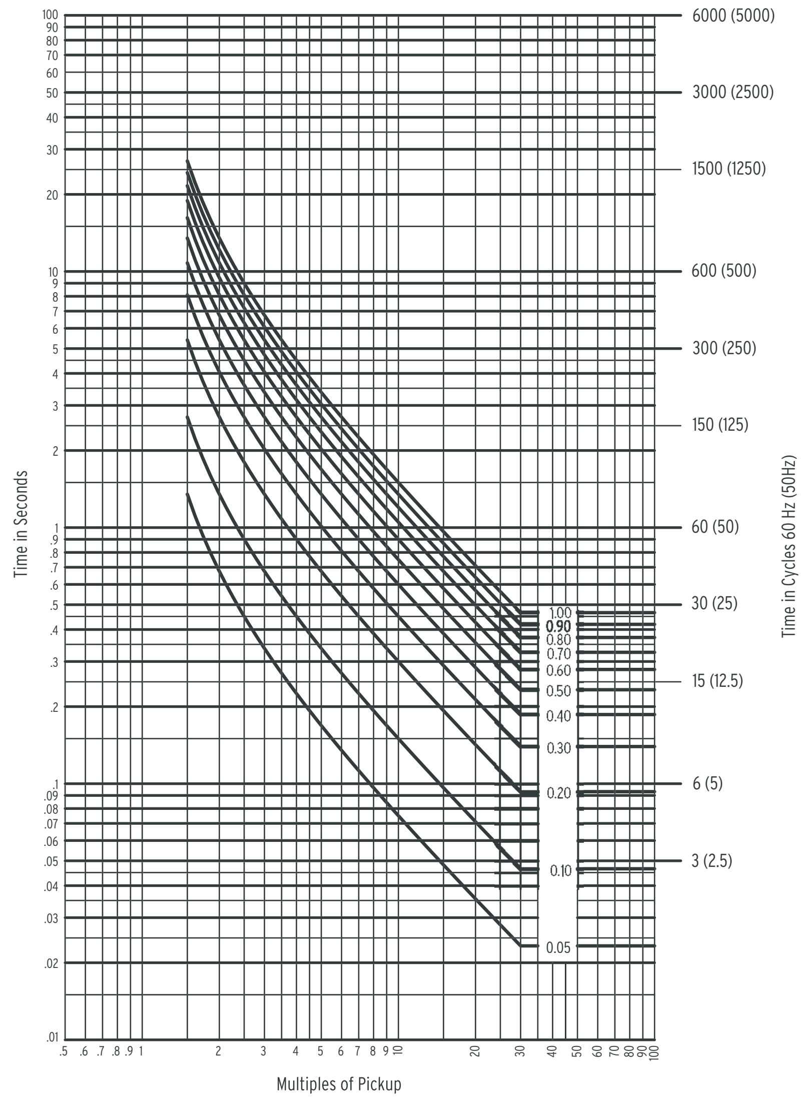


Figure 3.29 IEC Class B Curve (Very Inverse): C2

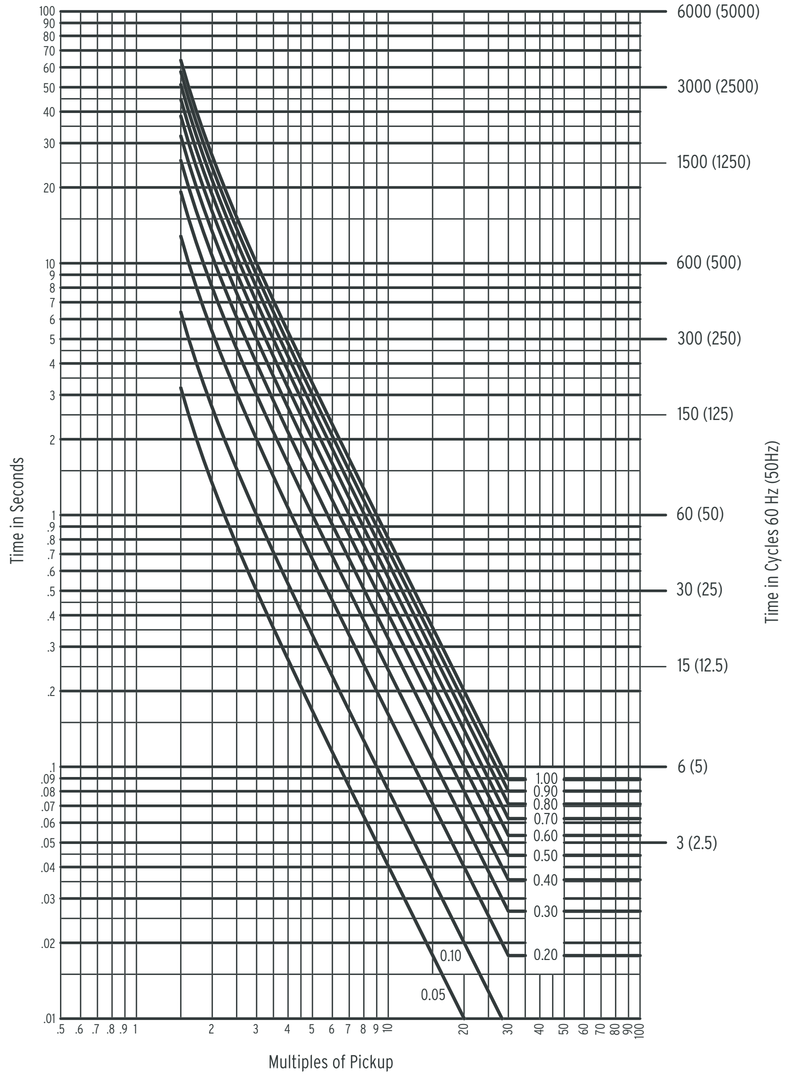


Figure 3.30 IEC Class C Curve (Extremely Inverse): C3

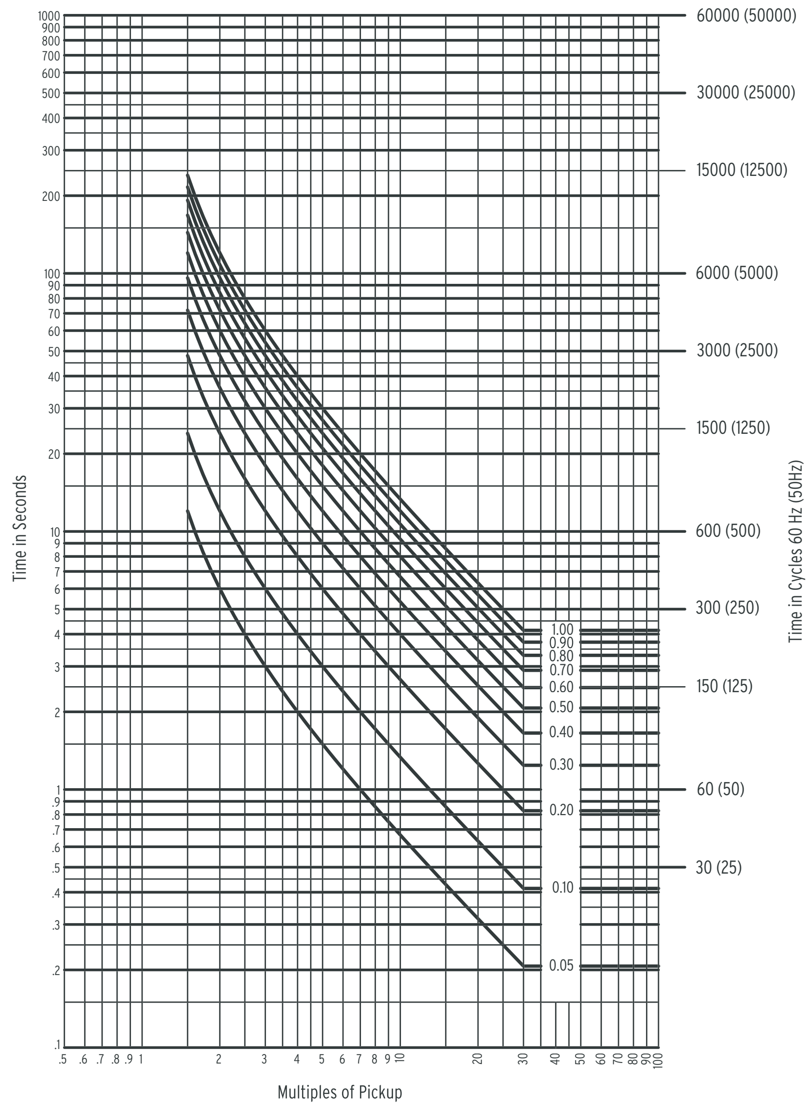


Figure 3.31 IEC Long-Time Inverse Curve: C4

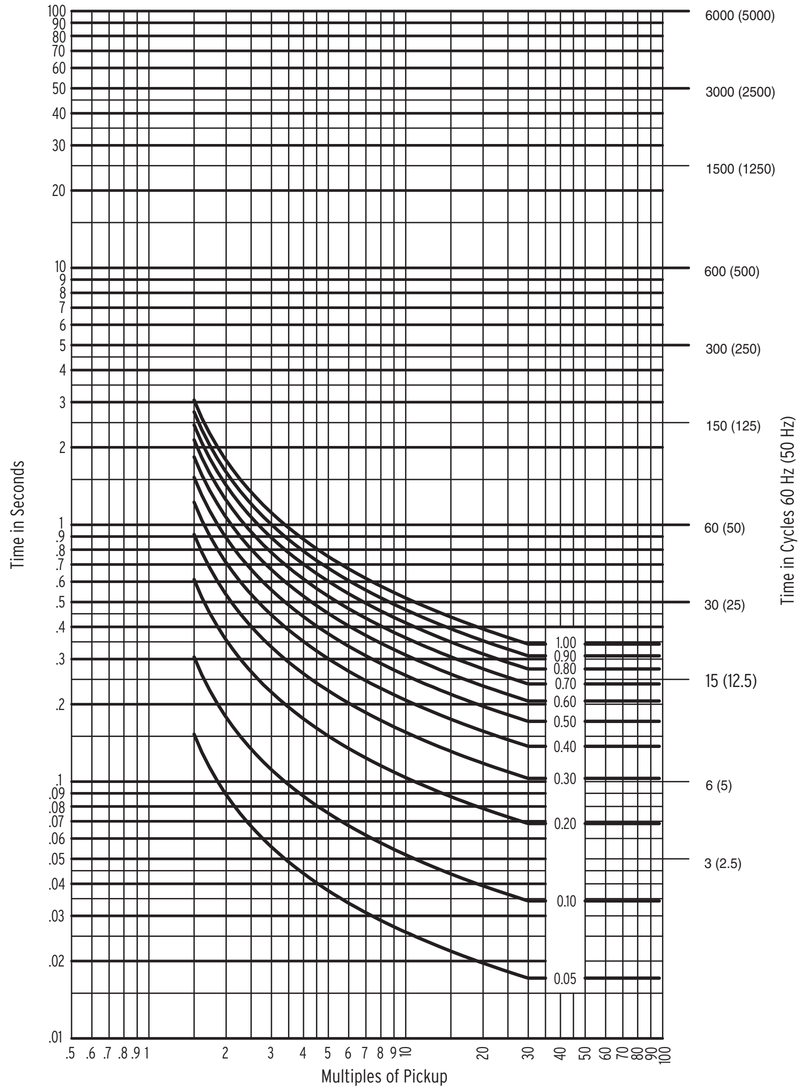


Figure 3.32 IEC Short-Time Inverse Curve: C5

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Section 4
Control Logic

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 through RB16)
Multiple setting groups	(Group switching settings SS1 through 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 the 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 through IN106, and IN201 through 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.

Figure 4.1 shows the standard main board (inputs IN101–IN106) with corresponding Relay Word bits IN101 through IN106. Similarly, *Figure 4.2* shows an additional interface board with eight inputs and corresponding Relay Word bits (IN201–IN208). The figures show examples of energized and de-energized optoisolated inputs and corresponding Relay Word bit states. To assert an input, apply rated control voltage to the appropriate terminal pair.

Figure 4.1 is used for the following discussion/examples. The optoisolated inputs in *Figure 4.2* operate similarly.

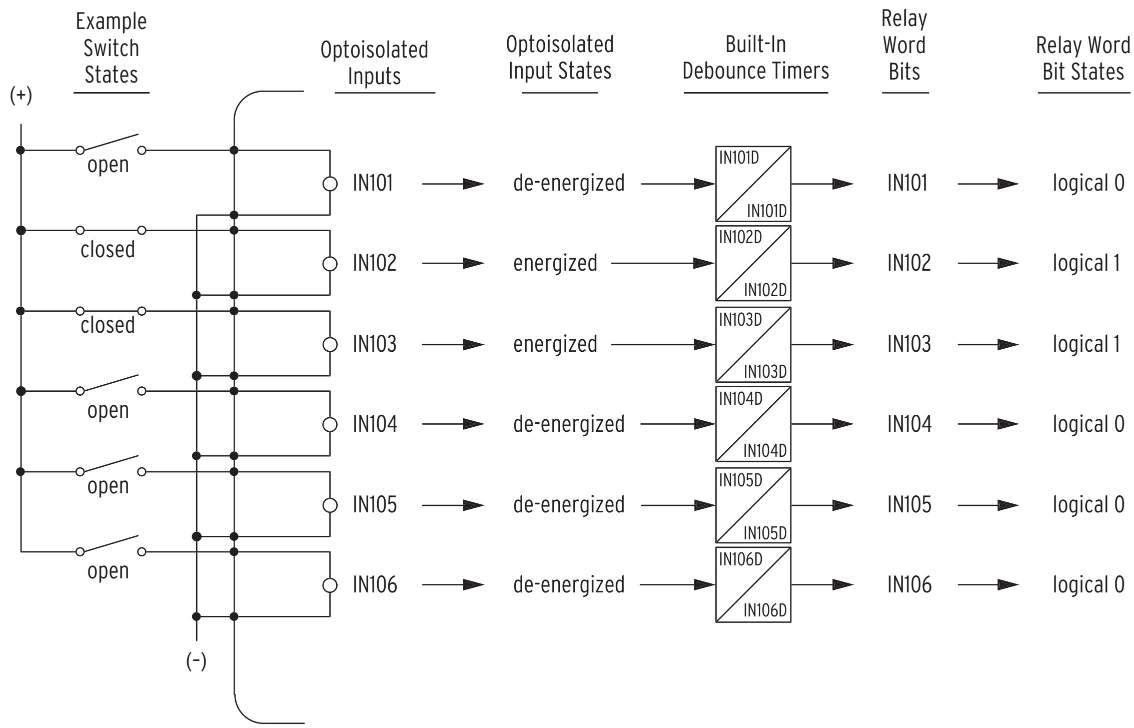

Figure 4.1 Example Operation of Optoisolated Inputs IN101 Through IN106 (Standard Mode)

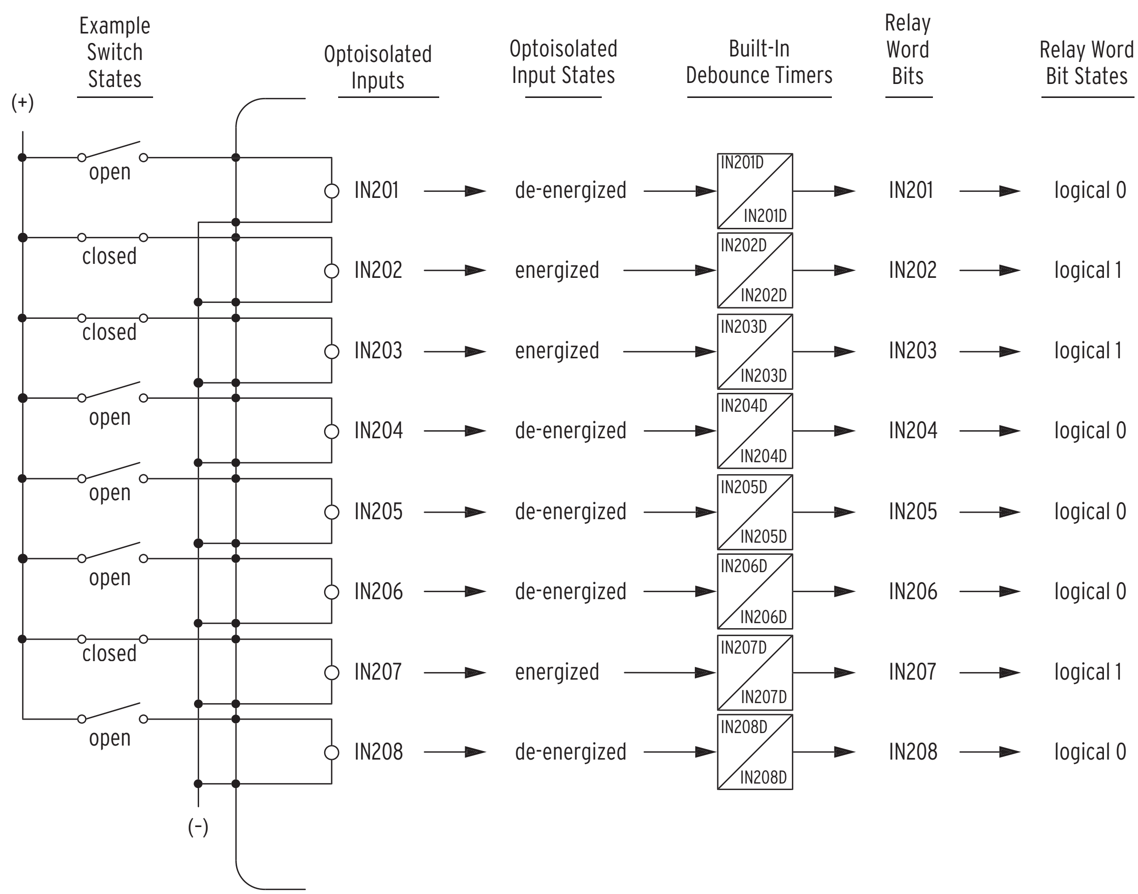

Figure 4.2 Example Operation of Optoisolated Inputs IN201 Through IN208 (Extra I/O Board)

Input Debounce Timers

Each input has settable pickup/dropout timers (IN101D through IN106D) for input energization/de-energization debounce. Note that a given time setting (e.g., IN101D = 0.50) is applied to both the pickup and dropout time for the corresponding input.

Time settings IN101D through IN106D are 0.00 to 2.00 cycles. Internally, the relay runs the entered time setting at the processing time interval of one-eighth of a power system cycle. For example, if setting IN105D = 0.8, the relay calculates the time delay as follows: delay = setting • processing interval, i.e., delay = 0.8 • 8 = 6.40 cycles. This value is then rounded to 6.00, the nearest integer, resulting in the actual time delay of 6/8 = 0.75 cycles.

For most applications, the input pickup/dropout debounce timers should be set in 1/8-cycle increments. The relay processing interval is one-eighth cycle, so Relay Word bits IN101 through IN106 are updated every one-eighth cycle.

If more than two cycles of debounce are needed, run Relay Word bit IN10*n* (*n* = 1 through 6) through a SELOGIC control equation variable timer and use the output of the timer for input functions. When an interface board with 16 digital inputs is used, only the first eight inputs of the board (IN201–IN208) will have debounce timers.

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 in *Factory Settings Examples*.

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 that 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 Interface*).

Remote Control Switches

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

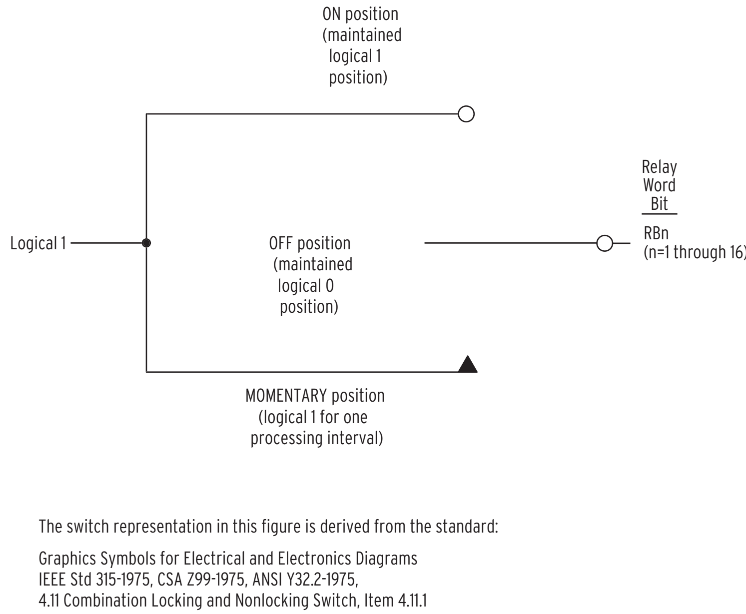

Figure 4.3 Remote Control Switches Drive Remote Bits RB1 Through RB16

The outputs of the remote control switches in *Figure 4.3* 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 when you want to remotely enable or disable certain logic, 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 independent setting groups. Each group contains Configuration Settings, General Data, Differential Elements, Overcurrent 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 **GROUP *n*** command (see *Section 7: Serial Port Communications and Commands*), or
- The front-panel **GROUP** pushbutton (see *Section 8: Front-Panel Interface*).

SELOGIC control equation settings SS1 through SS6 have priority over the serial port **GROUP *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 (Sheet 1 of 2)

Setting	Definition
SS1	go to (or remain in) Setting Group 1
SS2	go to (or remain in) Setting Group 2

Table 4.1 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1 Through SS6 (Sheet 2 of 2)

Setting	Definition
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 **GROUP *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 **GROUP *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 **GROUP *n*** command or the front-panel **GROUP** pushbutton can be used to switch the active setting group.

See *Section 7: Serial Port Communications and Commands* for more information on the serial port **GROUP *n*** command. See *Section 8: Front-Panel Interface* for more information on the front-panel **GROUP** pushbutton.

Relay Disabled Momentarily During Active Setting Group Change

The relay is disabled for a few seconds 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 (e.g., latch bit states are retained during an active setting group change).

Active Setting Group Switching Example

Previous SEL relays (e.g., SEL-321 Relay and SEL-251 Relay) have 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

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
1	0	1	Group 5
1	1	0	Group 6

The SEL-387A Relay can be programmed to operate similarly. Use three optoisolated inputs to switch between the six setting groups in the SEL-387A. In this example, optoisolated inputs IN101, IN102, and IN103 on the relay are connected to a rotating selector switch in *Figure 4.4*.

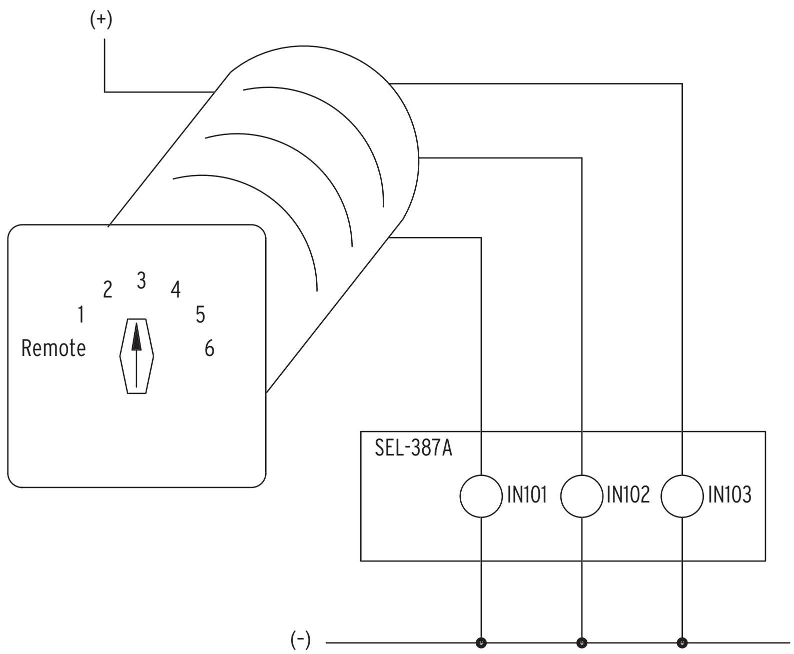

Figure 4.4 Rotating Selector Switch for Active Setting Group Selection

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 4.7* 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, it may be desirable 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 TR3 setting is TR3 = 87R + 87U; this could be changed to TR3 = 87R*!CHSG + 87U*!CHSG. CHSG optimizes (in this case minimizes) the amount of time to block TR3, 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 difference of a few cycles 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.

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 1 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 SELOGIC control equations. In the SEL-387A these variables are of two types: timed variables and latch bits. The variables are processed in the order in which they appear in the Setting Sheets. If variables that appear earlier are used as input 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 timed variables and 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 Variables

SELOGIC Control Equation Set	Timers	Latch Control Switches (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:	SnV*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:

0.00 through 999999.00 cycles in 0.125-cycle increments

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

Variables/Timers

Table 4.5 shows the logic for the variables and timers. 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.

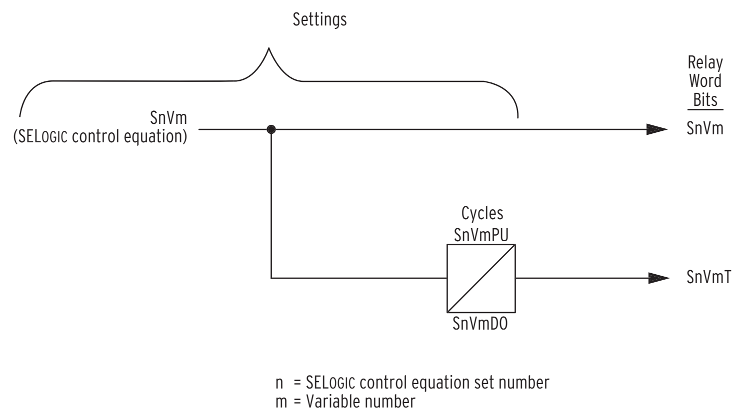

Figure 4.5 Timed Variables in SELOGIC Control Equation Sets

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 equation 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 4.6*). 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.).

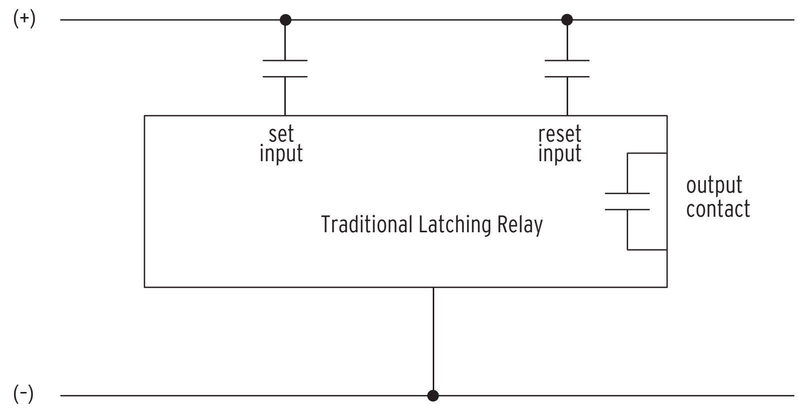

Figure 4.6 Traditional Latching Relay

The latch bits in the SEL-387A provide latching relay type functions (*Figure 4.7*).

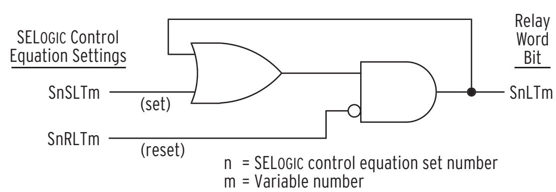

Figure 4.7 Latch Bits in SELOGIC Control Equation Sets

The output of the latch bit logic is a Relay Word bit S*n*LTm. The bit is set by application of S*n*SLTm (Set latch bit), and reset by the application of S*n*RLTm (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*SLTm (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 or may not 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 4.7*. 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-387A 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 OUT101 through OUT107 and OUT201 through OUT212 control Relay Word bits having the same names. These Relay Word bits in turn control the output contacts OUT101 through OUT107 and OUT201 through OUT212 (interface board). Alarm logic/circuitry controls the ALARM output contact.

Factory Settings Example

The factory SELOGIC control equation settings use standard main board output contacts:

OUT101 = TRIP1	Used to trip Breaker 1
OUT102 = TRIP2	Used to trip Breaker 2
OUT103 = TRIP3	Used to energize 86 device for tripping Breakers 1 and 2
OUT105 = CLS1	Used to close Breaker 1
OUT106 = CLS2	Used to close Breaker 2

Operation of Output Contacts for Different Output Contact Types

Output Contacts OUT101 through OUT107 and OUT201 through OUT212

The execution of the serial port command **PULSE *xxx*** (*xxx* = OUT101–OUT107, OUT201–OUT212), asserts the corresponding Relay Word bit (e.g., OUT103) 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 necessary.

To verify ALARM output contact functionality, execute the serial port command **PULSE ALARM**. 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-387A is operating correctly. When the serial port command **PULSE ALARM** (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 falls closed. The ALARM contact also drops closed 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 Interface* for details.

LED Targeting Logic

The SEL-387A has 16 LEDs on the front panel. One (EN) is dedicated to indication of the relay's operational condition. Ten are dedicated to specific targeting functions. Three (LEDA, LEDB, and LEDC) have default targeting logic but are fully programmable by the user. Two more, LED15 and LED16, have no default targeting logic and are fully programmable by the user.

The states of the 10 dedicated LEDs (all but EN, A, B, C, LED15, LED16) are stored in nonvolatile memory. If power is lost to the relay, these 10 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, C, LED15, and LED16 respond to the present state of their respective Global SELOGIC control equation settings.

The array of LEDs is shown in *Figure 4.8*.

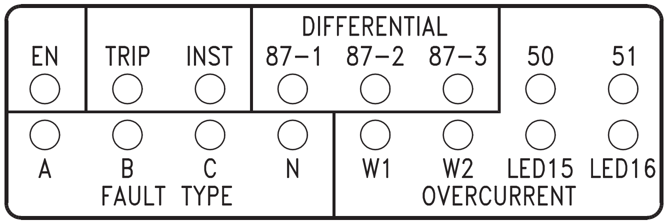

Figure 4.8 SEL-387A Front-Panel LEDs

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	50[a]	Instantaneous O/C element asserted at, or 1 cycle after, rising edge of trip
8	51[a]	Time O/C 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	LED15	Programmable LED15
16	LED16	Programmable LED16

[a] Nonvolatile target.

The operation of each LED is 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 five trip elements, TRIP1 through TRIP5. It remains illuminated 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 TR5 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 restricted earth fault forward direction bit, 32IF, as well as the 87R and 87U differential elements. LED 3 remains illuminated 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 TR5 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 illuminated 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 TR5 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 illuminated 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 TR5 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 illuminated 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—50—Instantaneous or Definite-Time Overcurrent Trip

This LED will illuminate if any instantaneous or definite-time overcurrent element present in the TR1 through TR5 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***" or "50***T" and the restricted earth fault forward direction bit, 32IF. LED 7 remains illuminated 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—51—Inverse-Time Overcurrent Element Trip

This LED will illuminate if any inverse-time overcurrent element present in the TR1 through TR5 settings has timed out and 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 "51**(*)T," which include the four combined overcurrent elements, as well as the REFP bit indicating time-out of the restricted earth fault inverse-time curve. LED 8 remains illuminated 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 **Wn** LED is illuminated, 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 discussion).

LED 10—B—B-Phase Involved in the Fault (Programmable LEDB)

LED 10 is programmable via the LEDB SELOGIC control equations 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 **Wn** LED is illuminated, 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 discussion).

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 **Wn** LED is illuminated, 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 discussion).

LED 12—N—Residual Overcurrent Element Trip

This LED will illuminate if any residual overcurrent element present in the TR1 through TR5 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." Also included are Combined Overcurrent elements indicated by Relay Word bits 51NC1T and 51NC2T and the restricted earth fault bits, 32IF and REFP. LED 12 remains illuminated 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 TR5 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 illuminated 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 TR5 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 illuminated 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—Programmable LED15

LED 15 is programmable via the LED15 SELOGIC control equation Global setting. It is updated each processing interval. If LED15 is true, LED 15 is illuminated. Otherwise, it is reset. The factory-default setting is LED15 = 0.

LED 16—Programmable LED16

LED 16 is programmable via the LED16 SELOGIC control equation Global setting. It is updated each processing interval. If LED16 is true, LED 16 is illuminated. Otherwise, it is reset. The factory-default setting is LED16 = 0.

Trip and Close Logic

The trip logic and close logic for the SEL-387A 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 five specific sets of trip logic within the SEL-387A. They are designed to operate when SELOGIC control equation trip variable setting TR*m* is asserted (*m* = 1, 2, 3, 4, 5) 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 4.9 shows the logic diagram for the TRIP1 logic. The remaining logic for TRIP2 through TRIP5 is identical, using variables TR2 through TR5 and ULTR2 through ULTR5, respectively.

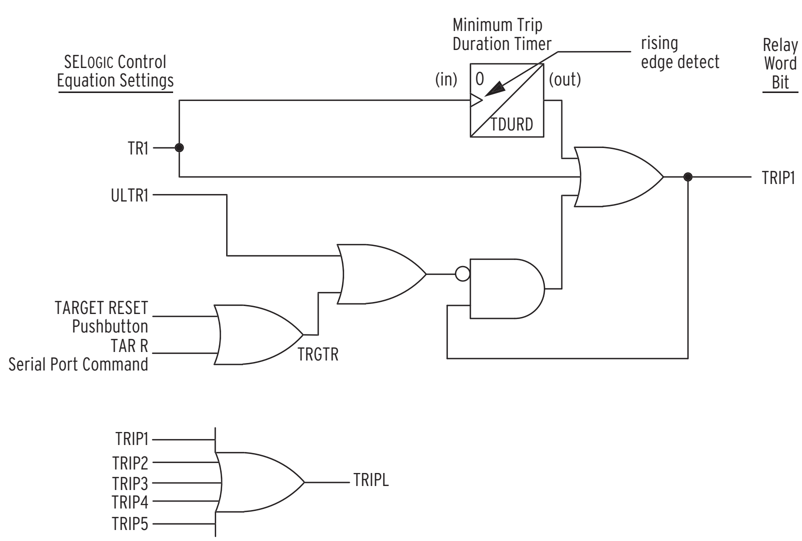

Figure 4.9 SEL-387A Trip Logic (TRIP1)

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, Latch Bit 3 (LB3), 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 only assert briefly while a more lengthy assertion of TRIP1 is desired. 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 itself in 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.

The unlatching of the trip logic is accomplished via three means. 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 so 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 the length of time TR1 has been asserted. This is the essence of the trip logic.

At the bottom of *Figure 4.9* is an additional OR gate. The five 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-387A.

Close Logic

There are four specific sets of close logic within the SEL-387A. They are designed to operate when SELOGIC control equation close variable setting CL*m* is asserted (*m* = 1, 2, 3, 4), 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 4.10 shows the logic diagram for the CLS1 logic. The remaining logic for CLS2 through CLS4 is identical, using variables CL2 through CL4 and ULCL2 through ULCL4, respectively.

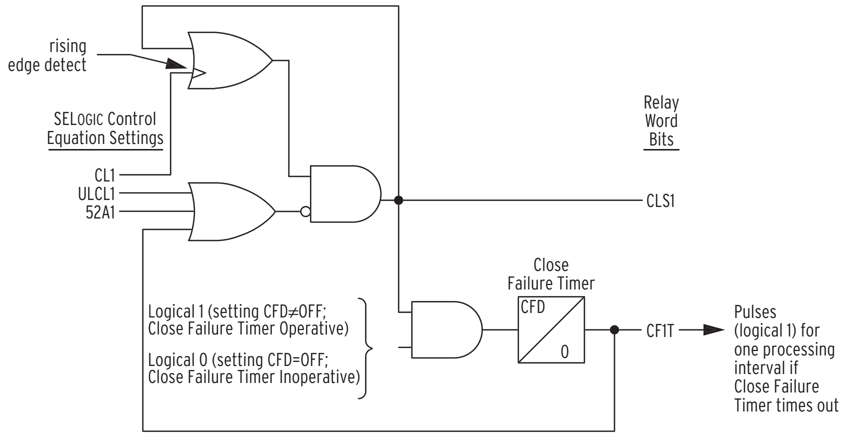

Figure 4.10 SEL-387A Close Logic (CLS1)

The logic begins with the assertion of SELOGIC control equation CL1, one of the Group variables. In our example application, CL1 = CC1 + LB4 + /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, or LB4 asserted. 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 that 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, it effectively will be ignored, 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 + TRIP3. 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 it will prevent it from going to completion if it has already begun.

Under normal circumstances, the second means of unlatching occurs. This is the closure of the Breaker 1 52a contact. 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 OFF if desired. This function is useful in the event the breaker does not close in response to energization of the closing circuit. This might be caused by 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. It is sent to the OR gate for the unlatch functions and interrupts the closing process. This prevents the closing circuit from being energized too long. It 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 would be worth 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.

SELOGIC Control Equations

This manual refers throughout to settings or variables that take the form of SELOGIC control equations. It is a convenient method for providing customized control logic to the relay, to enhance the relay performance for specific customer needs and practices.

While most users of SEL relays are at least somewhat familiar with SELOGIC control equations in a general sense, the capabilities of this logic, the types of logical operators, the number of allowable variables, and the construction rules of the equations have varied from one relay product to another. This portion of the manual is intended to inform the user of how SELOGIC control equations work in general and how they are implemented in the SEL-387A.

SELOGIC Control Equations Fundamental Description

The basic building blocks of SELOGIC control equations are the Relay Word bits. A complete list of these bits is included at the end of this section of the manual. 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. Relay Word bits are asserted or deasserted by various elements within the relay, and are used in the fixed internal logic of the relay to make decisions, to interpret inputs, or to drive outputs. These same bits are made available to the user, so that the user can 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 equation 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-387A, 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," that is you cannot have parentheses within parentheses. The following is an example:

S1V1 = (IN105 + RB3) * (87R + 87U)

The expressions within the parentheses are evaluated first. First, is IN105 OR RB3 asserted; next, is 87R OR 87U asserted. Assuming that at least one bit is asserted in each 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, it is represented by a small circle on an input or output line. 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. They are not interested in the present value of that bit, as are most operators. Rather, they are only intended to detect a change of that 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 + TRIP5. All TRIPL needs to assert is a 1 from any of the five 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.

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.

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.

Set 51P1TC Directly to 1

If 51P1TC = 1, the 51P1 element is always ready to operate on current alone.

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 relay supports an average of one rising- or falling-edge operator for every two SELOGIC control equations and an average of three Relay Word bits per SELOGIC control equation, with a maximum of 17 bits per any single SELOGIC control equation.

An attempt to set the relay with more than 17 operands will cause the relay to display the message “Maximum of 17 elements allowed in a SELOGIC equation” and prompt you to reenter the equation. Exceeding the maximum settings for each setting class will cause the relay to display the message “Overall SELOGIC setting size too large. Try simplifying equations.” The relay will then prompt you to edit the first unhidden SELOGIC control equation.

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-387A 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 GRnCHK) is yyyy. The relay provides use and checksum results for the GLOBAL and GROUP *n* settings.

Relay Word Bits

The available Relay Word bits that can be used in SELOGIC control equations (except Row 0 or Row 1 target elements) are listed below in *Table 4.7* through *Table 4.9*. *Table 4.7* shows the names and locations in each row. The row number or bit name can be used when using the **TAR** command. *Reserved for future use or not available in the SEL-387A.

Table 4.8 lists the Relay Word bit definitions, in their row order. *Table 4.9* lists the Relay Word bits alphabetically to provide an easier method for looking for a specific bit.

Table 4.7 SEL-387A Word Bits and Locations (Sheet 1 of 3)

Row	SEL-387A Relay Word Bits[a]							
0	EN	TRIP	INST	87-1	87-2	87-3	50	51
1	A	B	C	N	W1	W2	LED15	LED16
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
7	50A23	50B23	50C23	50P23	50A24	50B24	50C24	50P24

Table 4.7 SEL-387A Word Bits and Locations (Sheet 2 of 3)

Row	SEL-387A Relay Word Bits[a]							
8	50N21	50N21T	50N22	51N2	51N2T	51N2R	NDEM2	OC2
9	50Q21	50Q21T	50Q22	51Q2	51Q2T	51Q2R	QDEM2	CC2
10	*	*	*	*	*	*	*	OCC
11	*	*	*	*	*	*	*	*
12	*	*	*	*	*	*	*	*
13	*	*	*	*	*	*	*	*
14	*	*	*	*	*	*	*	*
15	*	*	*	*	*	*	*	*
16	*	*	*	*	*	*	*	*
17	*	*	*	*	*	*	*	*
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	*
21	87O1	87O2	87O3	*	*	*	*	*
22	*	*	*	*	*	*	DC1	DC2
23	*	*	*	*	*	*	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	*
27	4HBL	DCBL	IN106	IN105	IN104	IN103	IN102	IN101
28	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201
29	IN216	IN215	IN214	IN213	IN212	IN211	IN210	IN209
30	*	*	*	*	*	*	*	*
31	*	*	*	*	*	*	*	*
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	*	*	*	*	*	*	*	*
39	BCWA1	BCWB1	BCWC1	BCW1	BCWA2	BCWB2	BCWC2	BCW2
40	*	*	*	*	*	*	*	*
41	TRIP1	TRIP2	TRIP3	TRIP4	TRIP5	TRIPL	*	TRGTR
42	CLS1	CLS2	CLS3	CLS4	CF1T	CF2T	CF3T	CF4T
43	NOTALM	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101
44	OUT201	OUT202	OUT203	OUT204	OUT205	OUT206	OUT207	OUT208
45	OUT209	OUT210	OUT211	OUT212	OUT213	OUT214	OUT215	OUT216
46	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*
48	LB1	LB2	LB3	LB4	LB5	LB6	LB7	LB8

Table 4.7 SEL-387A Word Bits and Locations (Sheet 3 of 3)

Row	SEL-387A Relay Word Bits[a]							
49	LB9	LB10	LB11	LB12	LB13	LB14	LB15	LB16
50	50GC1	50GN1	32IE1	32IR1	32IF1	REFP1	CTS1	*
51	50GC2	50GN2	32IE2	32IR2	32IF2	REFP2	CTS2	*
52	*	*	*	*	*	*	*	*
53	49A01A	49T01A	49A02A	49T02A	49A03A	49T03A	49A04A	49T04A
54	49A05A	49T05A	49A06A	49T06A	49A07A	49T07A	49A08A	49T08A
55	49A09A	49T09A	49A10A	49T10A	49A11A	49T11A	49A12A	49T12A
56	49A01B	49T01B	49A02B	49T02B	49A03B	49T03B	49A04B	49T04B
57	49A05B	49T05B	49A06B	49T06B	49A07B	49T07B	49A08B	49T08B
58	49A09B	49T09B	49A10B	49T10B	49A11B	49T11B	49A12B	49T12B
59	COMFLA	RTDINA	COMFLB	RTDINB	*	*	*	ISQTAL
60	50NN11	50NN1T	50NN12	50NN13	50NN14	51NN1	51NN1T	51NN1R
61	50NN21	50NN2T	50NN22	50NN23	50NN24	51NN2	51NN2T	51NN2R
62	50NN31	50NN3T	50NN32	50NN33	50NN34	51NN3	51NN3T	51NN3R

[a] * = Reserved for future use or not available in the SEL-387A.

Table 4.8 Relay Word Bit Definitions (Sheet 1 of 12)

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

Table 4.8 Relay Word Bit Definitions (Sheet 2 of 12)

Row	Bit	Definition
	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
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

Table 4.8 Relay Word Bit Definitions (Sheet 3 of 12)

Row	Bit	Definition
	QDEM2	Winding 2 neg.-seq. demand current threshold exceeded
	CC2	Breaker 2 **CLOSE** command execution
10	*	
	*	
	*	
	*	
	*	
	*	
	*	
	OCC	O/C element C-Phase selection
11–17	*	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
	*	Reserved for future use
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
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use

Table 4.8 Relay Word Bit Definitions (Sheet 4 of 12)

Row	Bit	Definition
	*	Reserved for future use
	*	Reserved for future use
22	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
	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
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

Table 4.8 Relay Word Bit Definitions (Sheet 5 of 12)

Row	Bit	Definition
	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
	*	Reserved
	*	Reserved
	*	Reserved
	*	Reserved
	*	Reserved
	*	Reserved
	*	Reserved
31	*	Reserved
	*	Reserved
	*	Reserved
	*	Reserved
	*	Reserved
	*	Reserved

Table 4.8 Relay Word Bit Definitions (Sheet 6 of 12)

Row	Bit	Definition
	*	Reserved
	*	Reserved
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
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

Table 4.8 Relay Word Bit Definitions (Sheet 7 of 12)

Row	Bit	Definition
	S2LT3	Set 2 latch bit S2LT3 asserted
	S2LT4	Set 2 latch bit S2LT4 asserted
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
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
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	*	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
41	TRIP1	Trip 1 logic asserted
	TRIP2	Trip 2 logic asserted
	TRIP3	Trip 3 logic asserted
	TRIP4	Trip 4 logic asserted
	TRIP5	Trip 5 logic asserted
	TRIPL	Any trip asserted

Table 4.8 Relay Word Bit Definitions (Sheet 8 of 12)

Row	Bit	Definition
	*	Reserved for future use
	TRGTR	**Target Reset** pushbutton/**TAR R** command
42	CLS1	Breaker 1 CLOSE output asserted
	CLS2	Breaker 2 CLOSE output asserted
	CLS3	Breaker 3 CLOSE output asserted
	CLS4	Breaker 4 CLOSE output asserted
	CF1T	Breaker 1 close failure timer timed out
	CF2T	Breaker 2 close failure timer timed out
	CF3T	Breaker 3 close failure timer timed out
	CF4T	Breaker 4 close failure timer timed out
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	*	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 4.8 Relay Word Bit Definitions (Sheet 9 of 12)

Row	Bit	Definition
	*	Reserved for future use
	*	Reserved for future use
47	*	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
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
50	50GC1	Element 1 winding residual current exceeded sensitivity threshold
	50GN1	Element 1 neutral current exceeded sensitivity threshold
	32IE1	Internal enable for the REF1 32I element
	32IR1	Element 1 32I element reverse (external) fault declaration
	32IF1	Element 1 32I element forward (internal) fault declaration
	REFP1	Element 1 REF inverse-time O/C element timed out
	CTS1	Element 1 current transformer saturation
	*	Reserved for future use
51	50GC2	Element 2 winding residual current exceeded sensitivity threshold
	50GN2	Element 2 neutral current exceeded sensitivity threshold
	32IE2	Internal enable for the REF2 32I element
	32IR2	Element 2 32I element reverse (external) fault declaration
	32IF2	Element 2 32I element forward (internal) fault declaration
	REFP2	Element 2 REF inverse-time O/C element timed out

Table 4.8 Relay Word Bit Definitions (Sheet 10 of 12)

Row	Bit	Definition
	CTS2	Element 2 current transformer saturation
	*	Reserved for future use
52	*	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
53	49A01A	RTD1A alarm picked up
	49T01A	RTD1A trip picked up
	49A02A	RTD2A alarm picked up
	49T02A	RTD2A trip picked up
	49A03A	RTD3A alarm picked up
	49T03A	RTD3A trip picked up
	49A04A	RTD4A alarm picked up
	49T04A	RTD4A trip picked up
54	49A05A	RTD5A alarm picked up
	49T05A	RTD5A trip picked up
	49A06A	RTD6A alarm picked up
	49T06A	RTD6A trip picked up
	49A07A	RTD7A alarm picked up
	49T07A	RTD7A trip picked up
	49A08A	RTD8A alarm picked up
	49T08A	RTD8A trip picked up
55	49A09A	RTD9A alarm picked up
	49T09A	RTD9A trip picked up
	49A10A	RTD10A alarm picked up
	49T10A	RTD10A trip picked up
	49A11A	RTD11A alarm picked up
	49T11A	RTD11A trip picked up
	49A12A	RTD12A alarm picked up
	49T12A	RTD12A trip picked up
56	49A01B	RTD1B alarm picked up
	49T01B	RTD1B trip picked up
	49A02B	RTD2B alarm picked up
	49T02B	RTD2B trip picked up
	49A03B	RTD3B alarm picked up
	49T03B	RTD3B trip picked up

Table 4.8 Relay Word Bit Definitions (Sheet 11 of 12)

Row	Bit	Definition
	49A04B	RTD4B alarm picked up
	49T04B	RTD4B trip picked up
57	49A05B	RTD5B alarm picked up
	49T05B	RTD5B trip picked up
	49A06B	RTD6B alarm picked up
	49T06B	RTD6B trip picked up
	49A07B	RTD7B alarm picked up
	49T07B	RTD7B trip picked up
	49A08B	RTD8B alarm picked up
	49T08B	RTD8B trip picked up
58	49A09B	RTD9B alarm picked up
	49T09B	RTD9B trip picked up
	49A10B	RTD10B alarm picked up
	49T10B	RTD10B trip picked up
	49A11B	RTD11B alarm picked up
	49T11B	RTD11B trip picked up
	49A12B	RTD12B alarm picked up
	49T12B	RTD12B trip picked up
59	COMFLA	Asserts when communications fails or when out-of-range temperature data received from RTDA
	RTDINA	State of external RTDA module's digital input
	COMFLB	Asserts when communications fails or when out-of-range temperature data received from RTDB
	RTDINB	State of external RTDB module's digital input
	*	Reserved for future use
	*	Reserved for future use
	*	Reserved for future use
	ISQTAL	Cumulative through-fault I^2t on a phase of a designated winding has exceeded the through-fault I^2t threshold ISQT
60	50NN11	Neutral Definite-Time O/C Element 1 Level 1 picked up
	50NN1T	Neutral Definite-Time O/C Element 1 Level 1 timed out
	50NN12	Neutral Instantaneous O/C Element 1 Level 2 picked up
	50NN13	Neutral Instantaneous O/C Element 1 Level 3 picked up
	50NN14	Neutral Instantaneous O/C Element 1 Level 4 picked up
	51NN1	Neutral Inverse-Time O/C Element 1 picked up
	51NN1T	Neutral Inverse-Time O/C Element 1 timed out
	51NN1R	Neutral Inverse-Time O/C Element 1 is reset
61	50NN21	Neutral Definite-Time O/C Element 2 Level 1 picked up
	50NN2T	Neutral Definite-Time O/C Element 2 Level 1 timed out
	50NN22	Neutral Instantaneous O/C Element 2 Level 2 picked up
	50NN23	Neutral Instantaneous O/C Element 2 Level 3 picked up
	50NN24	Neutral Instantaneous O/C Element 2 Level 4 picked up
	51NN2	Neutral Inverse-Time O/C Element 2 picked up

Table 4.8 Relay Word Bit Definitions (Sheet 12 of 12)

Row	Bit	Definition
	51NN2T	Neutral Inverse-Time O/C Element 2 timed out
	51NN2R	Neutral Inverse-Time O/C Element 2 is reset
62	50NN31	Neutral Definite-Time O/C Element 3 Level 1 picked up
	50NN3T	Neutral Definite-Time O/C Element 3 Level 1 timed out
	50NN32	Neutral Instantaneous O/C Element 3 Level 2 picked up
	50NN33	Neutral Instantaneous O/C Element 3 Level 3 picked up
	50NN34	Neutral Instantaneous O/C Element 3 Level 4 picked up
	51NN3	Neutral Inverse-Time O/C Element 3 picked up
	51NN3T	Neutral Inverse-Time O/C Element 3 timed out
	51NN3R	Neutral Inverse-Time O/C Element 3 is reset

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 1 of 9)

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
32IE1	Internal enable for the REF1 32I element	50
32IE2	Internal enable for the REF2 32I element	51
32IF1	Element 1 32I element forward (internal) fault declaration	50
32IF2	Element 2 32I element forward (internal) fault declaration	51
32IR1	Element 1 32I element reverse (external) fault declaration	50
32IR2	Element 2 32I element reverse (external) fault declaration	51
49A01A	RTD1A alarm picked up	53
49A01B	RTD1B alarm picked up	56
49A02A	RTD2A alarm picked up	53
49A02B	RTD2B alarm picked up	56
49A03A	RTD3A alarm picked up	53
49A03B	RTD3B alarm picked up	56
49A04A	RTD4A alarm picked up	53
49A04B	RTD4B alarm picked up	56
49A05A	RTD5A alarm picked up	54
49A05B	RTD5B alarm picked up	57
49A06A	RTD6A alarm picked up	54
49A06B	RTD6B alarm picked up	57
49A07A	RTD7A alarm picked up	54
49A07B	RTD7B alarm picked up	57
49A08A	RTD8A alarm picked up	54
49A08B	RTD8B alarm picked up	57
49A09A	RTD9A alarm picked up	55

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 2 of 9)

Bit	Definition	Row
49A09B	RTD9B alarm picked up	58
49A10A	RTD10A alarm picked up	55
49A10B	RTD10B alarm picked up	58
49A11A	RTD11A alarm picked up	55
49A11B	RTD11B alarm picked up	58
49A12A	RTD12A alarm picked up	55
49A12B	RTD12B alarm picked up	58
49T01A	RTD1A trip picked up	53
49T01B	RTD1B trip picked up	56
49T02A	RTD2A trip picked up	53
49T02B	RTD2B trip picked up	56
49T03A	RTD3A trip picked up	53
49T03B	RTD3B trip picked up	56
49T04A	RTD4A trip picked up	53
49T04B	RTD4B trip picked up	56
49T05A	RTD5A trip picked up	54
49T05B	RTD5B trip picked up	57
49T06A	RTD6A trip picked up	54
49T06B	RTD6B trip picked up	57
49T07A	RTD7A trip picked up	54
49T07B	RTD7B trip picked up	57
49T08A	RTD8A trip picked up	54
49T08B	RTD8B trip picked up	57
49T09A	RTD9A trip picked up	55
49T09B	RTD9B trip picked up	58
49T10A	RTD10A trip picked up	55
49T10B	RTD10B trip picked up	58
49T11A	RTD11A trip picked up	55
49T11B	RTD11B trip picked up	58
49T12A	RTD12A trip picked up	55
49T12B	RTD12B trip picked up	58
4HBL	Fourth-harmonic block asserted	27
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
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
50C13	Winding 1 C-Phase instantaneous O/C Level 3 element picked up	3

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 3 of 9)

Bit	Definition	Row
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
50GC1	Element 1 winding residual current exceeded sensitivity threshold	50
50GC2	Element 2 winding residual current exceeded sensitivity threshold	51
50GN1	Element 1 neutral current exceeded sensitivity threshold	50
50GN2	Element 2 neutral current exceeded sensitivity threshold	51
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
50NN11	Neutral Definite-Time O/C Element 1 Level 1 picked up	65
50NN12	Neutral Instantaneous O/C Element 1 Level 2 picked up	65
50NN13	Neutral Instantaneous O/C Element 1 Level 3 picked up	65
50NN14	Neutral Instantaneous O/C Element 1 Level 4 picked up	65
50NN1T	Neutral Definite-Time O/C Element 1 Level 1 timed out	65
50NN21	Neutral Definite-Time O/C Element 2 Level 1 picked up	66
50NN22	Neutral Instantaneous O/C Element 2 Level 2 picked up	66
50NN23	Neutral Instantaneous O/C Element 2 Level 3 picked up	66
50NN24	Neutral Instantaneous O/C Element 2 Level 4 picked up	66
50NN2T	Neutral Definite-Time O/C Element 3 Level 1 timed out	66
50NN32	Neutral Instantaneous O/C Element 3 Level 2 picked up	67
50NN33	Neutral Instantaneous O/C Element 3 Level 3 picked up	67
50NN34	Neutral Instantaneous O/C Element 3 Level 4 picked up	67
50NN3T	Neutral Definite-Time O/C Element 3 Level 1 timed out	67
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
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
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

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 4 of 9)

Bit	Definition	Row
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
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
51NN1	Neutral Inverse-Time O/C Element 1 picked up	65
51NN1R	Neutral Inverse-Time O/C Element 1 is reset	65
51NN1T	Neutral Inverse-Time O/C Element 1 timed out	65
51NN2	Neutral Inverse-Time O/C Element 2 picked up	66
51NN2R	Neutral Inverse-Time O/C Element 2 is reset	66
51NN2T	Neutral Inverse-Time O/C Element 2 timed out	66
51NN3	Neutral Inverse-Time O/C Element 3 picked up	67
51NN3R	Neutral Inverse-Time O/C Element 3 is reset	67
51NN3T	Neutral Inverse-Time O/C Element 3 timed out	67
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
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. inverse-time O/C 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
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
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	Restrained Differential Element 1 operating current above O87P	21
87O2	Restrained Differential Element 2 operating current above O87P	21

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 5 of 9)

Bit	Definition	Row
87O3	Restrained 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
BCWA1	A-Phase Breaker 1 contact wear threshold exceeded	39
BCWA2	A-Phase Breaker 2 contact wear threshold exceeded	39
BCWB1	B-Phase Breaker 1 contact wear threshold exceeded	39
BCWB2	B-Phase Breaker 2 contact wear threshold exceeded	39
BCWC1	C-Phase Breaker 1 contact wear threshold exceeded	39
BCWC2	C-Phase Breaker 2 contact wear threshold exceeded	39
CC1	Breaker 1 **CLOSE** command execution	5
CC2	Breaker 2 **CLOSE** command execution	9
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
CF4T	Breaker 4 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
CLS4	Breaker 4 CLOSE output asserted	42
COMFLA	Asserts when communication fails or when out-of-range temperature data received from RTDA	59
COMFLB	Asserts when communication fails or when out-of-range temperature data received from RTDB	59
ISQTAL	Cumulative through-fault I^2t on a phase of a designated winding has exceeded the through-fault I^2t threshold ISQT	59
CTS1	Element 1 current transformer saturation	50
CTS2	Element 2 current transformer saturation	51
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

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 6 of 9)

Bit	Definition	Row
IN102	Input IN102 asserted	27
IN103	Input IN103 asserted	27
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
LB1	Local Bit 1 asserted	48
LB10	Local Bit 10 asserted	49
LB11	Local Bit 11 asserted	49
LB12	Local Bit 12 asserted	49
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
NDEM1	Winding 1 residual demand current threshold exceeded	4
NDEM2	Winding 2 residual demand current threshold exceeded	8
NOTALM	ALARM output not asserted	43
OC1	Breaker 1 **OPEN** command execution	4

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 7 of 9)

Bit	Definition	Row
OC2	Breaker 2 **OPEN** command execution	8
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
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
PDEM1	Winding 1 phase demand current threshold exceeded	2
PDEM2	Winding 2 phase demand current threshold exceeded	6
QDEM1	Winding 1 neg.-seq. demand current threshold exceeded	5
QDEM2	Winding 2 neg.-seq. demand current threshold exceeded	9
RB1	Remote bit RB1 asserted	24
RB10	Remote bit RB10 asserted	25
RB11	Remote bit RB11 asserted	25
RB12	Remote bit RB12 asserted	25
RB13	Remote bit RB13 asserted	25
RB14	Remote bit RB14 asserted	25
RB15	Remote bit RB15 asserted	25
RB16	Remote bit RB16 asserted	25
RB2	Remote bit RB2 asserted	24
RB3	Remote bit RB3 asserted	24

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 8 of 9)

Bit	Definition	Row
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
REFP1	Element 1 REF inverse-time O/C element timed out	50
REFP2	Element 2 REF inverse-time O/C element timed out	51
RTDINA	State of external RTDA module's digital input	59
RTDINB	State of external RTDB module's digital input	59
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
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

Table 4.9 Relay Word Bits Sorted Alphabetically (Sheet 9 of 9)

Bit	Definition	Row
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
TRIP1	Trip 1 logic asserted	41
TRIP2	Trip 2 logic asserted	41
TRIP3	Trip 3 logic asserted	41
TRIP4	Trip 4 logic asserted	41
TRIP5	Trip 5 logic asserted	41
TRIPL	Any trip asserted	41

Section 5
Metering and Monitoring

Introduction

The SEL-387A Relay provides metering information in several report formats for each of the two three-phase winding current 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.

Winding 3 and Winding 4 Reporting

The SEL-387A satisfies the requirement for a two-winding differential relay equipped with extensive I/O. To this end, the SEL-387A is a subset of the larger SEL-387 Relay, including most functions of the SEL-387, but suitable for two-winding applications only. Because the SEL-387A retains the reporting structure of the SEL-387, the report formats still include rows and/or columns for Windings 3 and 4. Because current values for Winding 3 no longer apply, they are displayed as zeros and should be ignored. When you order an SEL-387A with the optional restricted earth fault (REF) elements, current channels assigned to Winding 4 in the SEL-387 are reassigned to represent neutral currents IN1, IN2, and IN3 (i.e., IAW4 = IN1, IBW4 = IN2, and ICW4 = IN3). In an SEL-387A without the REF option, the current values for Winding 4 are displayed as zeros.

Metering Functions

There are three types of fundamental frequency metering functions in the SEL-387A: instantaneous, demand (thermal), and peak demand. Quantities metered include phase currents for both winding inputs; positive-, negative-, and zero-sequence (residual) currents for both winding inputs; 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 display.

There is also a specialized metering function, Harmonic Metering. It provides a snapshot of harmonic current magnitudes in the phase currents, fundamental through the fifteenth 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 would 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 Interface*.

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 Current Meter Function (METER Command)

The **METER** or **MET** command, with no additional parameters, displays instantaneous magnitude values, in primary rms amperes of the three-phase currents, the positive-sequence current, negative-sequence current, and residual current, for both of the winding inputs, and measured current of the three neutral inputs. It also displays the value of the station battery dc supply voltage at the relay, 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. The format for the **MET** report is as follows:

```
=>>METER <Enter>

XFMER 1                                  Date: 01/13/02    Time: 10:30:27.930
STATION A

                  Phase Currents                    Sequence Currents

Wdg1            IAW1      IBW1      ICW1          3I1W1     3I2W1      IRW1
I (A,pri)       12345     12345     12345         12345     12345      12345

Wdg2            IAW2      IBW2      ICW2          3I1W2     3I2W2      IRW2
I (A,pri)       12345     12345     12345         12345     12345      12345

Wdg3            IAW3      IBW3      ICW3          3I1W3     3I2W3      IRW3
I (A,pri)           0         0         0             0         0          0

Wdg4             IN1       IN2       IN3          3I1W4     3I2W4      IRW4
I (A,pri)       12345     12345     12345             0         0          0

VDC (V)            123
```

Demand Ammeter Function (METER D Command)

The SEL-387A includes a thermal demand metering function for both windings. In response to the **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 **MET D** report is as follows:

```
=>>METER D <Enter>

XFMER 1                                 Date: 01/13/02    Time: 10:30:27.930
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)      0         0         0              0         0

    Wdg4             IN1       IN2       IN3          3I2W4      IRW4
    Dem I (A,pri)      0         0         0              0         0

LAST DEMAND RESET FOR     Wdg1:    00/00/00    00:00:00.000
                              Wdg2:    00/00/00    00:00:00.000
                              Wdg3:    00/00/00    00:00:00.000
                              Wdg4:    00/00/00    00:00:00.000
```

The most recent demand resets for each winding are shown in the **METER D** report.

The Demand Ammeter function simulates the long-term heating effects of current 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). DATC*n* can be set over a range of 5 to 255 minutes (4 hrs 15 min). 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 greatest 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.

The demand ammeter 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

$$\mathrm{Id}(t) = \mathrm{I_{NEW}} + (\mathrm{Id_0} - \mathrm{I_{NEW}}) \bullet e^{-[\ln(10)] \bullet t/\mathrm{DATC}n]}$$

Equation 5.1

Peak Demand Ammeter Function (METER P Command)

The next function, the peak demand ammeter function, keeps track of the greatest value of Id(*t*) since the last reset of the peak demand registers.

The peak demand ammeter function compares the value of the demand ammeter outputs for each winding, i.e., the largest of the phase current demands, the negative-sequence demand, and the residual demand, against registers containing the greatest demand value of each type since the last reset of the registers. This is done 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 **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. 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 **MET P** report is as follows:

```
=>>METER P <Enter>

XFMER 1                                 Date: 01/13/02    Time: 10:30:27.930
STATION A

                   Peak Dem I (A,pri)       Date:           Time:

             Wdg 1    IAW1         0        01/13/02        05:27:41.025
                      IBW1         0        01/13/02        04:41:19.042
                      ICW1         0        01/13/02        02:33:45.027
                     3I2W1         0        01/12/02        18:10:41.027
                      IRW1         0        01/12/02        18:10:41.027

             Wdg 2    IAW2         0        01/12/02        21:00:23.027
                      IBW2         0        01/13/02        06:22:21.028
                      ICW2         0        01/12/02        08:42:17.032
                     3I2W2         0        01/13/02        05:03:17.047
                      IRW2         0        01/13/02        05:03:17.047

             Wdg 3    IAW3         0        00/00/00        00:00:00.000
                      IBW3         0        00/00/00        00:00:00.000
                      ICW3         0        00/00/00        00:00:00.000
                     3I2W3         0        00/00/00        00:00:00.000
                      IRW3         0        00/00/00        00:00:00.000

             Wdg 4     IN1         0        00/00/00        00:00:00.000
                       IN2         0        00/00/00        00:00:00.000
                       IN3         0        00/00/00        00:00:00.000
                     3I2W4         0        00/00/00        00:00:00.000
                      IRW4         0        00/00/00        00:00:00.000

         LAST PEAK DEMAND RESET FOR Wdg1:  00/00/00        00:00:00.000
                                    Wdg2:  00/00/00        00:00:00.000
                                    Wdg3:  00/00/00        00:00:00.000
                                    Wdg4:  00/00/00        00:00:00.000
```

The report for **MET 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, then divided by the TAP*n* value for each winding, and 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 comprise 87-2 and 87-3, respectively.

In response to the **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 **MET DIF** report is as follows:

```
=>>MET DIFF <Enter>

XFMER 1                            Date: 01/13/02    Time: 10:30:27.930
STATION A

                        Operate Currents            Restraint Currents
                    IOP1      IOP2      IOP3      IRT1      IRT2      IRT3
I (Mult. of Tap)    0.00      0.00      0.00      0.00      0.00      0.00

                    Second Harmonic Currents      Fifth Harmonic Currents
                    I1F2      I2F2      I3F2      I1F5      I2F5      I3F5
I (Mult. of Tap)    0.00      0.00      0.00      0.00      0.00      0.00
```

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 Current Metering Function (METER SEC Command)

The phasor current 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 degrees 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 **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 **MET 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)     0.00      0.00      0.00         0.00      0.00     0.00
Angle (deg)   0.00      0.00      0.00         0.00      0.00     0.00

Wdg4           IN1       IN2       IN3        3I1W4     3I2W4     IRW4
I (A,sec)     123.12    123.12    123.12       0.00      0.00     0.00
Angle (deg)  ±123.12   ±123.12   ±123.12       0.00      0.00     0.00
```

The phase angles given are all referenced to current IAW1. That is, the full set of 24 calculated current phasors is rotated in a manner that brings IAW1 to an angle of zero degrees. However, if the magnitude of IAW1 is less than 0.05x I_{NOM} (0.25A for a 5 A relay), the angles are listed according to the phasor calculation without further adjustment.

Demand Reset Functions (MET RD and MET RP Commands)

The demand ammeter function performs an integration of current over time and, as such, contains a “history” of the currents dating back minutes or hours from the present time. The peak demand ammeter 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, it may be desirable to erase this “history.”

The **MET RD *n*** (Reset Demand) command returns the demand ammeter current 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 **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 or 2 will produce a reset of all the demand or peak demand values for Winding *n*. If the letter A is entered, reset will be done on both 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 ammeters 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.

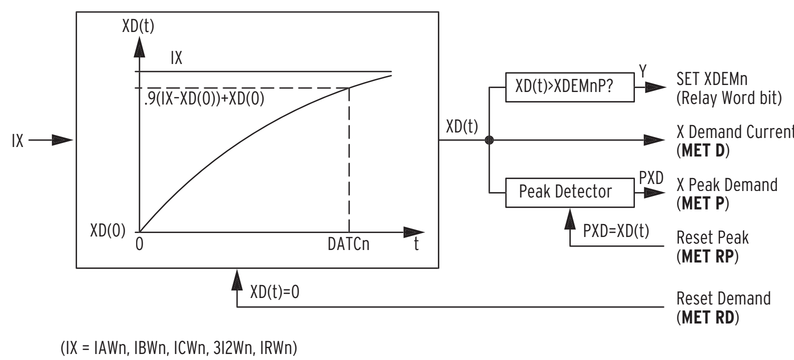

Figure 5.1 SEL-387A Demand Ammeter Functions and Commands

The Harmonic Metering function, in response to the **MET H** command, retrieves 1 full cycle of unfiltered sample data, at 64 samples per cycle, from each of the 12 analog current 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 fifteenth.

$$H_n = \sum_{k=0}^{N-1} h_k \bullet e^{j \cdot \frac{2\pi kn}{N}}$$ **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 the 15 harmonics are calculated, they are adjusted to compensate for filter gain, and the resulting magnitudes are listed in secondary amperes:

```
=>>MET H <Enter>
Processing harmonic spectrum ............

XFMR 1                                     Date: 01/21/02    Time: 08:03:58.920
STATION A

                     Magnitudes of Harmonic Currents (Amps Sec)
   H   IAW1  IBW1  ICW1  IAW2  IBW2  ICW2  IAW3  IBW3  ICW3   IN1   IN2   IN3

   1   2.09  2.08  2.09  1.73  1.74  1.73  0.00  0.00  0.00  4.98  1.99  4.99
   2   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   3   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.01  0.00
   4   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   5   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   6   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   7   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   8   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
   9   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
  10   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
  11   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
  12   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
  13   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
  14   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
  15   0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
=>
```

The Analog Input Labels, IAW1, etc., will be listed as they are set in the Global settings section of the relay.

Temperature Measurement

The relay accepts up to 12 RTD inputs from the SEL-2600 RTD Module at any one of the ports. The SEL-387A can use up to two SEL-2600s (two ports), processing the temperatures of a total of 24 RTDs.

```
=>>MET T <Enter>

XFMR 1                                     Date: 01/18/02    Time: 11:00:28.404
STATION A

RTDA Input Temperature Data (deg. C)
 Communication Failure

RTDB Input Temperature Data (deg. F)
 RTD 1B = 123
 RTD 2B = 123
 RTD 3B = 123
 RTD 4B = 123
 RTD 5B = 123
 RTD 6B = 123
 RTD 7B = 123
 RTD 8B = 123
 RTD 9B = 123
RTD 10B = 123
RTD 11B = 123
RTD 12B = 123

=>>
```

Station DC Battery Monitor

Use the station dc battery monitor in the SEL-387A 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.

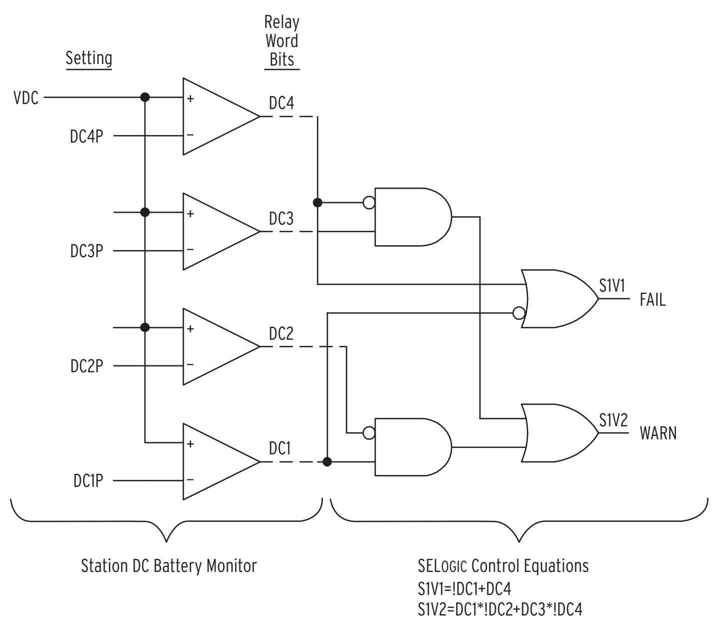

Figure 5.2 Station DC Battery Monitor Alarm Logic

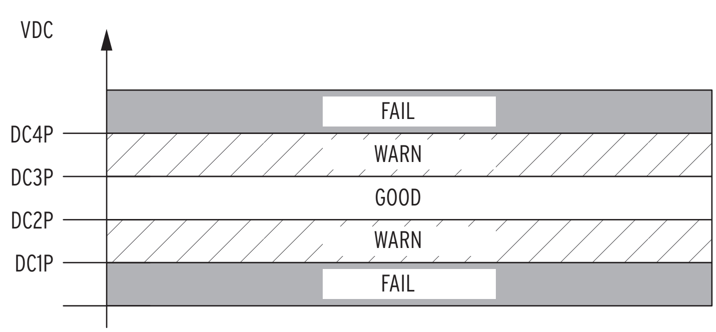

Figure 5.3 Undervoltage and Overvoltage Warning and Alarm Regions

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-387A breaker monitoring function is intended to capture information on the number of operations and total interrupted current for two breakers. These data are used to estimate the amount of contact wear per pole, based on a wear curve input by the user, and derived from the breaker manufacturer maintenance curves. Separate settings for each breaker determine under what conditions the monitoring function is initiated 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 and BKMON2 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 Winding 2 elements 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+OC1+LB3) or for a differential trip (86T device trip via OUT103 = TRIP3; TR3 = 87R+87U). In this case, we set **BKMON1 = TRIP1 + TRIP3**.

Winding 1 overcurrent trips (TRIP1) will be credited to the internal trip counter and current accumulators, and differential trips (TRIP3) will appear as external trips.

To capture trip information for other Breaker 1 trips initiated by devices other than the SEL-387A, 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 internal comparison with TRIP1 is then made to sort out internal versus external trips.

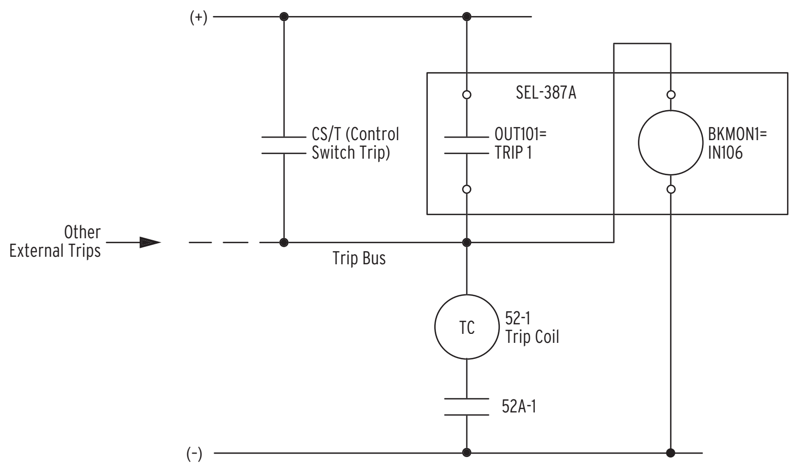

Figure 5.4 Trip Bus Sensing With Relay Input

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*).

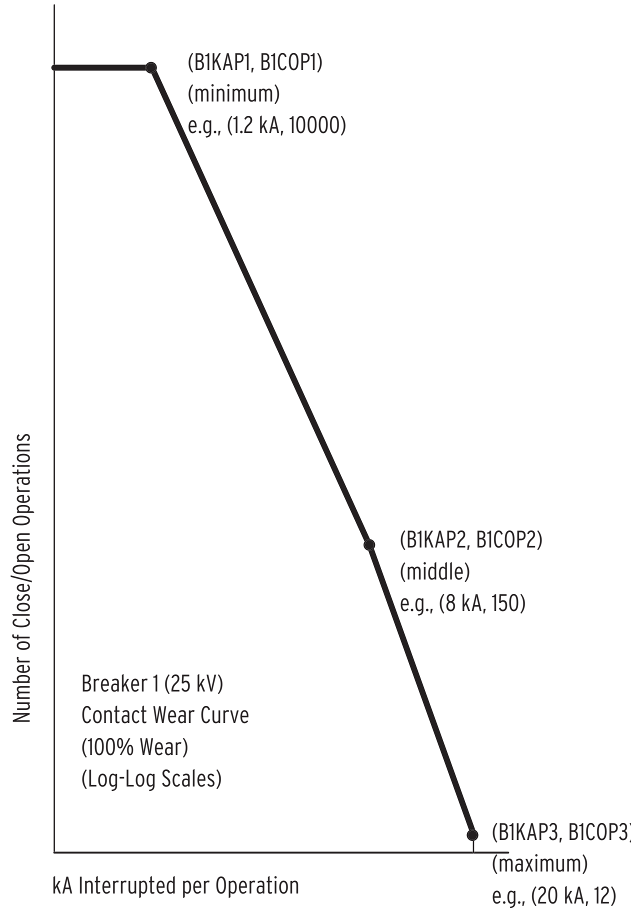

Figure 5.5 Breaker Contact Wear Curve

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 I 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 number of operations as a function of current in kiloamperes by an equation of the form:

$$O(I) = K \bullet I^{\alpha} \qquad \textbf{Equation 5.3}$$

To determine the constants K and alpha 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:

$$\alpha = \frac{\log_{10}\left(\frac{O1}{O2}\right)}{\log_{10}\left(\frac{I1}{I2}\right)} \qquad \textbf{Equation 5.4}$$

The K constant can be found by back-substitution:

$$K = \frac{O1}{I1^{\alpha}} \qquad \textbf{Equation 5.5}$$

or

$$K = \frac{O1}{I1^{\alpha}} \qquad \textbf{Equation 5.6}$$

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:

$$O(I) = 14972 \bullet I^{-2.214} \qquad \textbf{Equation 5.7}$$

and

$$O(I) = 46284 \bullet I^{-2.756} \qquad \textbf{Equation 5.8}$$

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.

Since 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 for each parameter 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 one 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 one if any of the individual pole bits are set to one. 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 Report Function (BRE Command)

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. Remember that Breakers 3 and 4 do not apply to the SEL-387A.

```
=>>BRE <Enter>

XFMER 1                               Date: 01/13/02    Time: 10:30:27.930
STATION A

BREAKER 1
Int Trips=     0   IAW1=     0.00  IBW1=     0.00  ICW1=     0.00 kA(pri)
Ext Trips=     0   IAW1=     0.00  IBW1=     0.00  ICW1=     0.00 kA(pri)
Percent Wear:     POLE1=        0 POLE2=        0 POLE3=        0

BREAKER 2
Int Trips=     0   IAW2=     0.00  IBW2=     0.00  ICW2=     0.00 kA(pri)
Ext Trips=     0   IAW2=     0.00  IBW2=     0.00  ICW2=     0.00 kA(pri)
Percent Wear:     POLE1=        0 POLE2=        0 POLE3=        0

BREAKER 3
Int Trips=     0   IAW3=     0.00  IBW3=     0.00  ICW3=     0.00 kA(pri)
Ext Trips=     0   IAW3=     0.00  IBW3=     0.00  ICW3=     0.00 kA(pri)
Percent Wear:     POLE1=        0 POLE2=        0 POLE3=        0

BREAKER 4
Int Trips=     0    IN1=     0.00   IN2=     0.00   IN3=     0.00 kA(pri)
Ext Trips=     0    IN1=     0.00   IN2=     0.00   IN3=     0.00 kA(pri)
Percent Wear:     POLE1=        0 POLE2=        0 POLE3=        0

LAST BREAKER MONITOR RESET FOR     Bkr1:  01/11/02      16:56:58.406
                                   Bkr2:  01/11/02      16:56:58.450
                                   Bkr3:  00/00/00      00:00:00.000
                                   Bkr4:  00/00/00      00:00:00.000

==>>
```

Through-Fault Event Monitor

Figure 5.6 shows a distribution feeder fault beyond the protection zone of the SEL-387 Relay. 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.

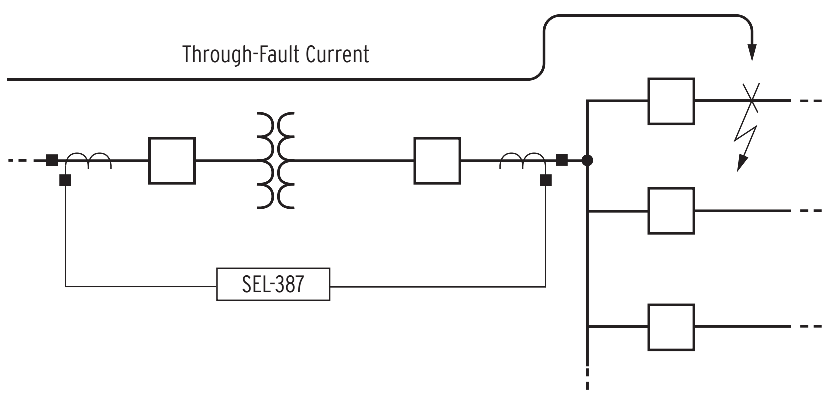

Figure 5.6 Distribution Feeder Faults Expose Transformer Bank to Through Faults

Monitor and document this through-fault activity with the through-fault event monitor in the SEL-387 Relays. 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 5.1*.

Table 5.1 Through-Fault Event Monitor Settings

Setting	Definition	Range
ETHRU	Enable Through-Fault Event Winding	N, 1, 2
THRU	Through-Fault Event Trigger (SELOGIC control equation)	Relay Word bits (*Table 4.9*)
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 **TFE C** and **TFE R** command discussions that follow).

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 previous 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 4.9 (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 deasserts (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.

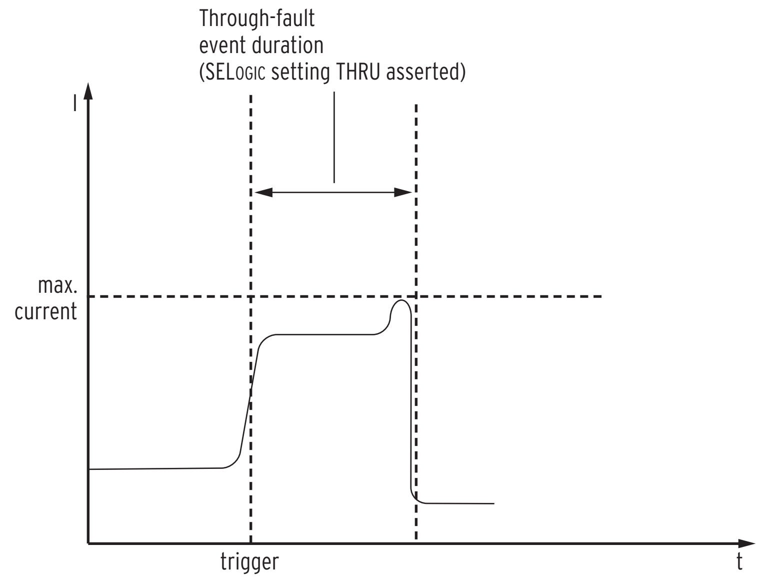

Figure 5.7 Through-Fault Triggering, Duration, and Maximum Current

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 store results of these calculations for each monitored phase. For example, if a through fault is 6000 A primary (maximum) and lasts 0.067 seconds, the monitor would calculate I^2t for that event as follows:

$$(6 \text{ kA})^2 \text{ x } 0.067 \text{ seconds} = 2.412 \text{ (kA)}^2 \text{ seconds}$$

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 auto-reclosing (e.g., reduce the number of reclosures from 3 to 2).

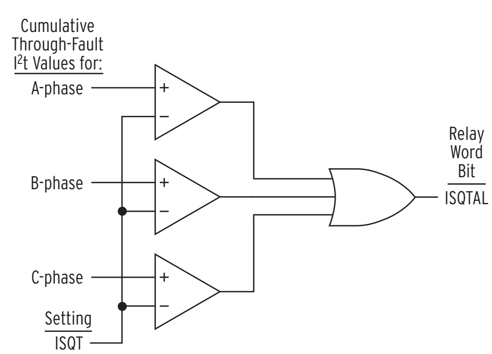

Figure 5.8 Cumulative I^2t Alarm (Relay Word Bit ISQTAL)

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: 02/12/04    Time: 18:59:49.130
STATION A

FID=SEL-387E-X300-V0-Z102102-D20040211
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: 02/12/04    Time: 18:59:49.130
STATION A

FID=SEL-387E-X300-V0-Z102102-D20040211
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 kA2 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-387A is designed to provide information on the internal health of the relay's major components. 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** command displays a report of the self-test diagnostics. The relay automatically executes the **STATUS** command whenever the self-test software enters a warning or failure state.

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 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 are 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 are 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.

```
=>>STA <Enter>

XFMER 1                                Date: 01/13/02    Time: 10:30:27.930
STATION A
FID=SEL-387A-R102-V0-Z003003-D20020111  CID=413E
SELF TESTS

W=Warn    F=Fail

       IAW1     IBW1     ICW1     IAW2     IBW2     ICW2
OS     -0        0        1       -0        0        0

       IAW3     IBW3     ICW3      IN1      IN2      IN3
OS      9       -0        1        8        0        0

       +5V_PS   +5V_REG  -5V_REG  +12V_PS  -12V_PS  +15V_PS  -15V_PS
PS      4.92     5.03    -4.98     12.07   -12.11    14.87   -14.79

       TEMP     RAM      ROM      A/D      CR_RAM   EEPROM   IO_BRD
        29.2    OK       OK       OK       OK       OK       OK

 Relay 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 5.2*.

The STATUS button on the front-panel interface can also be used to access the information in the report. See *Section 8: Front-Panel Interface*.

Channel Offset

The relay measures the dc offset (OS) voltage of each of the 12 analog current input channels and compares the value against a fixed limit of 30 mV. If an offset measurement is outside the fixed limit, the relay declares a warning.

Power Supply

The relay measures the internal power supply (PS) voltages and regulated +5 and –5 voltages, and compares the values against fixed limits. If a voltage measurement is outside the limits, the relay declares a warning or failure.

Temperature

The relay measures its internal temperatures (TEMP). If the relay measures a temperature less than –40°C or greater than +85°C, a warning is declared. If the relay measures a temperature less than –50°C or greater than +100°C, a failure is declared. The temperature warning does not pulse the ALARM output contact.

RAM

The relay checks the random-access memory (RAM). If a byte cannot be written to or read from, the relay declares a RAM failure. There is no warning state for this test.

Flash ROM

The relay checks the flash read-only memory (ROM) by computing a checksum. If the computed value does not agree with the stored value, the relay declares a ROM failure. There is no warning state for this test.

Analog-to-Digital Converter

The relay verifies the A/D converter function by checking the A/D conversion time. The test fails if conversion time is excessive or a conversion starts but does not finish. There is no warning state for this test.

Critical RAM

The particular area of RAM where the settings are stored is deemed Critical RAM. It is verified by computing a checksum. This must agree with a previously stored checksum value, or the relay will declare a Critical RAM (CR_RAM) failure. There is no warning state for the test.

EEPROM

EEPROM is checked by computing a checksum. If the computed value does not agree with the stored value, the relay declares a EEPROM failure. There is no warning state for the test.

I/O Boards

The relay checks the I/O board ID register against a stored value. If any values differ, the relay declares an I/O_BRD failure. There is no warning state for this test. Use the **INITIO <Enter>** command to reset the stored value for the new I/O configuration.

Self-Test Alarm Limits

Table 5.2 summarizes the limits for issuing warning or failure alarms during self-testing. The power supply and temperature alarms list the lower values below which, and upper values above which, the stated alarm is issued.

Table 5.2 Self-Test Alarm Limits (Sheet 1 of 2)

Self-Test	Warning Limits	Failure Limits
Channel Offset	30 mVdc	NA
+5 V Power Supply	4.80/5.20 Vdc	4.65/5.40 Vdc
+5 V Regulated	4.75/5.20 Vdc	4.50/5.40 Vdc
–5 V Regulated	–4.75/–5.25 Vdc	–4.50/–5.40 Vdc
+12 V Power Supply	11.50/12.50 Vdc	11.20/14.00 Vdc
–12 V Power Supply	–11.50/–12.50 Vdc	–11.20/–14.00 Vdc
+15 V Power Supply	14.40/15.60 Vdc	14.00/16.00 Vdc
–15 V Power Supply	–14.40/–15.60 Vdc	–14.00/–16.00 Vdc
Temperature	–40/+85°C	–50/+100°C
RAM	NA	Cannot READ/WRITE
Flash ROM	NA	Bad Checksum
A/D	NA	Slow Conversion
Critical RAM	NA	Bad Checksum

Table 5.2 Self-Test Alarm Limits (Sheet 2 of 2)

Self-Test	Warning Limits	Failure Limits
EEPROM	NA	Bad Checksum
IO_BRD	NA	Incorrect I/O Board Value

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Section 6
Setting the Relay

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 monitors, etc.
SET R	SER	Sequential Events Recorder trigger conditions and Load Profile settings.
SET P *n*	Port	Serial port settings for Serial Port *n* (*n* = 1, 2, 3, or 4).

View settings with the respective serial port **SHOWSET** commands (**SHO**, **SHO G**, **SHO R**, **SHO P**). See discussion of **SHO** commands in *Section 7: Serial Port Communications and Commands*. 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 8.8* 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: Serial Port Communications and Commands* 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…4). 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 typically are used to identify the equipment protected by the relay or the identifier of 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.

Demand Ammeter Settings (DATC, PDEM, QDEM, NDEM)

The relay provides demand ammeters for Windings 1 and 2, for phase, negative-sequence, and residual currents. 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 ammeters behave much like low-pass filters, responding to gradual trends in the current magnitude. The relay uses the demand ammeter time constant setting, DATC*n*, for all 5 demand ammeter calculations for Winding *n*. The time constant is settable from 5 to 255 minutes. The demand ammeters operate such that if demand current is reset and a constant input current is applied, the demand current output will be 90 percent of the constant input current value DATC*n* minutes later.

Settable demand ammeter thresholds are available for all five demand ammeters 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 ammeters, 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.

For our example, the Demand Ammeter 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 ammeter settings can be different in the six settings groups.

Instantaneous metering functions have no settings. These functions show primary phase, negative-sequence, and residual current magnitudes; secondary winding current magnitudes and angles; differential quantities (operate, restraint, second- and fifth-harmonics) in multiples of tap. Access is by the front panel or one of the communications ports.

Input and Output Assignments

Optoisolated inputs (IN101 through IN106) and contact outputs (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 form-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.

Trip and Close Logic

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 five trip variables to define conditions under which a trip will be issued. These are named TR1 to TR5. This will cover trip conditions for four 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 and TR2 are set to respond to overcurrent elements specific to the winding associated with Breakers 1 and 2. For example, TR1 = 50P11T + 51P1T + 51Q1T + OC1 + LB3. 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 + OC2. For group tripping of both breakers, TR3 = 87R + 87U. This results in a tripping output to an external 86 lockout device, which then trips both breakers with separate contacts. This takes place only if a differential operation, either restrained or unrestrained, is detected. TR4 and TR5 are not used, and are set to zero.

In general, definition of the TR1 and TR5 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 five 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 one, 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, and OUT103 = TRIP3. OUT101 and OUT102 go directly to the two breaker trip coils, and OUT103 goes to the 86 operate coil. These connections are shown in *Figure 2.9*.

Corresponding to the five trip variables in the Trip Logic setting area are five unlatch variables. The variables ULTR1 to ULTR5 define the conditions to unlatch the seal-in of trip logic that takes place when TR*n* goes to one. 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 = !(50P13 + 50P23) and unlatches TRIP3 when all phase currents on all windings drop below the 0.5 A setting. ULTR4 and ULTR5 are not used and are set to zero.

In the Close Logic setting area, inputs are defined to represent the 52a auxiliary contacts from the individual breakers. The four Close and four Unlatch Close variables are also defined, if the closing function is to be used.

In our example, inputs IN101 and IN102 are assigned to represent the 52a contacts. That is, 52A1 = IN101 and 52A2 = IN102. (Note again that inputs appear in the right side of an equation, outputs on the left side.) Contacts 52A3 and 52A4 are not used, and are set to zero. The connections for the 52a inputs are shown in *Figure 2.8*.

The four Close variables, CL1 through CL4, 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 + LB4 + /IN104 and CL2 = CC2 + /IN105, where "/" denotes detection of a "rising edge" for the input shown. CL3 and CL4 are not used, and are set to zero. Within these SELOGIC control equations, inputs IN104 and IN105 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 one, unless the logic is disabled by an unlatch condition, discussed below. Note that connections for the closing function are not shown in *Figure 2.8*.

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 and OUT106 = CLS2. These contacts must be wired to the closing circuits of the individual breakers.

In the Close Logic setting area, four variables remain. ULCL1 to ULCL4 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 + TRIP3 and ULCL2 = TRIP2 + TRIP3. ULC3 and ULCL4 are not used and are set to zero. 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.

The Trip Logic and Close Logic settings can be set differently in the six setting groups. See *Section 4: Control Logic* for more information on Trip and Close Logic.

There are two additional miscellaneous timer settings that apply to the Trip and Close Logic. These are TDURD and CFD. TDURD is the minimum trip duration time and 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. The CFD, or Close Failure Detection time delay, is an overriding timer to unlatch the close logic if the breaker has not yet closed. The default setting is 60 cycles.

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. Events will be generated from the pickup of the various overcurrent elements, whether they fully time out or not. 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.

The LER setting defines how long the overall report should be: 15, 30, 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. Since 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-387A Relay.

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.

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 can be set 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 take 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 SS*n* setting group change 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*. You may choose one of four dc voltage thresholds, DC1P through DC4P, to 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 two breakers, BKMON1 and BKMON2. 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 schedule breaker maintenance intervals.

Analog Input Labels

In the Global setting area, the user is permitted to rename the nine (including the three neutral inputs) analog current inputs to suit local preferences. The present names, IAW1 through ICW2, 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,” “Red, Blue, Yellow,” and so forth.

The new labels will appear wherever the currents were identified by the existing labels, including the displays for serial port commands **STA**tus, **BRE**aker, **EVE**nt, and **MET**er, including the variants of each command. The new labels will also appear in the front-panel LCD displays for the **STATUS** and **METER** pushbutton menus.

Setting Group Selection

In the Global settings there are settings to define which of the six settings groups is to be the active group. Use the **SET G** command from a communications port to access settings SS1 to SS6. The front panel cannot be used to access or change these settings. The settings are defined by SELOGIC control equations, using defined contact inputs or any Relay Word elements to switch groups. The simplest method is to set a value of one for the SS*n* setting corresponding to the desired settings Group *n*. The SELOGIC control equations permit greater user flexibility in defining when to switch setting groups. If any variable SS1 to SS6 is asserted, the ***GRO n*** serial port command and the front-panel **GROUP** pushbutton cannot be used to change setting groups.

Front-Panel Targeting, Displays, and Control

There are settings for elements of the front-panel display, if the user is interested in customizing an LED target or display for a specific function. Five of the 16 front-panel LEDs are fully programmable. These are the FAULT TYPE A, B, C, LED15, and LED16 LEDs in the second row. The default settings for the first three LEDs are based on phase selection logic for overcurrent trips or differential trips by a specific element, and the last two are set to zero. For example, the A-Phase LED is programmed normally as follows: LEDA = OCA + 87E1. This means that the LED will come on if it is determined that A-Phase was involved in an overcurrent trip or that Differential Element 1 issued a trip. The user may define any SELOGIC control equation to operate these targets by programming LEDA, LEDB, LEDC, LED15, or LED16.

There are 16 programmable Display Points, for creating customized messages on the LCD display. 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.

Use local control to enable/disable schemes, trip/close breakers, and so on via the front panel. Local control asserts (sets to logical 1) or deasserts (sets to logical 0) local bits LB1 through LB16. These local bits are available as Relay Word bits and are used in SELOGIC control equations.

For more information on the LEDs, Display Points, and Local Bits, see *Section 8: Front-Panel Interface*.

Sequential Events Recorder

The SER, or Sequential Events Recorder, lists up to 512 events. This may help the user in determining the correct order of operation during a complicated event with multiple device operations within a short time interval. The settings for the SER are the trigger conditions and the Relay Word bit ALIAS names. Up to 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*. Up to 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: Event Reports and SER*.

Communications Ports

There are four communications ports on the SEL-387A. 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 on the front 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 HyperTerminal.

Complete information on the communications ports and necessary settings can be found in *Section 7: Serial Port Communications and Commands*.

Default Settings

SEL-387A Default Settings (5 A)

```
=>>SHO <Enter>
Group 1


RID     =XFMR 1
TID     =STATION A
E87     = Y
EOC1    = Y         EOC2    = Y         EOCN    = Y
E49A    = N         E49B    = N
ESLS1   = N         ESLS2   = N         ESLS3   = N

W1CT    = Y         W2CT    = Y
CTR1    = 120       CTR2    = 240
CTRN1   = 80        CTRN2   = 80        CTRN3   = 24
MVA     = 100.0     ICOM    = Y
W1CTC   = 11        W2CTC   = 11
VWDG1   = 230.00    VWDG2   = 138.00

TAP1    = 2.09      TAP2    = 1.74
O87P    = 0.30      SLP1    = 25        SLP2    = 50        IRS1    = 3.0
U87P    = 10.0      PCT2    = 15        PCT4    = 15        PCT5    = 35
TH5P    = OFF       DCRB    = N         HRSTR   = N         IHBL    = N


E32I1   =0

Press RETURN to continue

E32I2   =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

Press RETURN to continue
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

50NN11P = OFF       50NN11D = 10.00     50NN11TC=1
50NN12P = OFF
50NN13P = OFF       50NN14P = OFF
51NN1P  = OFF       51NN1C  = U2        51NN1TD = 1.00
51NN1RS = Y         51NN1TC =1

50NN21P = OFF       50NN21D = 10.00     50NN21TC=1
50NN22P = OFF

Press RETURN to continue
50NN23P = OFF       50NN24P = OFF
51NN2P  = OFF       51NN2C  = U2        51NN2TD = 1.00
51NN2RS = Y         51NN2TC =1

50NN31P = OFF       50NN31D = 10.00     50NN31TC=1
50NN32P = OFF
50NN33P = OFF       50NN34P = OFF
51NN3P  = OFF       51NN3C  = U2        51NN3TD = 1.00
51NN3RS = Y         51NN3TC =1

TDURD   = 9.000     CFD     = 60.000
```

```
TR1     =50P11T + 51P1T + 51Q1T + OC1 + LB3
TR2     =51P2T + 51Q2T + OC2

TR3     =87R + 87U
TR4     =0
TR5     =0
ULTR1   =!50P13
ULTR2   =!50P23
ULTR3   =!(50P13 + 50P23)

Press RETURN to continue
ULTR4   =0
ULTR5   =0
52A1    =IN101
52A2    =IN102
52A3    =0
52A4    =0
CL1     =CC1 + LB4 + /IN104
CL2     =CC2 + /IN105
CL3     =0
CL4     =0
ULCL1   =TRIP1 + TRIP3
ULCL2   =TRIP2 + TRIP3
ULCL3   =0
ULCL4   =0
ER      =/50P11 + /51P1 + /51Q1 + /51P2 + /51Q2
OUT101  =TRIP1
OUT102  =TRIP2
OUT103  =TRIP3
OUT104  =0
OUT105  =CLS1

Press RETURN to continue
OUT106  =CLS2
OUT107  =0

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     45.8
GR1CHK     E73F
```

SEL-387A Default Settings (1 A)

```
=>>SHO <Enter>
Group 1


RID     =XFMR 1
TID     =STATION A
E87     = Y
EOC1    = Y         EOC2    = Y         EOCN    = Y
E49A    = N         E49B    = N
ESLS1   = N         ESLS2   = N         ESLS3   = N

W1CT    = Y         W2CT    = Y
CTR1    = 600       CTR2    = 1200
CTRN1   = 400       CTRN2   = 400       CTRN3   = 120
MVA     = 100.0     ICOM    = Y
W1CTC   = 11        W2CTC   = 11
VWDG1   = 230.00    VWDG2   = 138.00

TAP1    = 0.42      TAP2    = 0.35
O87P    = 0.30      SLP1    = 25        SLP2    = 50        IRS1    = 3.0
U87P    = 10.0      PCT2    = 15        PCT4    = 15        PCT5    = 35
TH5P    = OFF       DCRB    = N         HRSTR   = N         IHBL    = N


E32I1   =0

Press RETURN to continue

E32I2   =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

Press RETURN to continue
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


50NN11P = OFF       50NN11D = 10.00     50NN11TC=1
50NN12P = OFF
50NN13P = OFF       50NN14P = OFF
51NN1P  = OFF       51NN1C  = U2        51NN1TD = 1.00
51NN1RS = Y         51NN1TC =1

50NN21P = OFF       50NN21D = 10.00     50NN21TC=1
50NN22P = OFF

Press RETURN to continue
50NN23P = OFF       50NN24P = OFF
51NN2P  = OFF       51NN2C  = U2        51NN2TD = 1.00
51NN2RS = Y         51NN2TC =1

50NN31P = OFF       50NN31D = 10.00     50NN31TC=1
50NN32P = OFF
50NN33P = OFF       50NN34P = OFF
51NN3P  = OFF       51NN3C  = U2        51NN3TD = 1.00
51NN3RS = Y         51NN3TC =1

TDURD   = 9.000     CFD     = 60.000

TR1     =50P11T + 51P1T + 51Q1T + OC1 + LB3
TR2     =51P2T + 51Q2T + OC2
TR3     =87R + 87U
```

```
TR4     =0
TR5     =0

ULTR1   =!50P13
ULTR2   =!50P23
ULTR3   =!(50P13 + 50P23)

Press RETURN to continue
ULTR4   =0
ULTR5   =0
52A1    =IN101
52A2    =IN102
52A3    =0
52A4    =0
CL1     =CC1 + LB4 + /IN104
CL2     =CC2 + /IN105
CL3     =0
CL4     =0

ULCL1   =TRIP1 + TRIP3
ULCL2   =TRIP2 + TRIP3
ULCL3   =0
ULCL4   =0
ER      =/50P11 + /51P1 + /51Q1 + /51P2 + /51Q2
OUT101  =TRIP1
OUT102  =TRIP2
OUT103  =TRIP3
OUT104  =0
OUT105  =CLS1

Press RETURN to continue
OUT106  =CLS2
OUT107  =0

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     45.8
GR1CHK     E80F
=>>
```

The Group settings shown above are the only settings that are different from the 5 A relay settings. The Global, Port, and SER settings remain the same.

Settings Sheets

The rest of this section consists of Settings Sheets.

You can photocopy the Settings Sheets and write your settings on the copy before you enter the settings in the relay. The Settings Sheets begin with the Group Settings (**SET** Command), followed by Global Settings (**SET G** Command), Sequential Events Recorder Settings (**SET R** Command), and Port Settings (**SET P** Command).

SEL-387A Relay Settings Sheets Group Settings (SET Command)

Configuration Settings

Relay Identifier (39 Characters)
RID = ______________________

Terminal Identifier (59 Characters)
TID = ______________________

Enable Differential Element (Y, N)	**E87**	=
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 Neutral Elements (Y, N)	**EOCN**	=
Enable RTDA Element (Y, N)	**E49A**	=
Enable RTDB Element (Y, N)	**E49B**	=
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 1 CT Ratio (1–50000)	**CTR1**	=
Winding 2 CT Ratio (1–50000)	**CTR2**	=
Neutral 1 CT Ratio (1–50000)	**CTRN1**	=
Neutral 2 CT Ratio (1–50000)	**CTRN2**	=
Neutral 3 CT Ratio (1–50000)	**CTRN3**	=
Maximum Power Xfmr Capacity (OFF, 0.2–5000.0 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 1 Line-to-Line Voltage (1.00–1000.00 kV)	**VWDG1**	=________________
Winding 2 Line-to-Line Voltage (1.00–1000.00 kV)	**VWDG2**	=________________

Differential Elements

NOTE: TAP1 and TAP2 are auto-set by relay if MVA setting is not OFF.

Winding 1 Current Tap (0.50–155.00 A secondary) (5 A) (0.10–31.00 A secondary) (1 A)	**TAP1**	=________________
Winding 2 Current Tap (0.50–155.00 A secondary) (5 A) (0.10–31.00 A secondary) (1 A)	**TAP2**	=________________
Restrained Element Operating Current PU (0.10–1.00 TAP)	**O87P**	=________________
Restraint Slope 1 Percentage (5–100%)	**SLP1**	=________________
Restraint Slope 2 Percentage (OFF, 25–200%)	**SLP2**	=________________
Restraint Current Slope 1 Limit (1.0–20.0 TAP)	**IRS1**	=________________
Unrestrained Element Current PU (1–20 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 (OFF, 0.02–3.2 TAP)	**TH5P**	=________________
Fifth-Harmonic Alarm TDPU (0.000–8000.000 cyc)	**TH5D**	=________________
DC Ratio Blocking (Y, N)	**DCRB**	=________________
Harmonic Restraint (Y, N)	**HRSTR**	=________________
Independent Harmonic Blocking (Y, N)	**IHBL**	=________________

Restricted Earth Fault (Only Available if Ordered With the REF Option)

Enable 32I (SELOGIC control equation)

E32I1 = ____

Operating Quantity from Wdg. 1, Wdg. 2 (1, 2, 12)	**32IOP1**	=________________
Positive-Sequence Current Restraint Factor, I0/I1 (0.02–0.50)	**a01**	=________________
Residual Current Sensitivity Threshold (0.25–15 A secondary) (5 A) (0.05–3 A secondary) (1 A)	**50GP1**	=________________

Enable 32I (SELOGIC control equation)
E32I2 = ______________________________

Operating Quantity from Wdg. 1, Wdg. 2 (1, 2, 12) **32IOP2** = ______________

Positive-Sequence Current Restraint Factor, I0/I1 (0.02–0.50) **a02** = ______________

Residual Current Sensitivity Threshold
(0.25–15 A secondary) (5 A)
(0.05–3 A secondary) (1 A) **50GP2** = ______________

Winding 1 O/C Elements

Winding 1 Phase O/C Elements

Phase Def.-Time O/C Level 1 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P11P** = ______________

Phase Level 1 O/C Delay (0.00–16000.00 cycles) **50P11D** = ______________

50P11 Torque Control (SELOGIC control equation)
50P11TC = ______________________________

Phase Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P12P** = ______________

50P12 Torque Control (SELOGIC control equation)
50P12TC = ______________________________

Phase Inst. O/C Level 3 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P13P** = ______________

Phase Inst. O/C Level 4 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P14P** = ______________

Phase Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 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
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50Q11P** =________________

Neg.-Seq. Level 1 O/C Delay (0.50–16000.00 cycles) **50Q11D** =________________

50Q11 Torque Control (SELOGIC control equation)
50Q11TC = ________________________________

Neg.-Seq. Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50Q12P** =________________

50Q12 Torque Control (SELOGIC control equation)
50Q12TC = ________________________________

Neg.-Seq. Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 A secondary) (1 A) **51Q1P** =________________

Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) **51Q1C** =________________

Neg.-Seq. Inv.-Time O/C Time-Dial (US 0.5–15, IEC 0.05–1.00) **51Q1TD** =________________

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
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50N11P** =________________

Residual Level 1 O/C Delay (0.00–16000.00 cycles) **50N11D** =________________

50N11 Torque Control (SELOGIC control equation)
50N11TC = ________________________________

Residual Inst. O/C Level 2 PU
(OFF, 0.25–100.00 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50N12P** =________________

50N12 Torque Control (SELOGIC control equation)
50N12TC = ________________________________

Residual Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 A secondary) (1 A) **51N1P** =________________

Residual Inv.-Time O/C Curve (U1–U5, C1–C5) **51N1C** = ______________

Residual Inv.-Time O/C Time-Dial (US 0.50–15.00, 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 Ammeter Time Constant (OFF, 5–255 min) **DATC1** = ______________

Phase Demand Ammeter Threshold
(0.50–16.00 A secondary) (5 A)
(0.10–3.20 A secondary) (1 A) **PDEM1P** = ______________

Neg.-Seq. Demand Ammeter Threshold
(0.50–16.00 A secondary) (5 A)
(0.10–3.20 A secondary) (1 A) **QDEM1P** = ______________

Residual Demand Ammeter Threshold
(0.50–16.00 A secondary) (5 A)
(0.10–3.20 A secondary) (1 A) **NDEM1P** = ______________

Winding 2 O/C Elements

Winding 2 Phase O/C Elements

Phase Def.-Time O/C Level 1 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P21P** = ______________

Phase Level 1 O/C Delay (0.00–16000.00 cycles) **50P21D** = ______________

50P21 Torque Control (SELOGIC control equation)
50P21TC = ______________________________

Phase Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P22P** = ______________

50P22 Torque Control (SELOGIC control equation)
50P22TC = ______________________________

Phase Inst. O/C Level 3 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P23P** = ______________

Phase Inst. O/C Level 4 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50P24P** = ____________

Phase Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 A secondary) (1 A) **51P2P** = ____________

Phase Inv.-Time O/C Curve (U1–U5, C1–C5) **51P2C** = ____________

Phase Inv.-Time O/C Time-Dial (US 0.50–15.00, 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
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50Q21P** = ____________

Neg.-Seq. Level 1 O/C Delay (0.50–16000.00 cycles) **50Q21D** = ____________

50Q21 Torque Control (SELOGIC control equation)
50Q21TC = ____________

Neg.-Seq. Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50Q22P** = ____________

50Q22 Torque Control (SELOGIC control equation)
50Q22TC = ____________

Neg.-Seq. Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 A secondary) (1 A) **51Q2P** = ____________

Neg.-Seq. Inv.-Time O/C Curve (U1–U5, C1–C5) **51Q2C** = ____________

Neg.-Seq. Inv.-Time O/C Time-Dial (US 0.5–15, IEC 0.05–1.00) **51Q2TD** = ____________

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
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50N21P** = ____________

Residual Level 1 O/C Delay (0.00–16000.00 cycles) **50N21D** = ____________

50N21 Torque Control (SELOGIC control equation)
50N21TC = ____

Residual Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50N22P** = ____________

50N22 Torque Control (SELOGIC control equation)
50N22TC = ____

Residual Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 A secondary) (1 A) **51N2P** = ____________

Residual Inv.-Time O/C Curve (U1–U5, C1–C5) **51N2C** = ____________

Residual Inv.-Time O/C Time-Dial (US 0.50–15.00, IEC 0.05–1.00) **51N2TD** = ____________

Residual Inv.-Time O/C EM Reset (Y, N) **51N2RS** = ____________

51N2 Torque Control (SELOGIC control equation)
51N2TC = ____

Winding 2 Demand Metering

Demand Ammeter Time Constant (OFF, 5–255 min) **DATC2** = ____________

Phase Demand Ammeter Threshold
(0.05–16.00 A secondary) (5 A)
(0.10–3.20 A secondary) (1 A) **PDEM2P** = ____________

Neg.-Seq. Demand Ammeter Threshold
(0.50–16.00 A secondary) (5 A)
(0.10–3.20 A secondary) (1 A) **QDEM2P** = ____________

Residual Demand Ammeter Threshold
(0.50–16.00 A secondary) (5 A)
(0.10–3.20 A secondary) (1 A) **NDEM2P** = ____________

Neutral Elements

Neutral 1 Elements

Neutral Def.-Time O/C Level 1 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN11P** =____________________

Neutral Level 1 O/C Delay (0.00–16000.00 cycles) **50NN11D** =____________________

50NN11 Torque Control (SELOGIC control equation)
50NN11TC = ____

Neutral Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN12P** =____________________

50NN12 Torque Control (SELOGIC control equation)
50NN12TC = ____

Neutral Inst. O/C Level 3 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN13P** =____________________

Neutral Inst. O/C Level 4 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN14P** =____________________

Neutral Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 A secondary) (1 A) **51NN1P** =____________________

Neutral Inv.-Time O/C Curve (U1–U5, C1–C5) **51NN1C** =____________________

Neutral Inv.-Time O/C Time-Dial (US 0.50–15.00, IEC 0.05–1.00) **51NN1TD** =____________________

Neutral Inv.-Time O/C EM Reset (Y, N) **51NN1RS** =____________________

51NN1 Torque Control (SELOGIC control equation)
51NN1TC = ____

Neutral 2 Elements

Neutral Def.-Time O/C Level 1 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN21P** =____________________

Neutral Level 1 O/C Delay (0.00–16000.00 cycles) **50NN21D** =____________________

50NN21 Torque Control (SELOGIC control equation)
50NN21TC = ____

Neutral Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN22P** = ____________

50NN22 Torque Control (SELOGIC control equation)
50NN22TC = ____________

Neutral Inst. O/C Level 3 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN23P** = ____________

Neutral Inst. O/C Level 4 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN24P** = ____________

Neutral Inv.-Time O/C PU
(OFF, 0.50–16.00 A secondary) (5 A)
(OFF, 0.10–3.20 A secondary) (1 A) **51NN2P** = ____________

Neutral Inv.-Time O/C Curve (U1–U5, C1–C5) **51NN2C** = ____________

Neutral Inv.-Time O/C Time-Dial (US 0.50–15.00, IEC 0.05–1.00) **51NN2TD** = ____________

Neutral Inv.-Time O/C EM Reset (Y, N) **51NN2RS** = ____________

51NN2 Torque Control (SELOGIC control equation)
51NN2TC = ____________

Neutral 3 Elements

Neutral Def.-Time O/C Level 1 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN31P** = ____________

Neutral Level 1 O/C Delay (0.00–16000.00 cycles) **50NN31D** = ____________

50NN31 Torque Control (SELOGIC control equation)
50NN31TC = ____________

Neutral Inst. O/C Level 2 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN32P** = ____________

50NN32 Torque Control (SELOGIC control equation)
50NN32TC = ____________

Neutral Inst. O/C Level 3 PU
(OFF, 0.25–100 A secondary) (5 A)
(OFF, 0.05–20 A secondary) (1 A) **50NN33P** = ____________

Neutral Inst. O/C Level 4 PU (OFF, 0.25–100 A secondary) (5 A) (OFF, 0.05–20 A secondary) (1 A)	**50NN34P**	=
Neutral Inv.-Time O/C PU (OFF, 0.50–16.00 A secondary) (5 A) (OFF, 0.10–3.20 A secondary) (1 A)	**51NN3P**	=
Neutral Inv.-Time O/C Curve (U1–U5, C1–C5)	**51NN3C**	=
Neutral Inv.-Time O/C Time-Dial (US 0.50–15.00, IEC 0.05–1.00)	**51NN3TD**	=
Neutral Inv.-Time O/C EM Reset (Y, N)	**51NN3RS**	=

51NN3 Torque Control (SELOGIC control equation)

51NN3TC = ____________________

RTD A Elements

RTD 1A Alarm Temperature (OFF, 32–482°F)	**49A01A**	=
RTD 1A Trip Temperature (OFF, 32–482°F)	**49T01A**	=
RTD 2A Alarm Temperature (OFF, 32–482°F)	**49A02A**	=
RTD 2A Trip Temperature (OFF, 32–482°F)	**49T02A**	=
RTD 3A Alarm Temperature (OFF, 32–482°F)	**49A03A**	=
RTD 3A Trip Temperature (OFF, 32–482°F)	**49T03A**	=
RTD 4A Alarm Temperature (OFF, 32–482°F)	**49A04A**	=
RTD 4A Trip Temperature (OFF, 32–482°F)	**49T04A**	=
RTD 5A Alarm Temperature (OFF, 32–482°F)	**49A05A**	=
RTD 5A Trip Temperature (OFF, 32–482°F)	**49T05A**	=
RTD 6A Alarm Temperature (OFF, 32–482°F)	**49A06A**	=
RTD 6A Trip Temperature (OFF, 32–482°F)	**49T06A**	=
RTD 7A Alarm Temperature (OFF, 32–482°F)	**49A07A**	=
RTD 7A Trip Temperature (OFF, 32–482°F)	**49T07A**	=
RTD 8A Alarm Temperature (OFF, 32–482°F)	**49A08A**	=
RTD 8A Trip Temperature (OFF, 32–482°F)	**49T08A**	=
RTD 9A Alarm Temperature (OFF, 32–482°F)	**49A09A**	=
RTD 9A Trip Temperature (OFF, 32–482°F)	**49T09A**	=
RTD 10A Alarm Temperature (OFF, 32–482°F)	**49A10A**	=
RTD 10A Trip Temperature (OFF, 32–482°F)	**49T10A**	=

RTD 11A Alarm Temperature (OFF, 32–482°F)	**49A11A**	= ____________
RTD 11A Trip Temperature (OFF, 32–482°F)	**49T11A**	= ____________
RTD 12A Alarm Temperature (OFF, 32–482°F)	**49A12A**	= ____________
RTD 12A Trip Temperature (OFF, 32–482°F)	**49T12A**	= ____________

RTD B Elements

RTD 1B Alarm Temperature (OFF, 32–482°F)	**49A01B**	= ____________
RTD 1B Trip Temperature (OFF, 32–482°F)	**49T01B**	= ____________
RTD 2B Alarm Temperature (OFF, 32–482°F)	**49A02B**	= ____________
RTD 2B Trip Temperature (OFF, 32–482°F)	**49T02B**	= ____________
RTD 3B Alarm Temperature (OFF, 32–482°F)	**49A03B**	= ____________
RTD 3B Trip Temperature (OFF, 32–482°F)	**49T03B**	= ____________
RTD 4B Alarm Temperature (OFF, 32–482°F)	**49A04B**	= ____________
RTD 4B Trip Temperature (OFF, 32–482°F)	**49T04B**	= ____________
RTD 5B Alarm Temperature (OFF, 32–482°F)	**49A05B**	= ____________
RTD 5B Trip Temperature (OFF, 32–482°F)	**49T05B**	= ____________
RTD 6B Alarm Temperature (OFF, 32–482°F)	**49A06B**	= ____________
RTD 6B Trip Temperature (OFF, 32–482°F)	**49T06B**	= ____________
RTD 7B Alarm Temperature (OFF, 32–482°F)	**49A07B**	= ____________
RTD 7B Trip Temperature (OFF, 32–482°F)	**49T07B**	= ____________
RTD 8B Alarm Temperature (OFF, 32–482°F)	**49A08B**	= ____________
RTD 8B Trip Temperature (OFF, 32–482°F)	**49T08B**	= ____________
RTD 9B Alarm Temperature (OFF, 32–482°F)	**49A09B**	= ____________
RTD 9B Trip Temperature (OFF, 32–482°F)	**49T09B**	= ____________
RTD 10B Alarm Temperature (OFF, 32–482°F)	**49A10B**	= ____________
RTD 10B Trip Temperature (OFF, 32–482°F)	**49T10B**	= ____________
RTD 11B Alarm Temperature (OFF, 32–482°F)	**49A11B**	= ____________
RTD 11B Trip Temperature (OFF, 32–482°F)	**49T11B**	= ____________
RTD 12B Alarm Temperature (OFF, 32–482°F)	**49A12B**	= ____________
RTD 12B Trip Temperature (OFF, 32–482°F)	**49T12B**	= ____________

Miscellaneous Timers

Minimum Trip Duration Time Delay (4.000–8000.000 cycles)	**TDURD**	=________________
Close Failure Logic Time Delay (OFF, 0.000–8000.000 cycles)	**CFD**	=________________

SELOGIC Control Equations Set 1

Set 1 Variable 1 (SELOGIC control equation)
S1V1 = ________________________________

S1V1 Timer Pickup (OFF, 0.000–999999.000 cycles)	**S1V1PU**	=________________
S1V1 Timer Dropout (OFF, 0.000–999999.000 cycles)	**S1V1DO**	=________________

Set 1 Variable 2 (SELOGIC control equation)
S1V2 = ________________________________

S1V2 Timer Pickup (OFF, 0.000–999999.000 cycles)	**S1V2PU**	=________________
S1V2 Timer Dropout (OFF, 0.000–999999.000 cycles)	**S1V2DO**	=________________

Set 1 Variable 3 (SELOGIC control equation)
S1V3 = ________________________________

S1V3 Timer Pickup (OFF, 0.000–999999.000 cycles)	**S1V3PU**	=________________
S1V3 Timer Dropout (OFF, 0.000–999999.000 cycles)	**S1V3DO**	=________________

Set 1 Variable 4 (SELOGIC control equation)
S1V4 = ________________________________

S1V4 Timer Pickup (OFF, 0.000–999999.000 cycles)	**S1V4PU**	=________________
S1V4 Timer Dropout (OFF, 0.000–999999.000 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 (OFF, 0.000–999999.000 cycles) **S2V1PU** = ______________

S2V1 Timer Dropout (OFF, 0.000–999999.000 cycles) **S2V1DO** = ______________

Set 2 Variable 2 (SELOGIC control equation)
S2V2 = ______________________________

S2V2 Timer Pickup (OFF, 0.000–999999.000 cycles) **S2V2PU** = ______________

S2V2 Timer Dropout (OFF, 0.000–999999.000 cycles) **S2V2DO** = ______________

Set 2 Variable 3 (SELOGIC control equation)
S2V3 = ______________________________

S2V3 Timer Pickup (OFF, 0.000–999999.000 cycles) **S2V3PU** = ______________

S2V3 Timer Dropout (OFF, 0.000–999999.000 cycles) **S2V3DO** = ______________

Set 2 Variable 4 (SELOGIC control equation)
S2V4 = ______________________________

S2V4 Timer Pickup (OFF, 0.000–999999.000 cycles) **S2V4PU** = ______________

S2V4 Timer Dropout (OFF, 0.000–999999.000 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 Equations Set 3

Set 3 Variable 1 (SELOGIC control equation)
S3V1 = ______________________________

S3V1 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V1PU** = ____________

S3V1 Timer Dropout (OFF, 0.000–999999.000 cycles) **S3V1DO** = ____________

Set 3 Variable 2 (SELOGIC control equation)
S3V2 = ______________________________

S3V2 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V2PU** = ____________

S3V2 Timer Dropout (OFF, 0.000–999999.000 cycles) **S3V2DO** = ____________

Set 3 Variable 3 (SELOGIC control equation)
S3V3 = ______________________________

S3V3 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V3PU** = ____________

S3V3 Timer Dropout (OFF, 0.000–999999.000 cycles) **S3V3DO** = ____________

Set 3 Variable 4 (SELOGIC control equation)
S3V4 = ______________________________

S3V4 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V4PU** = ____________

S3V4 Timer Dropout (OFF, 0.000–999999.000 cycles) **S3V4DO** = ____________

Set 3 Variable 5 (SELOGIC control equation)
S3V5 = ______________________________

S3V5 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V5PU** = ____________

S3V5 Timer Dropout (OFF, 0.000–999999.000 cycles) **S3V5DO** = ____________

Set 3 Variable 6 (SELOGIC control equation)
S3V6 = ______________________________

S3V6 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V6PU** = ____________

S3V6 Timer Dropout (OFF, 0.000–999999.000 cycles) **S3V6DO** = ____________

Set 3 Variable 7 (SELOGIC control equation)
S3V7 = ______________________________

S3V7 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V7PU** = ____________

S3V7 Timer Dropout (OFF, 0.000–999999.000 cycles) **S3V7DO** = ____________

Set 3 Variable 8 (SELogic control equation)
S3V8 = ____________________

S3V8 Timer Pickup (OFF, 0.000–999999.000 cycles) **S3V8PU** = ____________

S3V8 Timer Dropout (OFF, 0.000–999999.000 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	=
TR5	=
ULTR1	=
ULTR2	=
ULTR3	=
ULTR4	=
ULTR5	=

Close Logic

52A1	=
52A2	=
52A3	=
52A4	=
CL1	=
CL2	=
CL3	=
CL4	=
ULCL1	=
ULCL2	=
ULCL3	=
ULCL4	=

Event Report Triggering

ER	=

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 = ________________

Relay Settings

Length of Event Report (15, 30, 60 cycles)	**LER**	= ________
Length of Pre-fault in Event Report (1 to 14 cycles)	**PRE**	= ________
Nominal Frequency (50, 60 Hz)	**NFREQ**	= ________
Phase Rotation (ABC, ACB)	**PHROT**	= ________
Date Format (MDY, YMD)	**DATE_F**	= ________
Display Update Rate (1–60 seconds)	**SCROLD**	= ________
Front-Panel Time-out (OFF, 0–30 minutes)	**FP_TO**	= ________
Group Change Delay (0–900 seconds)	**TGR**	= ________
RTDA Temperature Preference (C, F)	**TMPREFA**	= ________
RTDB Temperature Preference (C, F)	**TMPREFB**	= ________

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**	=________

Debounce Timers

Input debounce time (0.00–2.00 cyc)	**IN101D**	=________
Input debounce time (0.00–2.00 cyc)	**IN102D**	=________
Input debounce time (0.00–2.00 cyc)	**IN103D**	=________
Input debounce time (0.00–2.00 cyc)	**IN104D**	=________
Input debounce time (0.00–2.00 cyc)	**IN105D**	=________
Input debounce time (0.00–2.00 cyc)	**IN106D**	=________
Input debounce time (0.00–2.00 cyc)	**IN201D**	=________
Input debounce time (0.00–2.00 cyc)	**IN202D**	=________
Input debounce time (0.00–2.00 cyc)	**IN203D**	=________
Input debounce time (0.00–2.00 cyc)	**IN204D**	=________
Input debounce time (0.00–2.00 cyc)	**IN205D**	=________
Input debounce time (0.00–2.00 cyc)	**IN206D**	=________
Input debounce time (0.00–2.00 cyc)	**IN207D**	=________
Input debounce time (0.00–2.00 cyc)	**IN208D**	=________

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 pri)	**B1KAP1**	=________
Close/Open Set Point 2 max (1–65000 operations)	**B1COP2**	=________
kA Interrupted Set Point 2 min (0.1–999.0 kA pri)	**B1KAP2**	=________
Close/Open Set Point 3 max (1–65000 operations)	**B1COP3**	=________
kA Interrupted Set Point 3 min (0.1–999.0 kA pri)	**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 pri)	**B2KAP1**	= ____________
Close/Open Set Point 2 max (1–65000 operations)	**B2COP2**	= ____________
kA Interrupted Set Point 2 min (0.1–999.0 kA pri)	**B2KAP2**	= ____________
Close/Open Set Point 3 max (1–65000 operations)	**B2COP3**	= ____________
kA Interrupted Set Point 3 min (0.1–999.0 kA pri)	**B2KAP3**	= ____________

Through-Fault Event Monitor

Enable Through-Fault Event Winding (N, 1, 2)	**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 IAW4 (1–4 characters)	**IAW4 (IN1)**	= ____________
Rename Current Input IBW4 (1–4 characters)	**IBW4 (IN2)**	= ____________
Rename Current Input ICW4 (1–4 characters)	**ICW4 (IN3)**	= ____________

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**	= ______________

Energize LED15 (SELOGIC control equation)
DP15 = ______________________________

Energize LED16 (SELOGIC control equation)
DP16 = ______________________________

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**	=______________

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. LMD PREFIX, ADDR, and SETTLE do not appear if PROTO = SEL or DNP. See Appendix C: SEL Distributed Port Switch Protocol (LMD) for details on LMD protocol and see Appendix G: Distributed Network Protocol (DNP3) for details on DNP protocol.

Port 1 (SET P 1) Rear Panel, EIA-485 Plus IRIG-B

Port Protocol (SEL, LMD, DNP, RTDA, RTDB)	**PROTO**	= ________
LMD Prefix (@, #, $, %, &)	**PREFIX**	= ________
LMD Address (1–99)	**ADDR**	= ________
LMD Settling Time (0.00–30.00 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 2 (SET P 2) Rear Panel, EIA-232 With IRIG-B

Port Protocol (SEL, LMD, DNP, RTDA, RTDB)	**PROTO**	= ________
LMD Prefix (@, #, $, %, &)	**PREFIX**	= ________
LMD Address (1–99)	**ADDR**	= ________
LMD Settling Time (0.00–30.00 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, RTDA, RTDB)	**PROTO**	= ______________
LMD Prefix (@, #, $, %, &)	**PREFIX**	= ______________
LMD Address (1–99)	**ADDR**	= ______________
LMD Settling Time (0.00–30.00 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, RTDA, RTDB)	**PROTO**	= ______________
LMD Prefix (@, #, $, %, &)	**PREFIX**	= ______________
LMD Address (1–99)	**ADDR**	= ______________
LMD Settling Time (0.00–30.00 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 N (SET P N) Front Panel, EIA-232 for PROTO = RTDA

Number of RTDA (0–12)	**RTDNUMA**	= ______________
RTD 1A Type (NA, PT100, NI100, NI120, CU10)	**RTD1TA**	= ______________
RTD 2A Type (NA, PT100, NI100, NI120, CU10)	**RTD2TA**	= ______________
RTD 3A Type (NA, PT100, NI100, NI120, CU10)	**RTD3TA**	= ______________
RTD 4A Type (NA, PT100, NI100, NI120, CU10)	**RTD4TA**	= ______________
RTD 5A Type (NA, PT100, NI100, NI120, CU10)	**RTD5TA**	= ______________
RTD 6A Type (NA, PT100, NI100, NI120, CU10)	**RTD6TA**	= ______________
RTD 7A Type (NA, PT100, NI100, NI120, CU10)	**RTD7TA**	= ______________
RTD 8A Type (NA, PT100, NI100, NI120, CU10)	**RTD8TA**	= ______________
RTD 9A Type (NA, PT100, NI100, NI120, CU10)	**RTD9TA**	= ______________
RTD 10A Type (NA, PT100, NI100, NI120, CU10)	**RTD10TA**	= ______________
RTD 11A Type (NA, PT100, NI100, NI120, CU10)	**RTD11TA**	= ______________
RTD 12A Type (NA, PT100, NI100, NI120, CU10)	**RTD12TA**	= ______________

Port N (SET P N) Front Panel, EIA-232 for PROTO = RTDB

Number of RTDB (0–12)	**RTDNUMB**	= ______________
RTD 1B Type (NA, PT100, NI100, NI120, CU10)	**RTD1TB**	= ______________
RTD 2B Type (NA, PT100, NI100, NI120, CU10)	**RTD2TB**	= ______________
RTD 3B Type (NA, PT100, NI100, NI120, CU10)	**RTD3TB**	= ______________
RTD 4B Type (NA, PT100, NI100, NI120, CU10)	**RTD4TB**	= ______________
RTD 5B Type (NA, PT100, NI100, NI120, CU10)	**RTD5TB**	= ______________
RTD 6B Type (NA, PT100, NI100, NI120, CU10)	**RTD6TB**	= ______________
RTD 7B Type (NA, PT100, NI100, NI120, CU10)	**RTD7TB**	= ______________
RTD 8B Type (NA, PT100, NI100, NI120, CU10)	**RTD8TB**	= ______________
RTD 9B Type (NA, PT100, NI100, NI120, CU10)	**RTD9TB**	= ______________
RTD 10B Type (NA, PT100, NI100, NI120, CU10)	**RTD10TB**	= ______________

RTD 11B Type (NA, PT100, NI100, NI120, CU10)	**RTD11TB**	=________________
RTD 12B Type (NA, PT100, NI100, NI120, CU10)	**RTD12TB**	=________________

Section 7

Serial Port Communications and Commands

Introduction

The SEL-387A Relay is equipped with four serial ports: one EIA-232 port on the front, two EIA-232 ports on the rear, and one EIA-485 port on the rear. Establish communication by connecting a terminal to one of the serial ports with the appropriate cable. Connect computers, modems, protocol converters, printers, an SEL-2020 or an SEL-2030 Communications Processor, an SEL-2885, a SCADA serial port, and/or RTUs for local or remote communications.

Use one of the SEL protocols for communication. The SEL ASCII commands and structure are defined in detail in this section. Other SEL protocols used for interfacing other intelligent electronic devices for automated communication are described in detail in the appendices.

Establish Communication

Establish communication with the SEL-387A through one of its serial ports by using standard "off-the-shelf" software and the appropriate cable connections, depending on the device.

Software

Use any system that emulates a standard terminal system. Such PC-based terminal emulation programs include: ProComm Plus, Relay/Gold, Microsoft Windows Terminal, Microsoft Windows HyperTerminal, SmartCOM, and CROSSTALK. Many terminal emulation programs will work with the SEL-387A. For the best display, use VT-100 terminal emulation or the closest variation.

The default communication settings for the serial ports follow:

Baud Rate = 2400

Data Bits = 8

Parity = N

Stop Bits = 1

RTS/CTS = N

Change the port settings by using the front panel or the **SET P <Enter>** command.

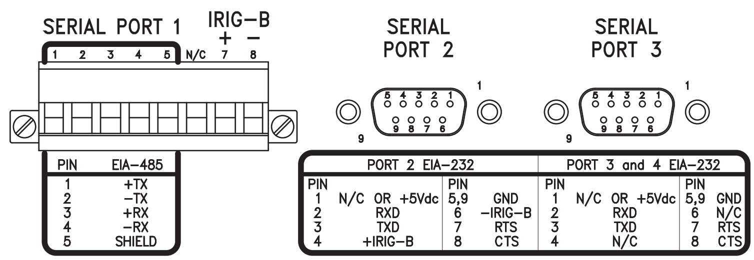
Port Identification

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

Connect the SEL-387A to another device using the appropriate cable. The pin definitions for Ports 1, 2, 3, and 4 are given on the relay rear panel and detailed in *Table 7.1*.

A 9-pin port connector drawing and pin definitions appear in *Figure 7.1*.



(female chassis connectors as viewed from outside panel)

Figure 7.1 SEL-387A Serial Port Connectors

Pinouts for EIA-232 and EIA-485 ports follow:

Table 7.1 Serial Port Pin Definitions

Pin Number	Port 1 Rear EIA-485	Port 2 Rear EIA-232 with IRIG-B	Port 3 Rear EIA-232	Port 4 Front EIA-232
1	+TX (Out)	N/C or +5 Vdc[a]	N/C or +5 Vdc[a]	N/C
2	–TX (Out)	RXD (In)	RXD (In)	RXD (In)
3	+RX (In)	TXD (Out)	TXD (Out)	TXD (Out)
4	–RX (In)	N/C or +IRIG-B[a]	N/C	N/C
5	Shield	GND	GND	GND
6	N/C	N/C or –IRIG-B[a]	N/C	N/C
7	+IRIG-B	RTS (Out)	RTS (Out)	RTS (Out)
8	–IRIG-B	CTS (In)	CTS (In)	CTS (In)
9	NA	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.

Port 1 is an EIA-485 protocol connection on the rear of the relay. It accepts a pluggable terminal block that supports wire sizes from 24 AWG up to 12 AWG. The connector is supplied 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. Any combination of these ports or all of them may be used for relay communication. *Table 7.2* lists cables that can be purchased from SEL for various communication applications.

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.

Table 7.2 SEL-387A Communications Cable Numbers

SEL-387 Port #	Connect to Device (gender refers to 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-2020 or SEL-2030 without IRIG-B	SEL-C272A
2	SEL-2020 or SEL-2030 with IRIG-B	SEL-C273A
2	SEL-IDM, Ports 2 through 11	Requires an SEL-C254 and SEL-C257 cable
2, 3	Modem, 5 Vdc Powered (pin 10)	SEL-C220[a]
2, 3	Standard Modem, 25-Pin Female (DCE)	SEL-C222

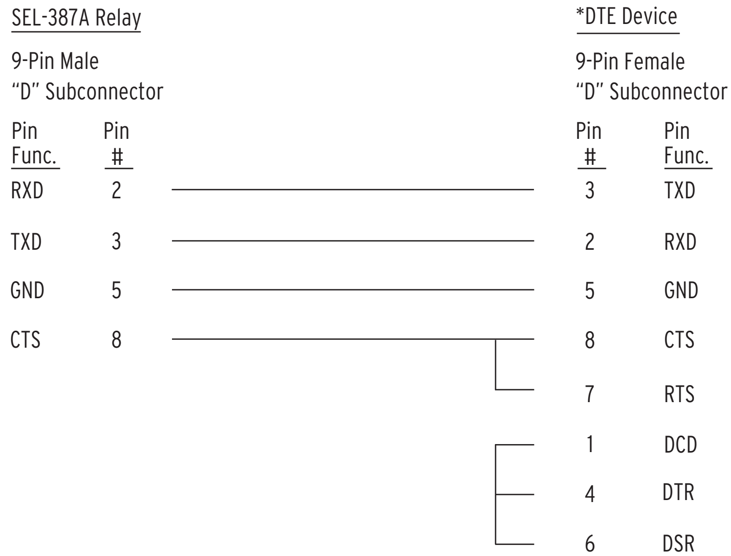
[a] The 5 Vdc serial port jumper must be installed to power the Modem using C220. See Section 2: Installation.

For example, to connect the SEL-387A Ports 2, 3, or 4 to the 9-pin male connector on a laptop, order cable number C234A and specify the length needed. To connect the SEL-387A Port 2 to the SEL-2020 or SEL-2030 Communications Processor that supplies the communications link and the time-synchronization signal, order cable number C273A, and specify the length necessary. For connecting devices at over 100 feet, fiber-optic transceivers are available. The SEL-2800 and SEL-2810 provide fiber-optic links between devices for electrical isolation and long-distance signal transmission. Call the factory for further information on these products.

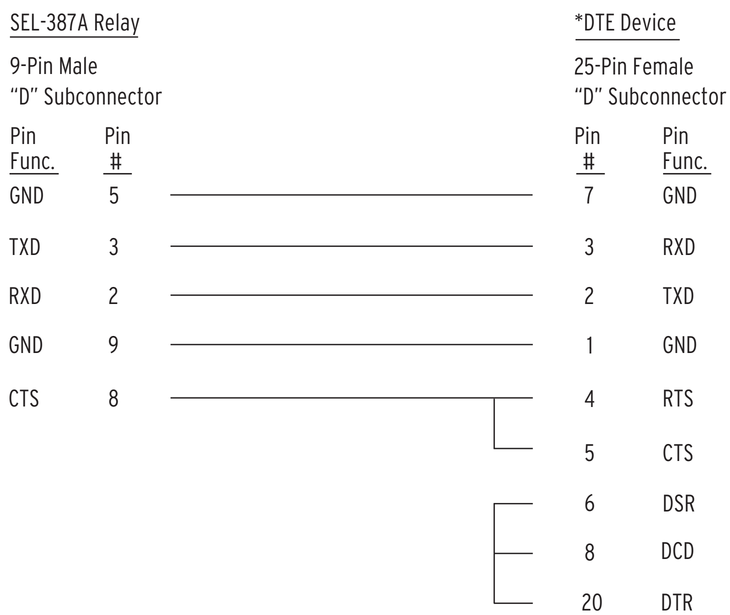
The following cable diagrams show several types of EIA-232 serial communications cables. These and other cables are available from SEL. Contact the factory for more information.

SEL-387A to Computer

Cable SEL-C234A



Cable SEL-C227A



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

SEL-387A to Modem

Cable SEL-C222

SEL-387A Relay: 9-Pin Male "D" Subconnector
*DCE Device: 25-Pin Male "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

Cable SEL-C220

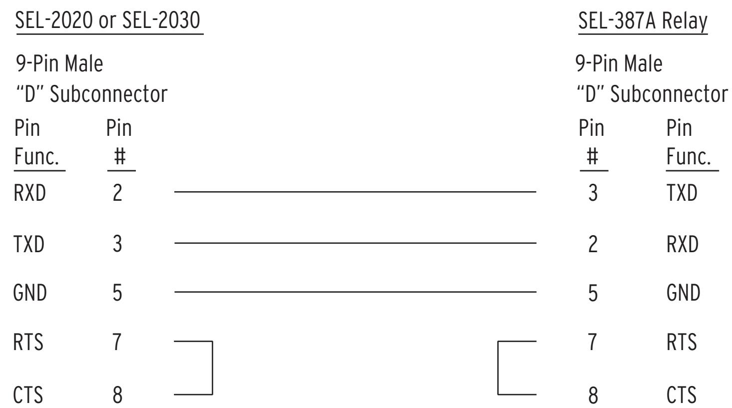
SEL-387A Relay: 9-Pin Male "D" Subconnector
Modem 5Vdc Powered *DCE Device: 25-Pin Male "D" Subconnector

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)
+5 VDC	1	10	PWR (IN)
GND	9	1	GND

*DCE = Data Communications Equipment (Modem, etc.)

SEL-387A to SEL-2020 or SEL-2030

Cable SEL-C272A



Cable SEL-C273A

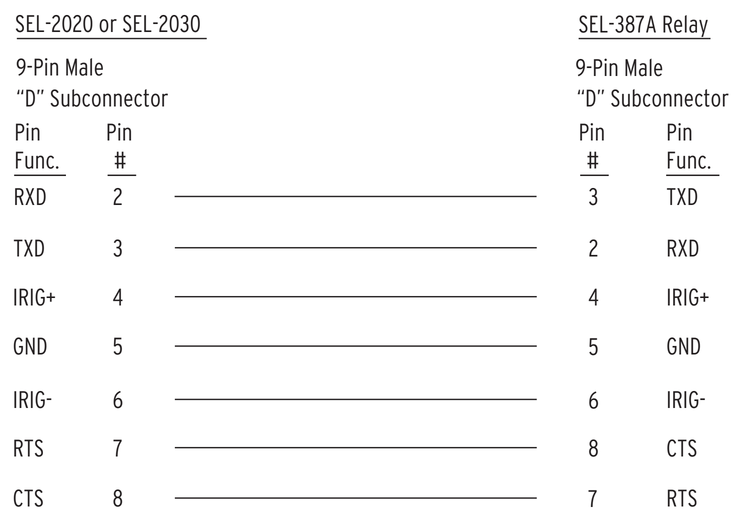


Table 7.3 Serial Communications Port Pin Function Definitions

Pin Function	Definition
N/C	No Connection
+5 Vdc	5 Vdc Power Connection
RXD, RX	Receive Data
TXD, TX	Transmit Data
+(–)IRIG-B	IRIG-B Time-Code Input
GND	Ground
SHIELD	Shielded Ground
RTS	Request to Send
CTS	Clear to Send
DCD	Data Carrier Detect
DTR	Data Terminal Ready
DSR	Data Set Ready

Communications Protocol

NOTE: In this document, commands you type appear in bold/uppercase: **STATUS**. Keys you press appear in bold/brackets: **<Enter>**.

This section explains the serial port communications protocol used by the SEL-387A. You set and operate the SEL-387A via the serial communications ports.

Relay output appears boxed and in the following format:

```
XFMR 1                          Date: 02/01/97    Time: 11:03:25.180
```

The communications protocol consists of hardware and software features.

Hardware Protocol

All EIA-232 serial ports support RTS/CTS hardware handshaking. RTS/CTS handshaking is not supported on the EIA-485 serial port.

To enable hardware handshaking, use the **SET P** command (or front-panel **SET** pushbutton) to set RTSCTS = Y. Disable hardware handshaking by setting RTSCTS = N.

If RTSCTS = N, the relay permanently asserts the RTS line.

If RTSCTS = Y, the relay deasserts RTS when it is unable to receive characters.

If RTSCTS = Y, the relay does not send characters until the CTS input is asserted.

Software Protocol

Software protocols consist of standard SEL ASCII, SEL Distributed Port Switch (LMD), SEL Distributed Network Protocol (DNP), SEL Fast Meter, SEL Fast Operate, and SEL Compressed ASCII. Based on the port PROTOCOL setting, the relay activates SEL ASCII, SEL LMD, or SEL DNP protocol. SEL Fast Meter and SEL Compressed ASCII commands are always active.

SEL ASCII Protocol

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 more than 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)

SEL Distributed Port Switch Protocol

The SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. Select the protocol by setting **PROTOCOL = LMD**, a SET P setting. See *Appendix C: SEL Distributed Port Switch Protocol (LMD)* for more information.

SEL Distributed Network Protocol

SEL Distributed Network Protocol (DNP) meets DNP3 Level 2 requirements. Select the protocol by setting **PROTOCOL = DNP**, a SET P setting. See *Appendix G: Distributed Network Protocol (DNP3)* for more information.

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 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 Unsolicited Sequential Events Recorder (SER) Protocol

SEL Unsolicited Sequential Events Recorder (SER) Protocol provides SER events to an automated data collection system. SEL Unsolicited SER Protocol is available on any serial port. The protocol is described in *Appendix F: Unsolicited SER Protocol*.

SEL ASCII Protocol Details

Automatic Messages

The SEL-387A 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

Startup Message

Immediately after power is applied, the relay transmits the following automatic message:

```
XFMR 1                                       Date: 03/13/97    Time: 14:26:22.324
STATION A
SEL-387
=
```

Group Switch Message

The SEL-387A 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.

NOTE: The SET G settings SS1 through SS6 take precedence over the **GRO n** command.

```
XFMR 1                                  Date: 03/13/97    Time: 14:33:49.109
STATION A

Active Group = 2
=>>
```

- ➤ RID and TID settings for the new active group
- ➤ Date and time of group change
- ➤ Active setting group now being used

Status Report

The relay automatically generates a status report whenever the self-tests declare a failure state and some warning states.

```
XFMR 1                                   Date: 01/08/02    Time: 07:50:20.999
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228  CID=A659
SELF TESTS

W=Warn    F=Fail

       IAW1     IBW1     ICW1     IAW2     IBW2     ICW2
OS     -2       -1        0       -0       -2       -1

       IAW3     IBW3     ICW3      IN1      IN2      IN3
OS     -1       -2       -1       -2       -2       -1

       +5V_PS   +5V_REG  -5V_REG  +12V_PS  -12V_PS  +15V_PS  -15V_PS
PS      4.90     5.03    -4.98     12.07   -12.11    14.84   -14.86

       TEMP     RAM      ROM      A/D      CR_RAM   EEPROM   IO_BRD
        36.8    OK       OK       OK       OK       OK       OK

 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

Summary Event Report

An automatic message is generated each time an event is triggered. The message is a summary of the event.

```
XFMR 1                                   Date: 01/08/02    Time: 07:53:19.360
STATION A

Event: TRIG
Targets:
Winding 1 Currents (A Sec), ABC:   1.1   1.1   1.1
Winding 2 Currents (A Sec), ABC:   1.1   1.1   1.1
Winding 3 Currents (A Sec), ABC:   0.0   0.0   0.0
Winding 4 Currents (A Sec), ABC:   1.1   1.1   1.1
```

- RID and TID settings for the active group
- Date and time the event was triggered
- The event type
- Target information
- Phase currents for two windings, plus the neutral elements

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 7.2*, and summarized by level in *SEL-387A 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 four 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) on page 7.22*. Below are the access level hierarchy, the access level prompts, and commands allowed in each of the four 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 7.2 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 7.2*). Enter the **ACC** command at the Access Level 0 prompt to go to Access Level 1.

Access Level 1

After issuing the **ACC** command and entering the password, if it is required [see *PAS (Passwords) on page 7.22*) for default factory passwords], the relay is 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 **2AC** command allows the relay to go to Access Level 2. 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 issuing the **BAC** command and entering the password, if it is required [see *PAS (Passwords) on page 7.22* for default factory passwords], the relay pulses the ALARM contact and is 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.

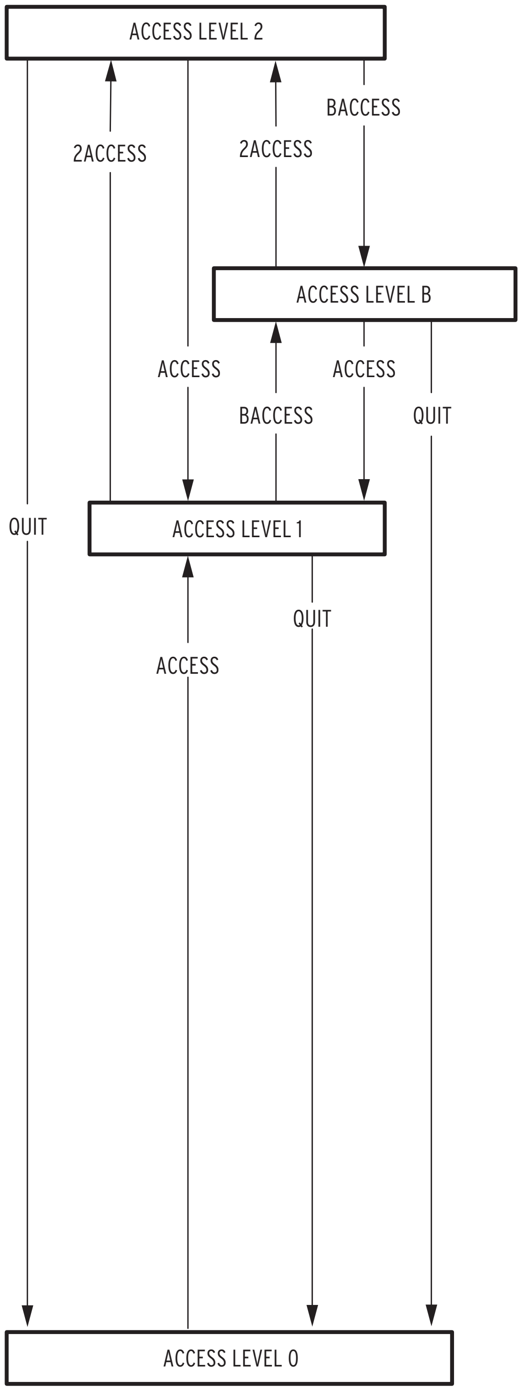
Access Level 2

After issuing the **2AC** command and entering the password, if it is required [see *PAS (Passwords) on page 7.22* for default factory passwords], the relay pulses the ALARM contact and is in Access Level 2. The Access Level 2 prompt appears (=>>).

This is the highest 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

The **CAL** (Calibration Access Level) command is used to enter the calibration access level in the relay. Normal relay operation does not require access to this level. The only user command that may be necessary to use from this level is the **R_S** command, which resets factory-default settings. Do not access this level unless instructed by the factory or using the **R_S** command. The relay is calibrated at the factory and will not need field calibration. Contact the factory if you suspect the relay is not calibrated.



Access Level	0	1	B	2	C
Prompt	=	=>	==>	=>>	==>>
				CONTROL	
				COPY	
				PASSWORD	
				RESET51	
				SET	
				SET G	
				SET P	
				SET R	
			BREAKER R	BREAKER R	
			BREAKER W	BREAKER W	
			CLOSE	CLOSE	
			GROUP	GROUP	
			OPEN	OPEN	
			PULSE	PULSE	
		2ACCESS	2ACCESS		
		BACCESS		BACCESS	
		BREAKER	BREAKER	BREAKER	
		CEV	CEV	CEV	
		DATE	DATE	DATE	
		EVENT	EVENT	EVENT	
		GROUP	GROUP	GROUP	
		HISTORY	HISTORY	HISTORY	
		HISTORY C	HISTORY C	HISTORY C	
		INITIO	INITIO	INITIO	
		IRIG	IRIG	IRIG	
		METER	METER	METER	
		METER H	METER H	METER H	
		METER T	METER T	METER T	
		SER	SER	SER	
		SER C	SER C	SER C	
		SHOWSET	SHOWSET	SHOWSET	
		SHOWSET G	SHOWSET G	SHOWSET G	
		SHOWSET P	SHOWSET P	SHOWSET P	
		SHOWSET R	SHOWSET R	SHOWSET R	
		STATUS	STATUS	STATUS	
		TARGET	TARGET	TARGET	
		TARGET F	TARGET F	TARGET F	
		TARGET R	TARGET R	TARGET R	
		TFE	TFE	TFE	
		TFEC	TFEC	TFEC	
		TFEP	TFEP	TFEP	
		TFER	TFER	TFER	
		TIME	TIME	TIME	
		TRIGGER	TRIGGER	TRIGGER	
	QUIT	QUIT	QUIT	QUIT	
	ACCESS		ACCESS	ACCESS	
	ID	ID	ID	ID	

Figure 7.2 Access Level Relationships

Command Definitions

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 **2ACCESS** command to enter Access Level 2. The default password for Level 2 is shown in the table under *PAS (Passwords) on page 7.22*. Use the **PASSWORD** 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: ? @@@@@

XFMR 1                             Date: 11/09/96    Time: 14:23:41.758
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 **ACCESS** command to enter Access Level 1. The default password for Level 1 is shown in the table under *PAS (Passwords) on page 7.22*. Use the **PASSWORD** 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: ? @@@@@

XFMR 1                                   Date: 11/09/96    Time: 14:23:41.758
STATION A

Level 1
=>
```

BAC (Access Level B)

Access Levels 1, 2

Use the **BACCESS** command to enter Access Level B. The default password for Level B is shown in the table under *PAS (Passwords) on page 7.22*. Use the **PASSWORD** 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: ?  @@@@@

XFMR 1                             Date: 11/11/96    Time: 14:04:51.251
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 **BREAKER** command to display a report of breaker operation information. The breaker report provides trip counter and trip current information for up to two 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: 01/09/02    Time: 10:45:32.636
STATION A

BREAKER 1
Int Trips=     0   IAW1=     0.00  IBW1=     0.00  ICW1=     0.00 kA(pri)
Ext Trips=    15   IAW1=    16.63  IBW1=    15.16  ICW1=    21.93 kA(pri)
Percent Wear:     POLE1=        0 POLE2=        0 POLE3=        0

BREAKER 2
Int Trips=     0   IAW2=     0.00  IBW2=     0.00  ICW2=     0.00 kA(pri)
Ext Trips=    15   IAW2=    46.39  IBW2=    68.63  ICW2=    62.25 kA(pri)
Percent Wear:     POLE1=        3 POLE2=        6 POLE3=       10

BREAKER 3
Int Trips=     0   IAW3=     0.00  IBW3=     0.00  ICW3=     0.00 kA(pri)
Ext Trips=     0   IAW3=     0.00  IBW3=     0.00  ICW3=     0.00 kA(pri)
Percent Wear:     POLE1=        0 POLE2=        0 POLE3=        0

BREAKER 4
Int Trips=     0    IN1=     0.00   IN2=     0.00   IN3=     0.00 kA(pri)
Ext Trips=     0    IN1=     0.00   IN2=     0.00   IN3=     0.00 kA(pri)
Percent Wear:     POLE1=        0 POLE2=        0 POLE3=        0

LAST BREAKER MONITOR RESET FOR     Bkr1:  01/07/02      15:33:11.872
                                   Bkr2:  01/07/02      15:33:11.987
                                   Bkr3:  00/00/00      00:00:00.000
                                   Bkr4:  00/00/00      00:00:00.000
=>>
```

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 has already experienced some fault duty before the relay is installed. The command prompts for percentage wear for each pole of the breaker. These 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

Internal Trips (0-65000)            ITRIP   =     0 ? 432
Internal Current (0.00-99999 kA)    IAW1    =     0 ? 12
                                    IBW1    =     0 ? 15
                                    ICW1    =     0 ? 17

External Trips (0-65000)            EXTRIP  =    15 ? 16
External Current (0.00-99999 kA)    IAW1    =    17 ? 12
                                    IBW1    =    15 ? 13
                                    ICW1    =    22 ? 15

Percent Wear (0-100%)               POLE1   =     0 ? 23
                                    POLE2   =     0 ? 34
                                    POLE3   =     0 ? 32

Are you sure (Y/N) ? Y <Enter>
```

After entering the values, use the **BRE** command to verify that the data have been accepted properly.

CAL (Calibration Access Level)

Access Level 2

The **CALIBRATION** command is used to enter the calibration access level in the relay. Normal relay operation does not require access to this level. The only user command that may be necessary to use from this level is the **R_S** command, which resets factory-default settings. Do not access this level unless instructed by the factory or using the **R_S** command. The relay is calibrated at the factory and will not need field calibration. Contact the factory if you suspect the relay is not calibrated.

CEV (Compressed Event)

Access Levels 1, B, 2

The SEL-5601-2 SYNCHROWAVE Event Software is available for graphical analysis of event reports. The **CEV** command is a compressed (comma-delimited formatting) version of the **EVE** command. Use the **CEV** command to download events for the SYNCHROWAVE Event.

The **CEV** command can generate both winding and differential reports.

The command syntax is **CEV [DIF R][*n* S*x* L*y*[-[*w*]] C]**. All parameters are optional. Enter them in any order.

DIF specifies generation of the differential element report in compressed form. Otherwise, the winding report will be produced.

R specifies "raw," or unfiltered analog data (not debounced), in a format [1.5 cycles + L*y*].

Letter *n* specifies the event number.

S*x* specifies samples per cycle. The *x* value can be 4, 8, 16, 32, or 64 for raw reports (default is 16) or 4, 8 for filtered reports (default is 4). Digital elements will be displayed at the resolution specified by S*x*, up to a maximum of eight samples per cycle.

L*y* specifies the report length in cycles. The y value can be from 1 to the LER setting. Default is 15 cycles. L*y*- specifies reporting from cycle *y* to the end of the report. L*y*-*w* specifies reporting from cycle *y* to cycle *w*.

C specifies using the eight samples per cycle compressed format for compatibility with the SEL-2020 or SEL-2030 and is equivalent to using the **EVE C** command.

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 **CLOSE *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 **COPY** 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 **COPY** 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

The **DATE** 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 like the 9 in 11/9/96.

NOTE: After setting the date, allow at least 60 seconds before powering down the relay, or the new setting may be lost.

```
=>>DAT <Enter>
01/08/02
=>>SHO G DATE_F

RELAY SETTINGS
DATE_F  = MDY       SCROLD  = 2         FP_TO   = 16        TGR     = 3

=>>DAT 11/9/99
11/09/99
```

EVE (Event Reports)

Access Levels 1, B, 2

Use the **EVENT** command to view event reports. Use the **CEV** command to retrieve event reports to be analyzed by SYNCHROWAVE Event or used with other equipment. See *Section 9: Event Reports and SER* for further details on retrieving event reports.

GRO and GRO n (Setting Group)

Access Levels 1, B, 2

The **GROUP** command, at Access Level 1, displays the setting group variable for the currently active setting group. Changing the variable is not permitted. The **GROUP *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 = 1
=>>GRO 2 <Enter>
Change to Group 2
Are you sure (Y/N) ? Y <Enter>
=>>
```

The **GROUP** 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:

NOTE: The relay will be disabled momentarily while the change in groups takes place.

```
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 **HISTORY** command displays the 80 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
30 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 5), CLS*m* (*m* = 1 to 4), ER (SELOGIC control equation 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 80) 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 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: 11/09/99    Time: 08:52:40.702
STATION A

#    DATE       TIME      EVENT  GRP  TARGETS

1  11/09/99 08:52:24.926  ER      2
2  11/09/99 08:52:24.430  TRIP2   2   TRIP INST 87_1 87_2 87_3 51 A B C W2
3  11/09/99 08:52:20.923  ER      2
4  11/09/99 08:52:17.440  TRIP3   2   TRIP INST 87_1 87_2 87_3 A B C
5  01/08/02 07:53:19.360  TRIG    1
6  01/08/02 07:52:54.360  TRIG    1

=>>
```

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 the corresponding events from nonvolatile Flash memory. The clearing process may take up to 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

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 (Identification)

Access Levels 0, 1, B, 2

The **ID** command displays a variety of identification and configuration information about the relay.

FID: reports the FID string; CID: reports the checksum of the ROM code; DEVID: reports the terminal ID as set by the TID setting; DEVCODE: reports the Modbus code (32).

PARTNO: Reports the part number. Because this relay does not allow modification of the part number in firmware, the number reported here contains Xs for all options.

```
=>>ID <Enter>

"FID=SEL-387A-R102-V0-Z003003-D20020111","0913"
"CID=413E","025A"
"DEVID=STATION A","049C"
"DEVCODE=32","030C"
"PARTNO=0387A010HX3X941","05EE"
"CONFIG=111100","0387"

=>>
```

INI (Initialize Interface Boards)

Access Levels 1, B, 2

The **INITIO** 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 relay last turned on, INITIO will confirm that the interface boards present are correct from Access Level 2.

```
=>>INI <Enter>
I/O BOARD       INPUTS    OUTPUTS
Main              6         7
1                 8         12
2                 No Board Connected

=>>
```

IRI (IRIG-B Synchronization)

Access Levels 1, B, 2

The **IRIG** 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: 02/01/96    Time: 01:45:40.762
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 **METER** command displays currents, demand currents, peak demand currents, 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 current metering data, in primary amperes
MET D	Displays winding demand ammeter data, in primary amperes
MET DIF	Displays differential metering data, in multiples of TAP
MET H	Displays harmonic spectrum of currents (see MET H below)
MET P	Displays peak demand ammeter data, in primary amperes
MET RD *n*	Resets demand ammeter for Winding *n* (*n* = 1, 2, A)
MET RP *n*	Resets peak demand ammeter values for Winding *n* (*n* = 1, 2, A)
MET SEC	Displays winding current metering data, with magnitude and phase angle, in secondary amperes
MET T	Displays the temperature values of up to 12 RTDs per port (maximum of 24 RTDs)

Use the **MET XXX *k*** command, where *k* is a positive integer, to repeat the MET XXX report *k* 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 H (Harmonic Metering)

Access Levels 1, B, 2

The **METER H** command is different from the normal metering functions, in that it uses 1 full cycle of unfiltered data, at 64 samples per cycle, to provide a snapshot of total harmonic content of all 6 analog current inputs. It uses a Fast Fourier Transform technique to provide secondary current values 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.

MET T (Temperature Metering)

Access Levels 1, B, 2

METER T reports the temperature values of up to 24 RTD inputs: RTDA Input Temperature Data (deg. X); RTD 1A through RTD 12A; RTDB Input Temperature Data (deg. Y); RTD 1B through RTD 12B.

where:

deg X: C or F depending on the TMPREFA setting,

deg Y: C or F depending on the TMPREFB setting.

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 Levels 2, C

The factory-default passwords for Access Levels 1, B, 2, and C are:

Access Level	Factory-default Password
1	OTTER
B	EDITH
2	TAIL
C	CLARKE

⚠WARNING
This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

The **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 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). 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 7.4* 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
- Ih2dcs4u-Iwg
- .0387e.Nt9g-t

Table 7.4 Valid Password Characters

Alpha	ABCDEFGHIJKLMNOPQRSTUVWXYZ abcdefghijklmnopqrstuvwxyz
Numeric	0123456789
Special	! " # $ % & ' ( ) * , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

The relay will 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 state 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 **PULSE *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 1 second. Main board breaker jumper JMP6B must be in place. After issuing the **PULSE** 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 **QUIT** 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 **QUIT** 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: 02/01/93    Time: 15:15:32.161
STATION A

=
```

RES (RESET51—Reset Inverse-Time O/C Elements)

Access Level 2

The **RESET51** command clears the inverse-time overcurrent element accumulators (phase, negative-sequence, and residual) for both windings. This command is useful in testing of 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: Differential, Restricted Earth Fault, and Overcurrent Elements*.

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 SER 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: Event Reports and SER* for a complete description of the report.

```
=>>SER <Enter>

XFMR 1                                  Date: 11/09/99    Time: 08:57:22.984
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228
#      DATE         TIME           ELEMENT          STATE

8     01/07/02  16:09:50.353    Relay newly powered up
7     11/09/99  08:50:07.335    Relay settings changed
6     11/09/99  08:52:17.440   OUT103             Asserted
5     11/09/99  08:52:24.430   OUT102             Asserted
4     11/09/99  08:56:23.859   OUT107             Asserted
3     11/09/99  08:56:27.108   OUT107             Deasserted
2     11/09/99  08:56:43.359   OUT105             Asserted
1     11/09/99  08:56:47.485   OUT105             Deasserted

=>
```

SER C (Clear Sequential Events Recorder)

Access Levels 1, B, 2

Clear the sequential event records from relay memory with the **SER C** command. The process may take up to 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
Clearing Complete

=>>
```

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:

```
=>>SET CTR1 TE <Enter>
Group 2


GENERAL DATA
Wdg 1 CT Ratio (1-50000)                    CTR1   = 120      ? 100 <Enter>
Wdg 2 CT Ratio (1-50000)                    CTR2   = 240      ? END <Enter>
Save Changes (Y/N) ? Y <Enter>
Please Wait While Saving Settings...
Settings saved

SCEUSE     45.8
```

Figure 7.3 Change the CTR1 Setting

```
GR2CHK     FA17
=>>SHO CTR1 <Enter>
Group 2


GENERAL DATA
CTR1    = 100      CTR2    = 240
CTRN1   = 80       CTRN2   = 80       CTRN3   = 24
MVA     = 100.0    ICOM    = Y
W1CTC   = 11       W2CTC   = 11
VWDG1   = 230.00   VWDG2   = 138.00

TAP1    = 2.51     TAP2    = 1.74
O87P    = 0.30     SLP1    = 25       SLP2    = 50       IRS1    = 3.0
U87P    = 10.0     PCT2    = 15       PCT5    = 35
TH5P    = OFF      IHBL    = N


=>>
```

Issue **<Ctrl+X>** to Stop Scrolling

Figure 7.4 Verify the CTR1 Setting

Table 7.5 lists the editing keys that you can use with the **SET** command.

Table 7.5 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 only disabled for approximately one second when settings are saved.

Refer to *Section 6: Setting the Relay* for all default settings and setting worksheets.

SET G (Edit Global Settings)

Access Level 2

Configure the relay Global settings by using the **SET G** command. The Global settings include Event Report parameters, frequency, phase rotation, date format, front-panel time-out, rotating display update rate, 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 7.5* lists the editing keys that you can use with the **SET** command.

Refer to *Section 6: Setting the Relay* for all default settings and setting worksheets.

SET P (Edit Port Settings)

Access Level 2

Configure the relay port settings by 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, or 4). 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 7.5* lists the editing keys that you can use with the **SET** command.

The settings for each communications port are as follows:

PROTO:	protocol can be SEL, LMD, DNP, RTDA, or RTDB.
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.
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 *Section 6: Setting the Relay* for all default settings and setting worksheets.

SET R (Edit SER Settings)

Access Level 2

Configure the Sequential Events Recorder settings by using the **SET R** command. The settings are the four sequential events recorder 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 7.5* lists the editing keys that you can use with the **SET** command.

Refer to *Section 6: Setting the Relay* for setting worksheets. Refer to *Section 9: Event Reports and SER* for more details on default settings and data retrieval.

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

SHOWSET 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 *Section 6: Setting the Relay* for information on all settings. The following example demonstrates the report for the **SHO** command.

```
=>>SHO 2 <Enter>
Group 2


RID     =XFMR 1
TID     =STATION A
E87     = Y
EOC1    = Y         EOC2    = Y         EOCN    = Y
E49A    = N         E49B    = N
ESLS1   = N         ESLS2   = N         ESLS3   = N

W1CT    = Y         W2CT    = Y
CTR1    = 100       CTR2    = 240
CTRN1   = 80        CTRN2   = 80        CTRN3   = 24
MVA     = 100.0     ICOM    = Y
W1CTC   = 11        W2CTC   = 11
VWDG1   = 230.00    VWDG2   = 138.00

TAP1    = 2.51      TAP2    = 1.74
O87P    = 0.30      SLP1    = 25        SLP2    = 50        IRS1    = 3.0
U87P    = 10.0      PCT2    = 15        PCT5    = 35
TH5P    = OFF       IHBL    = N


E32I1   =0

Press RETURN to continue

E32I2   =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

Press RETURN to continue
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

50NN11P = OFF       50NN11D = 10.00     50NN11TC=1
50NN12P = OFF
50NN13P = OFF       50NN14P = OFF
51NN1P  = OFF       51NN1C  = U2        51NN1TD = 1.00
51NN1RS = Y         51NN1TC =1

50NN21P = OFF       50NN21D = 10.00     50NN21TC=1
50NN22P = OFF

Press RETURN to continue
50NN23P = OFF       50NN24P = OFF
51NN2P  = OFF       51NN2C  = U2        51NN2TD = 1.00
51NN2RS = Y         51NN2TC =1

50NN31P = OFF       50NN31D = 10.00     50NN31TC=1
50NN32P = OFF
50NN33P = OFF       50NN34P = OFF
51NN3P  = OFF       51NN3C  = U2        51NN3TD = 1.00
51NN3RS = Y         51NN3TC =1

TDURD   = 9.000     CFD     = 60.000

TR1     =50P11T + 51P1T + 51Q1T + OC1 + LB3
TR2     =51P2T + 51Q2T + OC2
TR3     =87R + 87U
TR4     =0
TR5     =0
ULTR1   =!50P13
ULTR2   =!50P23
```

```
ULTR3   =!(50P13 + 50P23)
Press RETURN to continue
ULTR4   =0
ULTR5   =0
52A1    =IN101
52A2    =IN102
52A3    =0
52A4    =0
CL1     =CC1 + LB4 + /IN104
CL2     =CC2 + /IN105
CL3     =0
CL4     =0
ULCL1   =TRIP1 + TRIP3
ULCL2   =TRIP2 + TRIP3
ULCL3   =0
ULCL4   =0
ER      =/50P11 + /51P1 + /51Q1 + /51P2 + /51Q2
OUT101  =TRIP1
OUT102  =TRIP2
OUT103  =TRIP3
OUT104  =0
OUT105  =CLS1

Press RETURN to continue
OUT106  =CLS2
OUT107  =0

SCEUSE     45.8
GR2CHK     FA17
=>>
```

SHO G (Show Global Settings)

Access Levels 1, B, 2

SHOWSET 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 *Section 6: Setting the Relay* for information on all settings. The following example demonstrates the report for the **SHO G** command.

```
=>>SHO G <Enter>
LER     = 15        PRE     = 4         NFREQ   = 60        PHROT   = ABC
DATE_F  = MDY       SCROLD  = 2         FP_TO   = 16        TGR     = 3
TMPREFA = F         TMPREFB = F
DC1P    = OFF       DC2P    = OFF       DC3P    = OFF       DC4P    = OFF
IN101D  = 0.13      IN102D  = 0.13      IN103D  = 0.13
IN104D  = 0.13      IN105D  = 0.13      IN106D  = 0.13
IN201D  = 0.13      IN202D  = 0.13      IN203D  = 0.13
IN204D  = 0.13      IN205D  = 0.13      IN206D  = 0.13
IN207D  = 0.13      IN208D  = 0.13

BKMON1  =TRIP1 + TRIP3
B1COP1  = 10000     B1KAP1  = 1.2
B1COP2  = 160       B1KAP2  = 8.0
B1COP3  = 12        B1KAP3  = 20.0

BKMON2  =TRIP2 + TRIP3
B2COP1  = 10000     B2KAP1  = 1.2
B2COP2  = 160       B2KAP2  = 8.0
B2COP3  = 12        B2KAP3  = 20.0


Press RETURN to continue
IAW1    =IAW1
IBW1    =IBW1
ICW1    =ICW1
IAW2    =IAW2
IBW2    =IBW2
ICW2    =ICW2

IAW4    =IN1
IBW4    =IN2
ICW4    =IN3

SS1     =0
SS2     =0
SS3     =0
SS4     =0
SS5     =0
SS6     =0
LEDA    =OCA + 87E1
LEDB    =OCB + 87E2
LEDC    =OCC + 87E3

Press RETURN to continue
LED15   =0
LED16   =0

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     =0
DP3_1   =                 DP3_0   =
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
Press RETURN to continue
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  =
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

Press RETURN to continue
```

```
NLB5    =              CLB5    =        SLB5    =        PLB5    =
NLB6    =              CLB6    =        SLB6    =        PLB6    =
NLB7    =              CLB7    =        SLB7    =        PLB7    =
NLB8    =              CLB8    =        SLB8    =        PLB8    =
NLB9    =              CLB9    =        SLB9    =        PLB9    =
NLB10   =              CLB10   =        SLB10   =        PLB10   =
NLB11   =              CLB11   =        SLB11   =        PLB11   =
NLB12   =              CLB12   =        SLB12   =        PLB12   =
NLB13   =              CLB13   =        SLB13   =        PLB13   =
NLB14   =              CLB14   =        SLB14   =        PLB14   =
NLB15   =              CLB15   =        SLB15   =        PLB15   =
NLB16   =              CLB16   =        SLB16   =        PLB16   =

SCEUSE     47.5
GBLCHK     0AC3
=>>
```

SHO P (Show Port Settings)

Access Levels 1, B, 2

SHOWSET 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, or 4). 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: Setting the Relay* for Settings Sheets.

```
=>>SHO P <Enter>
Port 2


PROTO   = SEL
SPEED   = 19200    BITS    = 8        PARITY  = N        STOP    = 1
T_OUT   = 0        AUTO    = Y        RTSCTS  = N        FASTOP  = N
=>>
```

SHO R (Show SER Settings)

Access Levels 1, B, 2

SHOWSET 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 *Section 6: Setting the Relay* for information on all settings. Following is an example of the display for the **SHO R** command.

```
=>>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

Press RETURN to continue
ALIAS14 =NA
ALIAS15 =NA
ALIAS16 =NA
ALIAS17 =NA
ALIAS18 =NA
ALIAS19 =NA
ALIAS20 =NA

=>>
```

STA (Status Report)

Access Levels 1, B, 2

The **STATUS** command displays a report of the self-test diagnostics. The relay automatically executes the **STATUS** 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 performs a warm boot of relay logic. This may clear some warnings, but do not ignore warnings; contact the factory.

The **STA C <Enter>** command clears any out-of-tolerance condition from the status report and restarts the relay. Do not ignore warnings; contact the factory.

If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the report as set. The STATUS report format appears below:

```
=>>STA <Enter>

XFMR 1                                    Date: 11/09/99    Time: 09:08:51.469
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228  CID=A659
SELF TESTS

W=Warn    F=Fail

       IAW1     IBW1     ICW1     IAW2     IBW2     ICW2
OS     -2       -1        0       -0       -2       -1

       IAW3     IBW3     ICW3      IN1      IN2      IN3
OS     -1       -2       -1       -2       -2       -1

       +5V_PS   +5V_REG  -5V_REG  +12V_PS  -12V_PS  +15V_PS  -15V_PS
PS      4.89     5.04    -4.98     12.07   -12.11    14.84   -14.86

       TEMP     RAM      ROM      A/D      CR_RAM   EEPROM   IO_BRD
        37.5    OK       OK       OK       OK       OK       OK

 Relay Enabled

=>>
```

TAR (Show Relay Word Targets On Screen)

Access Levels 1, B, 2

The **TARGET** 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 **QUIT** command is executed, **TAR 0** command is executed, or the **TAR R** command is executed.

The **TARGET** command does not remap the front-panel LEDs. See *TAR F n (Show Relay Word Targets on Front-Panel LEDs) on page 7.36*.

The following examples demonstrate the **TARGET** command:

```
=>>TAR <Enter>                        Default Row is 0

EN     TRIP   INST   87_1   87_2   87_3   50     51
1      1      1      1      1      1      0      1

=>>TAR 8                              Display and Change Default to Row 8

50N21  50N21T 50N22  51N2   51N2T  51N2R  NDEM2  OC2
0      0      0      0      0      1      0      0

=>>TAR                                Default is Row 8

50N21  50N21T 50N22  51N2   51N2T  51N2R  NDEM2  OC2
0      0      0      0      0      1      0      0

=>>TAR 8 5                            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                          Display Row 24 (RB4) But Do Not Change Default

RB1    RB2    RB3    RB4    RB5    RB6    RB7    RB8
0      0      0      0      0      0      0      0

=>>TAR

50N21  50N21T 50N22  51N2   51N2T  51N2R  NDEM2  OC2
0      0      0      0      0      1      0      0

=>>TAR R                              Reset Default to 0

EN     TRIP   INST   87_1   87_2   87_3   50     51
1      0      0      0      0      0      0      0
=>>
```

Refer to *Section 4: Control Logic* for a list of the Relay Word and the corresponding rows.

TAR F n (Show Relay Word Targets on Front-Panel LEDs)

Access Levels 1, B, 2

The **TARGET F** command works like the **TARGET** 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 for the command for the serial port display. The default is 1.
- X allows remapping 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 **QUIT** command is executed, **TAR 0** 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 and the corresponding rows.

TAR R (Reset Targets)

Access Levels 1, B, 2

The **TARGET 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 finish using the **TAR** or **TAR F** command for testing.

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, up to 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 **TIME** 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 h:m:s; 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 by using a source of demodulated IRIG-B time code.

TRI (Trigger an Event)

Access Levels 1, B, 2

The **TRIGGER** command generates an event record. The command is a convenient way to record all inputs and outputs from the relay at any time you desire (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: 11/09/99    Time: 09:39:45.641
STATION A

Event: TRIG
Targets:
Winding 1 Currents (A Sec), ABC:   2.1   2.1   2.1
Winding 2 Currents (A Sec), ABC:   1.7   1.7   1.7
Winding 3 Currents (A Sec), ABC:   0.0   0.0   0.0
Winding 4 Currents (A Sec), ABC:   0.0   0.0   0.0
=>>
```

Alarm Conditions

The SEL-387A asserts the ALARM output while turning 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 7.6*.

Table 7.6 Commands With Alarm Conditions

Command	Condition
2AC	Entering Access Level 2 or Three wrong password attempts into Access Level 2
ACC	Three wrong password attempts into Access Level 1
BAC	Entering Breaker Access Level or 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*	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 7.7* lists all jumpers you should be concerned with and their effects.

Table 7.7 Main Board Jumpers

Jumper	Comment
JMP6A	Disables password protection when installed
JMP6B	Enables **CLO**, **OPE**, and **PUL** commands when installed

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Section 8
Front-Panel Interface

Front-Panel Operation

A close-up view of the user interface portion of the SEL-387A Relay front panel is shown in *Figure 8.1*. It includes a two-line, 16-character LCD display; 16 LED target indicators; and 8 pushbuttons for local communication.

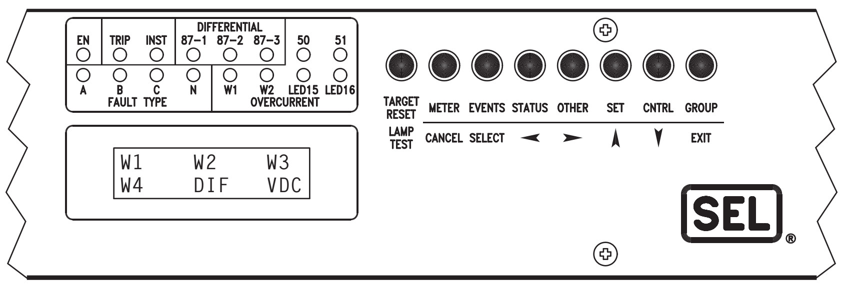


Figure 8.1 SEL-387A Front-Panel User Interface

The LCD display 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 a time period specified in the SET G setting FP_TO (Front-Panel Time-Out) and then takes the following actions:

- The front-panel LCD display 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 0 to 30 minutes. If zero is selected, the front panel will never time out. A zero setting is useful when testing, but do not leave the time-out set at zero. The backlight will fail if illuminated for prolonged periods of time, and the target LEDs that may have been changed using the **TAR F** command will not be reset to the default targets. Reset FP_TO to some non-zero value, then *push any button*—the relay will not revert to the new value of FP_TO until a button has been pushed.

Displays

The LCD display is controlled by the pushbuttons, automatic messages the relay generates, and user-programmed Display Points. Display Points and LCD scrolling controls 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 as many as four two-line displays of the A-, B-, and C-Phase currents in the two windings in primary amperes. If the Analog Input Label settings (IAW1, etc.) have been renamed, these will appear in the display as set. The two-line current display for Winding *n* is turned off if both of the settings E87 and EOC*n* are set to "N." Each display remains for Global setting SCROLD (seconds) before scrolling continues. Any message generated by the relay because of 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 occurs; refer to *Section 10: Testing and Troubleshooting* for further instructions.

While the relay is turning on and when executing the **R_S** command to reset factory-default settings, the LCD displays `Initializing`. It will then scroll through the winding current 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 display 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, but *Section 4: Control Logic* describes each target LED in detail.

The only times the target LEDs do not illuminate according to their labels is when (1) LEDA, LEDB, LEDC, LED15, or LED16 has been reprogrammed by the user 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 a Relay Word bit that is asserted illuminates the corresponding LED position. Refer to *Section 7: Serial Port Communications and Commands* for a complete description of the **TAR F** command.

The states of the 10 dedicated LEDs (all but **EN**, **A**, **B**, **C**, **LED15**, **LED16**) are stored in nonvolatile memory. If power to the relay is lost, these 10 targets will return to their last state when power is restored. **EN** responds only to internal self-test routines, while **A**, **B**, **C**, **LED15**, and **LED16** 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 are not password protected. The front panel is normally 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 six characters, shown initially as ABCDEF, with the A underscored. 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 by using the up/down arrows as before. Continue this process until all six characters are filled. If the password has fewer than six 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, and 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 clears 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 **W1**, **W2**, **W3**, **W4**, **DIF**, or **VDC** metering display. W1 through W4 are winding displays, DIF is the differential element display, and VDC is the Battery Monitor display. Winding 3 always displays 0 in the SEL-387A, but Winding 4 shows the neutral current inputs. Use any arrow button to highlight the choice. Then push **SELECT**.

Windings (W1, W2, W3, W4)

If a winding has been selected, a second menu appears prompting 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 to either **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.

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 (VDC)

If VDC is selected, the relay displays `Station Battery` and `VDC= nnn.n`.

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. Information displayed for a given event is the 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 up to 80 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 8.6, 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-387A-Rxxx-V0-Zxxxxxx-Dxxxxxxxx` (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, and 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, Bk3, or Bk4. Only Breakers 1 and 2 have information available; Breakers 3 and 4 always display zero values. 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 8.7, 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 the function is 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 appears prompting 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 79
TAR BKR_MON 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.

Single Step. From the Scroll Locked state, single-step through the display screens by pressing the **SELECT** key twice. Wait for the first press to display the next screen as the active display, then press the **SELECT** key a second time to freeze scrolling.

Exit. Press the **EXIT** key to leave Scroll Lock Control and return the rotating display to normal operation.

Cancel. Press the **CANCEL** key to return to the OTHER menu.

```
DATE TIME 79
TAR BKR_MON LCD
```

RESET51

This command exactly equates to the **RES** serial port command. RESET51 clears all time accumulators of all the inverse-time 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 illuminated 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 8.8, 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 you to `Press TARGET RESET for help during set/show routine`. This special use for the **TARGET RESET** button gives you a short description of the setting and the range of values, should you not recognize the setting by its Character string name.

The next menus to appear let you 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 desired section, 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, 30, 60 Cycles)` setting.

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.

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 of selection of 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, it returns 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 you if you intend 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, reminding the user to `Press TARGET RESET for help during set/show routine`. This special use for the **TARGET RESET** button gives you a short description of the setting and the range of values, should you not recognize the setting by its Character string name.

The next menus to appear let you 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**, **RESTRICTED EARTH**, **WINDING *n* ELEMS**, **NEUTRAL ELEMS**, **RTD 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, and 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 **E87=Y** appears in the second line of the display. If you do not recognize this setting, you can push the **TARGET RESET** button and a single scroll across the first line will indicate that this is the `Enable Wdg1 in Differential Element (Y, N)` setting.

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.

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 E87, 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 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 of selection of 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 it returns 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 it, 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 you if you intend 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 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. 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 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 `Protocol (SEL, LMD, DNP, RTDA, RTDB)` setting.

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.

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 PROTO, 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 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 Control

In more specific terms, local control asserts (sets to logical 1) or deasserts (sets to logical 0) local control switches referred to as 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*.

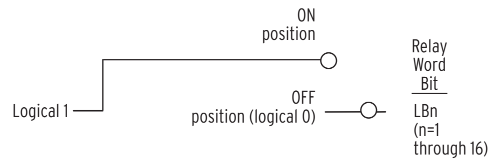


Figure 8.2 Local Control Switch Configured as an ON/OFF Switch

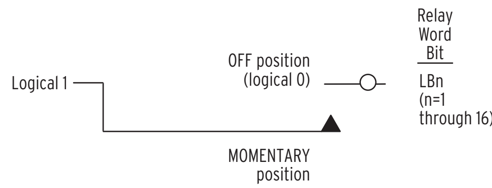


Figure 8.3 Local Control Switch Configured as an OFF/MOMENTARY Switch

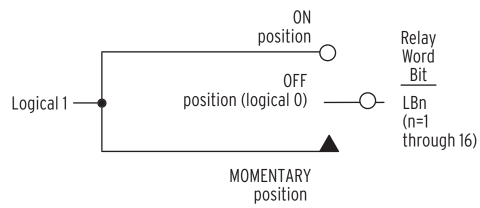


Figure 8.4 Local Control Switch Configured as an ON/OFF/MOMENTARY Switch

Local control switches are created by making corresponding switch position label settings. These text label settings are set with the **SET G** command or viewed with the **SHO G** command via the serial port. Refer to *SET G (Edit Global Settings) on page 7.27* and *SHO G (Show Global Settings) on page 7.31*.

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 LBn	logical 1
OFF	CLB*n*	"Clear" Local Bit LBn	logical 0
MOMENTARY	PLB*n*	"Pulse" Local Bit LBn	logical 1 for one processing interval

Note the first setting in *Table 8.1* (NLB*n*) is the overall switch name setting.

Label the switch positions to accurately describe the control function presented on the LCD. Use any printable ASCII characters in the local control switch position label settings; you can enter 14 characters for setting NLB*n* and 7 characters each for settings CLB*n*, SLB*n*, and PLB*n*.

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

Set NLB*n*, SLB*n*, CLB*n*, and PLB*n* to "NA" to disable local control switches thus "nulling" all the label settings for that switch. The local bit associated with this disabled local control switch is then fixed at logical 0.

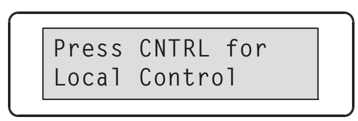
Factory Settings Examples:

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.

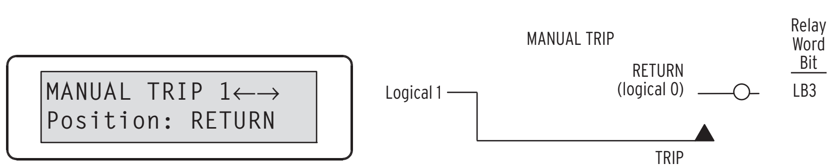
Local Bit	Label Settings	Function
LB3	NLB3 = MANUAL TRIP 1	trips breaker and drives reclosing relay to lockout
	CLB3 = RETURN	OFF position ("return" from MOMENTARY position)
	SLB3 =	ON position—not used (left blank)
	PLB3 = TRIP	MOMENTARY position
LB4	NLB4 = MANUAL CLOSE 1	closes breaker, separate from 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)

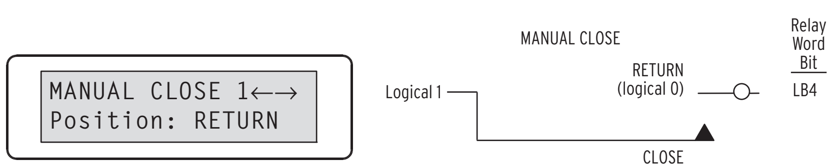
Access local control via the **CNTRL** pushbutton. If local control switches exist (i.e., corresponding switch position label settings were made), the following message displays with the rotating default display messages.



Press 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.

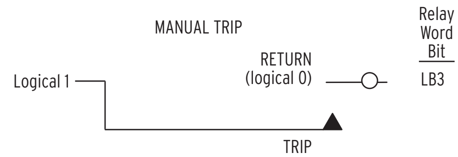
```
Output Contact ←→
Testing
```

This front-panel function provides the same function as the serial port **PUL** command.

Operate Local Control (With Factory Settings)

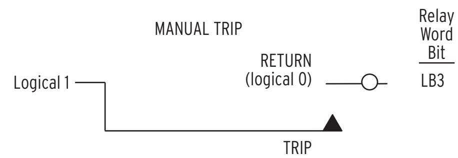
Press the right arrow pushbutton, and scroll back to the first set local control switch in the factory-default settings.

```
MANUAL TRIP 1←→
Position: RETURN
```



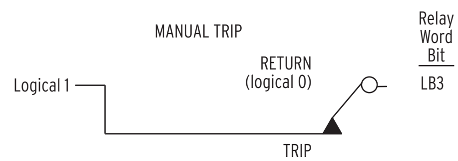
Press the **SELECT** pushbutton to display the operate option for the displayed local control switch.

```
MANUAL TRIP 1
Trip? Yes No ←→
```



Scroll left with the left arrow button and then select `Yes` to show the new local control switch position.

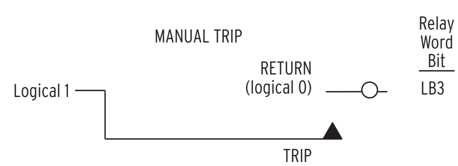
```
MANUAL TRIP 1
Position: TRIP
```



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.

```
MANUAL TRIP 1←→
Position: RETURN
```

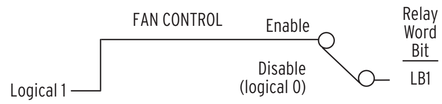


The MANUAL CLOSE 1 switch is an OFF/MOMENTARY type switch, like the MANUAL TRIP 1 switch, and operates similarly.

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 (see *Figure 8.2*).



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, 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 when power is restored.

Pulse Output Contacts

Use the control button **CTRL** to mimic the **PUL**se, **OPE**n, and **CLO**se serial port commands. This is useful during relay checkout to verify that output contacts actually function in response to a command.

Pulse Output Contacts are available in the **CTRL** menu after the **Local Bit** pushbutton functions. The screen will prompt for `Pulse Close  Open`. Use the right/left arrow keys and **SELECT** to choose.

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 Pulse is selected, the next screen will prompt for the output to be pulsed. These are OUT101 to OUT107 and NOTALM. 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.

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 asks 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 not 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-387A 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 LED A, LED B, LED C, LED15, LED16

Five of the LEDs in the second row can 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:

LED A = OCA + 87E1   **LED B** = OCB + 87E2   **LED C** = OCC + 87E3

LED LED15 = 0 **LED LED16** = 0

The Relay Word bits OCA, OCB, and OCC indicate selection of A-, B-, or C-Phase 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 A-, B-, and C-Phase. 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 so that observers of the front-panel labels will not be confused by seeing the LEDs illuminated for apparently no reason and being unable to verify why they are illuminated without having 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, which are of interest to the user.

Rotating Default Display

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. The message rank is:

- Error message
- Status message if no error message
- Selected strings associated with Display Points if present
- If no strings associated with Display Points are present, current magnitudes of two windings

The Display Point label settings are displayed two at a time for a two-second interval before rotating to the next screen.

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-387A is used.

There are 16 of these default displays available in the SEL-387A. Referred to as Display Points, each default display has 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 SELOGIC 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 by using the command **SET G**. View these text settings by using the serial port command **SHO G**. These text settings are displayed in pairs on the SEL-387A front-panel display in rotation. Global setting SCROLD determines how long each pair is displayed. They must not be longer than 16 characters maximum. 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

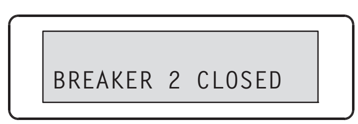
Display Point setting DP2 controls the display of the text settings.

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.



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.

Dynamic Display

You can display relay time-overcurrent pickup settings, metering values, breaker wear monitor values, and RTD readings on the SEL-387A front-panel LCD (subject to the number of available Display Points); these dynamic Display Points reflect actual settings and values in the relay and are in addition to the programmable text discussed previously. The relay displays these settings and metering quantities on the rotating default display.

Display Formats and Settings

The SEL-387A presents dynamic Display Points in a dual-line or a same-line format. Dual-line dynamic displays require two Display Points; the same-line format uses only one Display Point.

Dual-Line Format

Apply special control characters in Display Point settings DP*n*_0 and DP*n*_1 to display relay values. Use the Display Point settings with a leading two-character sequence "::" (double-colon) followed by the element name or mnemonic text setting. For a dual-line complementary-screen presentation format for the deasserted state (logical 0) use:

DP*n*_0 = ::XXXXXXXXXXXXXXXX

DP(*n*+1)_0 = ::NAME

where:

Xs indicate as many as 16 label characters,

n is Display Point 1, 3, 5, 7, 9, 11, 13, or 15,

(*n*+1) is the next Display Point, and

NAME is a relay element or mnemonic representing a time-overcurrent element pickup, a metering value, a breaker wear monitor value, or RTD readings.

For the asserted state (logical 1), replace DP*n*_0 with DP*n*_1.

For a setting example, see *Dual-Line Setting Example* in *Display Time-Overcurrent Element Pickup Settings on page 8.20*.

Same-Line Format (Time-Overcurrent Elements Only)

You can display time-overcurrent pickup settings on a single Display Point. For a same-line presentation format, use the Display Point settings with a prelabel (if needed), an embedded two-character sequence or an embedded three-character sequence, the mnemonic text, and a postlabel (if needed). The format for a same-line Display Point setting for the deasserted state (logical 0) is:

DP*n*_0 = XXX;;51*nn*P;YYY

or

DP*n*_0 = XXX;;;*kk*;YYY

where:

XXX is the prelabel,

YYY is the postlabel,

51*nn*P is the time-overcurrent element pickup, and

kk is a shorthand number indicating a particular time-overcurrent element pickup.

For the asserted state (logical 1) replace DP*n*_0 with DP*n*_1.

Table 8.4 shows the time-overcurrent element settings, resolution, and the maximum label characters. The maximum number of label characters in a same-line display is either six or nine characters. The relay shows six label characters when you use the embedded double semicolon (;;) and the actual name of the overcurrent element pickup; the relay displays nine label characters when you use the embedded triple semicolon (;;;) and overcurrent element number shown in *Table 8.4*. You can vary the number of label characters in the prelabel and the postlabel as long as the sum does not exceed the maximum.

You can omit either the prelabel or the postlabel. When excluding the postlabel, be sure to include the last semicolon.

For setting examples, see *Same-Line Setting Examples* in *Display Time-Overcurrent Element Pickup Settings*.

Table 8.4 Dynamic Display Same-Line Overcurrent Elements

Setting	Setting Displayed	Display Resolution	Label Characters (maximum)
;;51P1P	51P1P	#######.##	6
;;51Q1P	51Q1P	#######.##	6
;;51N1P	51N1P	#######.##	6
;;51P2P	51P2P	#######.##	6
;;51Q2P	51Q2P	#######.##	6
;;51N2P	51N2P	#######.##	6
;;51NN1P	51NN1P	#######.##	6
;;51NN2P	51NN2P	#######.##	6
;;51NN3P	51NN3P	#######.##	6
;;;0	51P1P	#######	9
;;;1	51Q1P	#######	9
;;;2	51N1P	#######	9
;;;3	51P2P	#######	9
;;;4	51Q2P	#######	9
;;;5	51N2P	#######	9
;;;12	51NN1P	#######	9
;;;13	51NN2P	#######	9
;;;14	51NN3P	#######	9

Display Time-Overcurrent Element Pickup Settings

Use Display Point text settings and logic settings to display the following relay elements in primary units:

51P1P, 51Q1P, 51N1P, 51P2P, 51Q2P, 51N2P, 51NN1P, 51NN2P, 51NN3P

The relay shows a dynamic display for these overcurrent element pickup settings in either a dual-line presentation or a same-line presentation.

Dual-Line Setting Example

Enter the following settings for a dual-line display:

DP1_0 = Brkr 1 Trips at
DP2_0 = ::51P1P

DP1 = 0
DP2 = 0

The following appears on the front-panel display:

```
BRKR 1 TRIPS AT
########.## A pri
```

where # designates the primary value of the 51P1P setting (51P1P multiplied by CTR1).

The relay recognizes the double-colon control string, locates the element name, validates the name, obtains the secondary value, multiplies the secondary value by setting CTR*n*, and displays the value with "A pri" appended.

Same-Line Setting Examples

Enter the following settings for a same-line display with six label characters:

DP1_0 = W=;;51P1P;Apri

DP1 = 0

The following appears on the front-panel display:

```
W=########.##APRI
BREAKER 2 CLOSED
```

where # designates the primary value of the 51P1P setting (51P1P multiplied by setting CTR1). The second Display Point on this display was previously programmed to show circuit breaker status.

Enter the following settings for a same-line display with nine label characters:

DP2_0 = Neut 1=;;;12;Ap

DP2 = 0

The following appears on the front-panel display:

```
BREAKER 1 CLOSED
NEUT 1=########AP
```

where # designates the primary value of the 51NN1P setting (51NN1P multiplied by CTRN1). The first Display Point on this display was previously programmed to show circuit breaker status.

Display Metering and Breaker Wear Monitor

The LCD displays the following secondary metering quantities as primary metering quantities (primary values) when you set the appropriate Display Point text settings and logic settings. Use the double-colon control string (::) for a dynamic display of the metering or breaker quantities listed in the following paragraphs.

Some of these display elements match internal Relay Word bits, and other display elements have mnemonics that represent the dynamic display quantity.

Matching Relay Word Bits

These dynamic display names have the same names as the Relay Word bits: IAW1, IBW1, ICW1, 3I1W1, 3I2W1, IRW1, IAW2, IBW2, ICW2, 3I1W2, 3I2W2, IRW2, IOP1, IOP2, IOP3, IRT1, IRT2, IRT3, I1F2, I2F2, I3F2, I1F5, I2F5, I3F5, VDC, RTD1A, RTD2A, RTD3A, RTD4A, RTD5A, RTD6A, RTD7A, RTD8A, RTD9A, RTD10A, RTD11A, RTD12A, RTD1B, RTD2B, RTD3B, RTD4B, RTD5B, RTD6B, RTD7B, RTD8B, RTD9B, RTD10B, RTD11B, RTD12B. For a description of these Relay Word bits, see *Section 4: Control Logic*.

Mnemonics

Table 8.5 lists the secondary metering quantities that differ from the Relay Word bits that the relay uses for demand metering, peak demand metering, and the breaker wear monitor.

Table 8.5 Dynamic Display Mnemonics (Sheet 1 of 2)

Mnemonic	Data
IAW1DEM	IAW1 demand current
IBW1DEM	IBW1 demand current
ICW1DEM	ICW1 demand current
3I2W1DEM	3I2W1 demand current
IRW1DEM	IRW1 demand current
IAW1PK	IAW1 peak demand current
IBW1PK	IBW1 peak demand current
ICW1PK	ICW1 peak demand current
3I2W1PK	3I2W1 peak demand current
IRW1PK	IRW1 peak demand current
IAW2DEM	IAW2 demand current
IBW2DEM	IBW2 demand current
ICW2DEM	ICW2 demand current
3I2W2DEM	3I2W2 demand current
IRW2DEM	IRW2 demand current
IAW2PK	IAW2 peak demand current
IBW2PK	IBW2 peak demand current
ICW2PK	ICW2 peak demand current
3I2W2PK	3I2W2 peak demand current
IRW2PK	IRW2 peak demand current
INTTRB1	Bkr1 internal trip count
INTIAW1	Bkr1 internal trip Σ IA
INTIBW1	Bkr1 internal trip Σ IB
INTICW1	Bkr1 internal trip Σ IC
EXTTRB1	Bkr1 external trip count
EXTIAW1	Bkr1 external trip Σ IA
EXTIBW1	Bkr1 external trip Σ IB
EXTICW1	Bkr1 external trip Σ IC
WEARAB1	Bkr1 A-Phase wear monitor

Table 8.5 Dynamic Display Mnemonics (Sheet 2 of 2)

Mnemonic	Data
WEARBB1	Bkr1 B-Phase wear monitor
WEARCB1	Bkr1 C-Phase wear monitor
INTTRB2	Bkr2 internal trip count
INTIAW2	Bkr2 internal trip Σ IA
INTIBW2	Bkr2 internal trip Σ IB
INTICW2	Bkr2 internal trip Σ IC
EXTTRB2	Bkr2 external trip count
EXTIAW2	Bkr2 external trip Σ IA
EXTIBW2	Bkr2 external trip Σ IB
EXTICW2	Bkr2 external trip Σ IC
WEARAB2	Bkr2 A-Phase wear monitor
WEARBB2	Bkr2 B-Phase wear monitor
WEARCB2	Bkr2 C-Phase wear monitor

Metering and Breaker Wear Monitor Resolution

The front-panel display automatically adjusts the reporting resolution for the DEMAND and INST metering Display Points with the exception of station dc battery voltage. The number of decimal places ranges from zero to three. The value of the quantity determines the decimal point position. For example, if IAW1 is less than 10 kA, the display shows 9.999 kA. If IAW1 is greater than 10 kA but less than 100 kA, the decimal point shifts one place to the right and the LCD displays 10.00 kA. If IAW1 is greater than 100 kA, the LCD shows 100.0 kA.

Scroll Lock Control of Front-Panel LCD

Select Scroll Lock

The rotating default display can be locked on a single screen. Access the scroll lock control with the **OTHER** pushbutton.

```
DATE TIME 79
TAR BKR_MON 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 or on the current meter display screen. While rotation is stopped, the active display is updated continuously so that current or 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 LCD and resumes the rotating display.

Single Step

From the Scroll Locked state, single-step through the display screens by pressing the **SELECT** key twice. Wait for the first press to display the next screen as the active display, then press the **SELECT** key a second time to freeze scrolling.

Exit

Press the **EXIT** key to leave Scroll Lock Control and return the rotating display to normal operation.

Figures of Selected Front-Panel Menu Structures

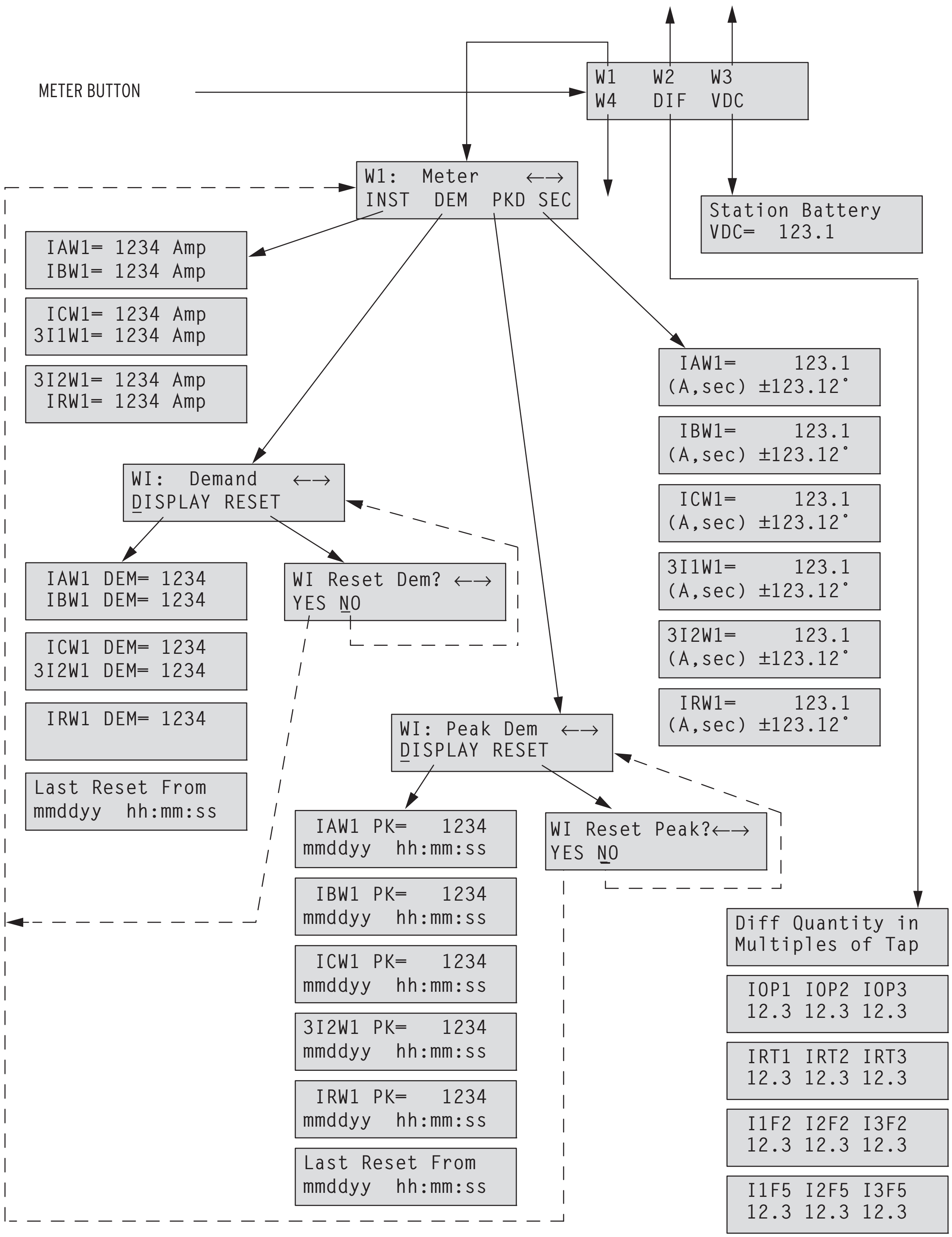
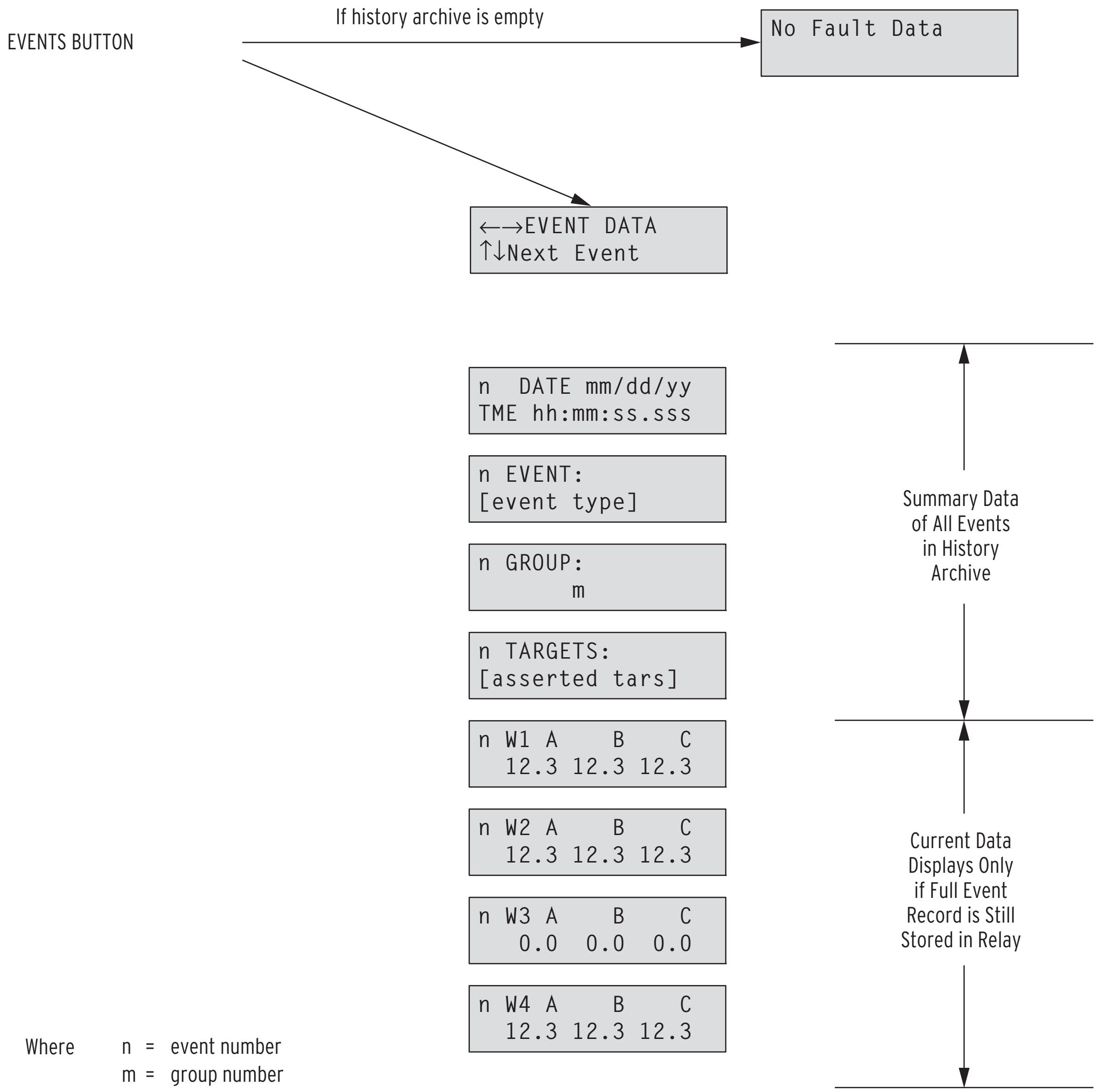


Figure 8.5 METER Menu and Display Structure



Where n = event number
m = group number

Note: If secondary currents > 99.9, drop the decimal place.

Figure 8.6 EVENTS Display Structure

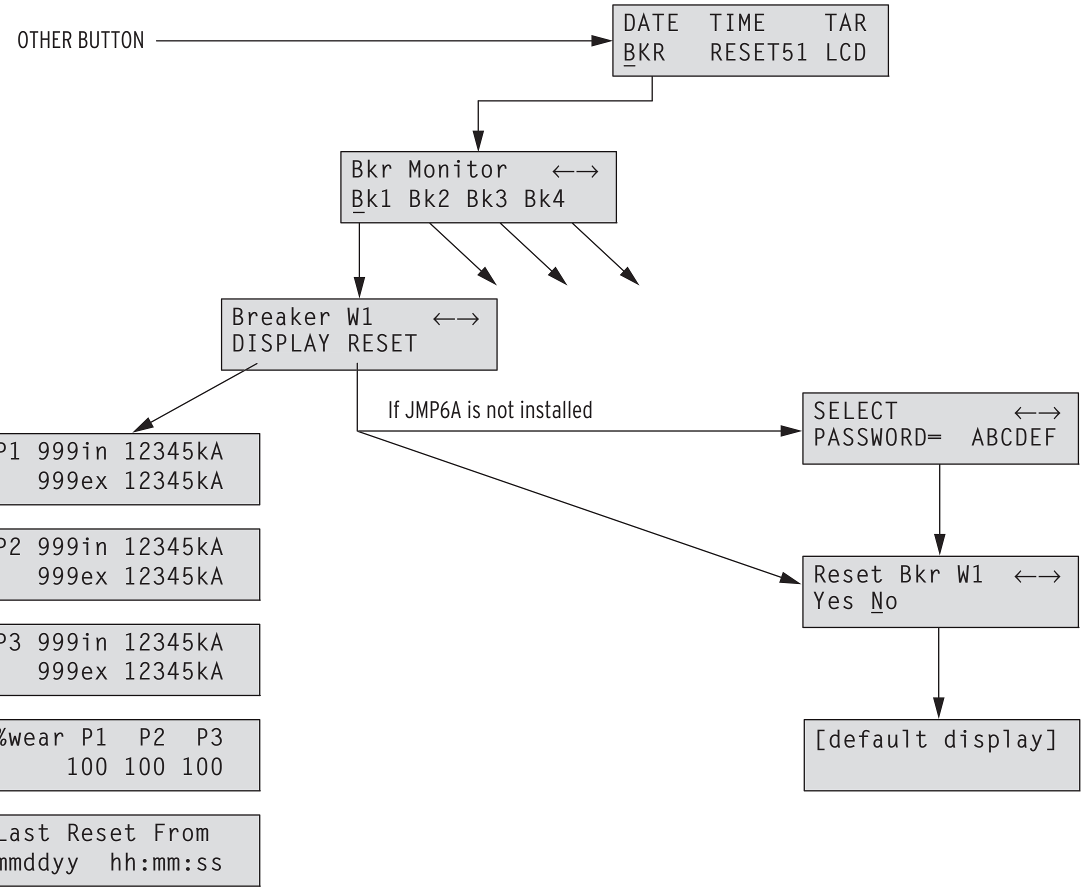


Figure 8.7 OTHER/BKR Menu and Display Structure

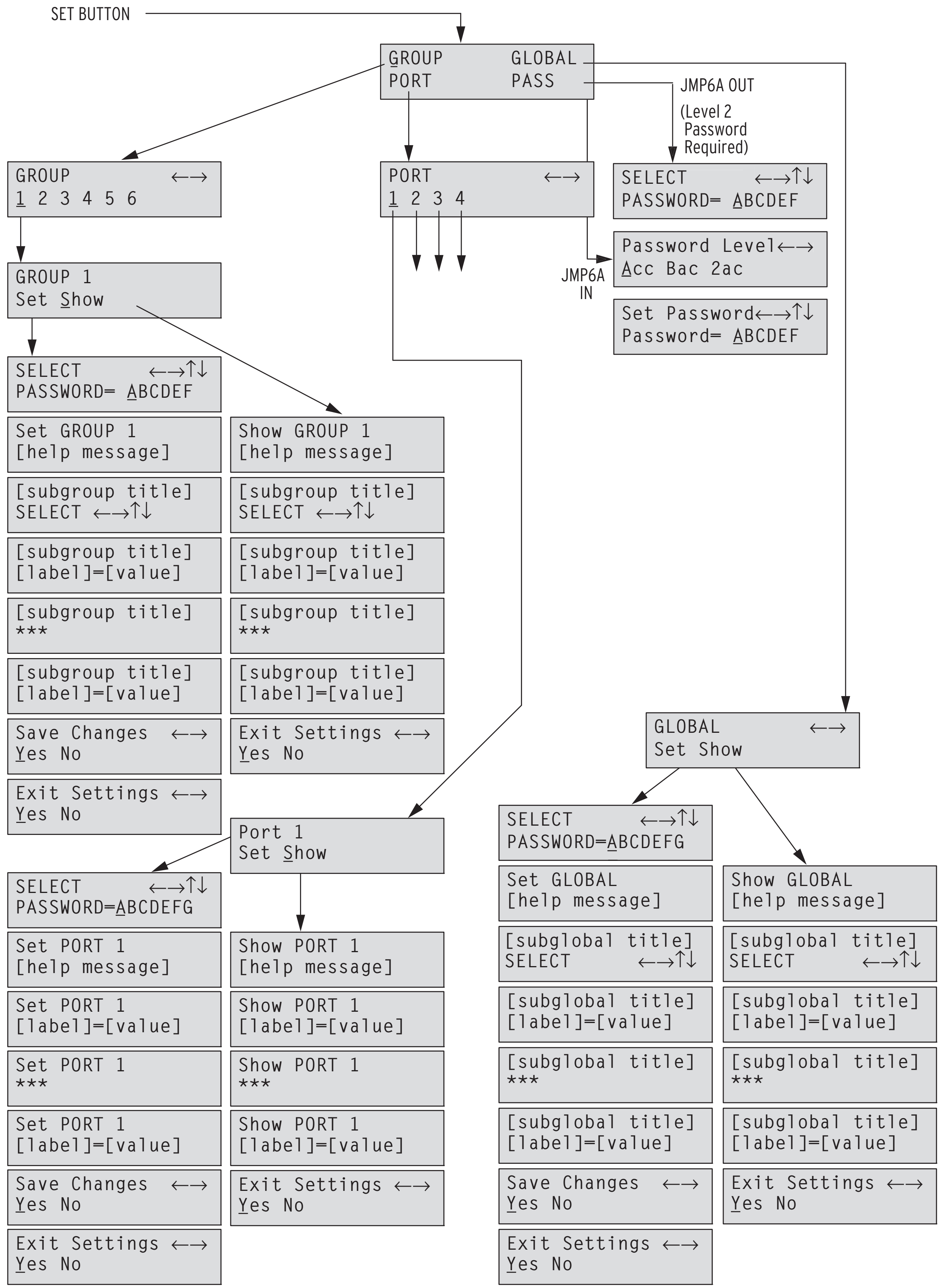


Figure 8.8 SET Menu and Display Structure

Section 9
Event Reports and SER

Winding 3 and Winding 4 Reporting

The SEL-387A Relay satisfies the requirement for a two-winding differential relay equipped with extensive I/O. To this end, the SEL-387A is a subset of the larger SEL-387 Relay, including most functions of the SEL-387, but suitable for two-winding applications only. Because the SEL-387A retains the reporting structure of the SEL-387, the report formats still include rows and/or columns for Windings 3 and 4. Because current values for Winding 3 no longer apply, they are displayed as zeros and should be ignored. When you order an SEL-387A with the optional restricted earth fault (REF) elements, current channels assigned to Winding 4 in the SEL-387 are reassigned to represent neutral currents IN1, IN2, and IN3 (i.e., IAW4 = IN1, IBW4 = IN2, and ICW4 = IN3). In an SEL-387A without the REF option, the current values for Winding 4 are displayed as zeros.

Introduction

The SEL-387A offers two styles of event reports:

- Standard 15-, 30-, 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-, 30-, or 60-cycle event reports by fixed and programmable conditions. These reports show information for 15, 30, 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
30	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 = 30) are stored together or if the relay is subjected to frequent off/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 9.1* 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-, 30-, or 60-Cycle Event Reports

Event Report Length (Settings LER and PRE)

The SEL-387A provides user-programmable event report length and pre-fault length. Event report length is set at 15, 30, 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 either via the **SET G** serial port command or via 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-, 30-, or 60-cycle event report when any of the following occur:

- Relay Word bits TRIP1 through TRIP5 assert
- Relay Word bits CLS1 through CLS4 assert
- Programmable SELOGIC control equation setting ER asserts to logical 1
- **PULSE** serial port/front-panel command executed for output contact OUT101 through OUT107 or other OUT*nnn* contacts if available
- **TRIGGER** serial port command executed

Relay Word Bits TRIP1–TRIP5, CLS1–CLS4

Relay Word bits TRIP*n* (*n* = 1, 2, 3, 4, or 5) usually would 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 4.7*). The Relay Word bit OC*m* (*m* = 1, 2, 3, 4), initiated by the “Open breaker *m*” serial port command **OPE *m*** or the front-panel CNTRL/Open command, normally would be assigned to TR*m*.

Similarly, Relay Word bits CLS*m* (*m* = 1, 2, 3, 4) would be assigned to an output contact for closing a circuit breaker (e.g., setting OUT105 = CLS1). SELOGIC control equations settings CL*m* initiate the Close Logic and control the assertion of Relay Word bits CLS*m* (see *Figure 4.8*). The Relay Word bit CC*m*, initiated by the “Close breaker *m*” serial port command **CLO *m*** or the front-panel CNTRL/Close command, normally would 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 equations setting ER. The assertion of Relay Word bit TRIP*n* or CLS*m* automatically triggers a standard 15-, 30-, or 60-cycle event report.

Programmable SELOGIC Control Equation Setting ER

The SELOGIC control equation setting ER is set to trigger standard 15-, 30-, 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

ER is factory-set with definite-time and inverse-time overcurrent element pickups for phase- and negative-sequence quantities on Windings 1 and 2. Thus, at the inception of a fault, whichever pickup asserts first will trigger a standard 15-, 30-, 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 **PULSE** serial port/front-panel command is used to assert the output contacts for testing purposes or for remote control. If an output contact OUT101–OUT107 or an available interface board contact OUT*nnn* is asserted with the **PULSE** command, a standard 15-, 30-, 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 **TRIGGER** serial port command is to generate standard 15-, 30-, or 60-cycle event reports primarily for testing purposes. Simply type **TRI <Enter>** to execute the command.

See *Section 7: Serial Port Communications and Commands* for more information on serial port commands **TRIGGER** and **PULSE**.

Standard Event Report Summary

Each time the relay generates a standard 15-, 30-, or 60-cycle event report, it also generates a corresponding event summary (see *Figure 9.1*). Use the **EVE T** command to generate this summary. 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 two (2) winding inputs

This event summary information is also contained in the corresponding standard 15-, 30-, or 60-cycle event report. The identifiers, date, and time information is at the top of the standard 15-, 30-, 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*.

NOTE: The relay sends event summaries to all serial ports with setting AUTO = Y each time an event triggers.

```
XFMR 1                          Date: 02/28/97    Time: 06:28:38.888
STATION A

Event: TRIP3
Targets: TRIP INST 87_1 87_2 87_3 A B C
Winding 1 Currents (A Sec), ABC:   2.1   2.1   2.1
Winding 2 Currents (A Sec), ABC:   0.0   0.0   1.7
Winding 3 Currents (A Sec), ABC:   0.0   0.0   0.0
Winding 4 Currents (A Sec), ABC:   0.0   0.0   0.0
```

Figure 9.1 Example Event Summary

The latest 80 event summaries are stored in nonvolatile memory and are accessed by the **HISTORY** command. The **HIS C** command clears the event summaries and corresponding full-length standard event reports from nonvolatile memory. See *HIS (History of Events)* and *HIS C (Clear History and Events)* in *Section 7: Serial Port Communications and Commands* 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* in this section).

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
TRIP5	Assertion of Relay Word bit TRIP5
CLS1	Assertion of Relay Word bit CLS1
CLS2	Assertion of Relay Word bit CLS2
CLS3	Assertion of Relay Word bit CLS3
CLS4	Assertion of Relay Word bit CLS4
ER	SELOGIC control equations setting ER
PULSE	Execution of **PULSE** serial port command
TRIG	Execution of **TRIGGER** serial port command

The order of precedence for listing the event type in the summary is: TRIP, CLOSE, ER, PULSE, TRIG (as *Table 9.1* implies). 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, 50, 51, A, B, C, N, W1, W2, LED15, and LED16.

Winding Currents

The “Winding n Currents (A Sec), ABC:” (*n* = 1 or 2) field shows each winding input current present in the event report row containing the maximum secondary phase current. The standard 15-, 30-, 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 two (2) winding inputs are:

Phase (A = channel IA, B = channel IB, C = channel IC)

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 two winding inputs as well as the status of the eight output contacts and six optoisolated inputs.

Use the **EVENT** command to retrieve winding event reports. There are several options to customize 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* = Displays *x* samples per cycle (4 or 8); defaults to 4 if not listed

L*y* = Displays *y* cycles of data (1 to LER); defaults to LER if not listed

L*y*- = Displays from cycle *y* to end of report

L*y*-*w* = Displays 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 and was retrieved with the **EVE <Enter>** command.

```
XFMR 1                                   Date: 11/09/99    Time: 09:45:00.566
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228
    Winding 1         Winding 2         Winding 3        Winding 4      OUT  IN
    Amps Sec          Amps Sec          Amps Sec         Amps Sec       1357 135
 IAW1  IBW1  ICW1  IAW2  IBW2  ICW2  IAW3  IBW3  ICW3   IN1   IN2   IN3 246A 246
[1]
-1.23 -0.85  2.08  1.02  0.70 -1.73  0.00  0.00  0.00  0.00  0.00  0.00 .... ...
 1.70 -1.90  0.21 -1.41  1.59 -0.19  0.00  0.00  0.00  0.00  0.00  0.00 .... ...
 1.23  0.85 -2.08 -1.02 -0.70  1.73  0.00  0.00  0.00  0.00  0.00  0.00 .... ...
-1.70  1.90 -0.22  1.41 -1.59  0.19  0.00  0.00  0.00  0.00  0.00  0.00 .... ...
[2]
-1.23 -0.85  2.08  1.02  0.70 -1.73  0.00  0.00  0.00  0.00  0.00  0.00 .... ...
 1.70 -1.90  0.22 -1.41  1.59 -0.19  0.00  0.00  0.00  0.00  0.00  0.00 .... ...
 1.23  0.85 -2.08 -1.02 -0.70  1.73  0.00  0.00  0.00  0.00  0.00  0.00 .... ...
-1.69  1.91 -0.22  1.40 -1.59  0.19  0.00  0.00  0.00  0.00  0.00  0.00 .... ...

.
.
.
 [15]
-1.28 -0.78  2.07  0.00  0.00 -1.73  0.00  0.00  0.00  0.00  0.00  0.00 .3.. ...
 1.65 -1.93  0.28  0.00  0.00 -0.25  0.00  0.00  0.00  0.00  0.00  0.00 .3.. ...
 1.28  0.77 -2.07  0.00  0.00  1.73  0.00  0.00  0.00  0.00  0.00  0.00 .3.. ...
-1.65  1.93 -0.28  0.00  0.00  0.25  0.00  0.00  0.00  0.00  0.00  0.00*.3.. ...

Event: TRIP3
Targets: TRIP INST 87_1 87_2 87_3 A B C
Winding 1 Currents (A Sec), ABC:   2.1   2.1   2.1
Winding 2 Currents (A Sec), ABC:   0.0   0.0   1.7
Winding 3 Currents (A Sec), ABC:   0.0   0.0   0.0
Winding 4 Currents (A Sec), ABC:   0.0   0.0   0.0
```

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 Z24. 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 (A, secondary)
IBW1	Current measured by Winding 1 input channel IB (A, secondary)
ICW1	Current measured by Winding 1 input channel IC (A, secondary)
IAW2	Current measured by Winding 2 input channel IA (A, secondary)
IBW2	Current measured by Winding 2 input channel IB (A, secondary)
ICW2	Current measured by Winding 2 input channel IC (A, secondary)
IAW3	
IBW3	
ICW3	
IN1	Current measured by neutral input channel IN1 (A secondary)
IN2	Current measured by neutral input channel IN2 (A, secondary)
IN3	Current measured by neutral input channel IN3 (A, 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
IN 12	1	IN101[a] asserted
	2	IN102[a] asserted
	b	IN101[a] and IN102[a] asserted
IN 34	3	IN103[a] asserted
	4	IN104[a] asserted
	b	IN103[a] and IN104[a] asserted
IN 56	5	IN105[a] asserted
	6	IN106[a] asserted
	b	IN105[a] and IN106[a] asserted

[a] In a raw event report, the IN columns display IN101R through IN106R Relay Word bits instead of the debounced IN101 through IN106 bits.

Event D (Digital Event Report)

The digital event report contains the status of the instantaneous, definite-time, and inverse-time overcurrent phase, single-phase, calculated residual, and negative-sequence overcurrent elements and the demand current thresholds for phase, calculated residual, and negative-sequence for each of the two winding inputs. The status of the Relay Word bits TRIP*n* (*n* = 1, 2, 3, 4, and 5) as well as the status of the eight output contacts and six optoisolated inputs is also included.

Use the **EVENT D** command to retrieve digital event reports. There are several options to customize 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*	=	Displays *x* samples per cycle (4 or 8); defaults to 4 if not listed
L*y*	=	Displays *y* cycles of data (1 to LER); defaults to LER if not listed
L*y*-	=	Displays from cycle *y* to end of report
L*y*-*w*	=	Displays 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 and was retrieved with the **EVE D <Enter>** command.

```
XFMR 1                                      Date: 11/09/99    Time: 09:45:00.566
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228
              Overcurrent Elements
Winding 1    Winding 2    Winding 3    Winding 4
50        51 50        51 50        51 50        51 51   DC TRP DEM    OUT  IN
PPABCNNQQPNQ PPABCNNQQPNQ PPABCNNQQPNQ PPABCNNQQPNQ PNPN        PPNNQQ
123331212    123331212    123331212    123331212    CCCC 13 135 131313 1357 135
  444          444          444          444        1122 24 24  242424 246A 246
[1]
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
[2]
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
[3]
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
..333....... ..333....... ............ ............ .... .. ... ...... .... ...
[4]
..333....... ...33....... ............ ............ .... .. ... ...... .... ...
..333....... ....3....... ............ ............ .... .. ... ...... .... ...
..333....... ....3....... ............ ............ .... .. ... ...... .... ...
..333....... ....3....... ............ ............ .... .. ... ...... .... ...
[5]
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...>
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...*
 .
.
.
[15]
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...
..333....... ....3....... ............ ............ .... .. .3. ...... .3.. ...

Event: TRIP3
Targets: TRIP INST 87_1 87_2 87_3 A B C
Winding 1 Currents (A Sec), ABC:   2.1   2.1   2.1
Winding 2 Currents (A Sec), ABC:   0.0   0.0   1.7
Winding 3 Currents (A Sec), ABC:   0.0   0.0   0.0
Winding 4 Currents (A Sec), ABC:   0.0   0.0   0.0
```

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.

Table 9.4 summarizes the digital event report columns.

Table 9.4 Digital Event Report Column Description (Sheet 1 of 3)

Column Heading	Symbol	Definition
All	.	All indication deasserted
Wdg 1	1	50P11 asserted
50P1	T	50P11T asserted
Wdg 1	2	50P12 asserted
50P2		
Wdg 1	3	50A13 asserted
50A34	4	50A14 asserted
	b	50A13 and 50A14 asserted
Wdg 1	3	50B13 asserted
50B34	4	50B14 asserted
	b	50B13 and 50B14 asserted
Wdg 1	3	50C13 asserted
50C34	4	50C14 asserted
	b	50C13 and 50C14 asserted
Wdg 1	1	50N11 asserted
50N1	T	50N11T asserted
Wdg 1	2	50N12 asserted
50N2		
Wdg 1	1	50Q11 asserted
50Q1	T	50Q11T asserted
Wdg 1	2	50Q12 asserted
50Q2		
Wdg 1	p	51P1 asserted
51P	T	51P1T asserted
	r	Timing to reset (51P1RS=Y)
	1	Timing to reset after 51P1T assertion (51P1RS=N)
	.	51P1R asserted
Wdg 1	p	51N1 asserted
51N	T	51N1T asserted
	r	Timing to reset (51N1RS=Y)
	1	Timing to reset after 51N1T assertion (51N1RS=N)
	.	51N1R asserted
Wdg 1	p	51Q1 asserted
51Q	T	51Q1T asserted
	r	Timing to reset (51Q1RS=Y)
	1	Timing to reset after 51Q1T assertion (51Q1RS=N)
	.	51Q1R asserted

Table 9.4 Digital Event Report Column Description (Sheet 2 of 3)

Column Heading	Symbol	Definition
Use same logic for overcurrent elements in Wdg 2		
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
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
TRP 5	5	TRIP5 asserted
DEM P12	1	PDEM1 asserted
	2	PDEM2 asserted
	b	PDEM1 and PDEM2 asserted
DEM P34	3	PDEM3 asserted
	4	PDEM4 asserted
	b	PDEM3 and PDEM4 asserted
DEM N12	1	NDEM1 asserted
	2	NDEM2 asserted
	b	NDEM1 and NDEM2 asserted
DEM N34	3	NDEM3 asserted
	4	NDEM4 asserted
	b	NDEM3 and NDEM4 asserted
DEM Q12	1	QDEM1 asserted
	2	QDEM2 asserted
	b	QDEM1 and QDEM2 asserted
DEM Q34	3	QDEM3 asserted
	4	QDEM4 asserted
	b	QDEM3 and QDEM4 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

Table 9.4 Digital Event Report Column Description (Sheet 3 of 3)

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

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 REF function, the Relay Word bits TRIP*n* (*n* = 1, 2, 3, 4, and 5), the SELOGIC control equation Timed Variables and Latch Bits, eight of the 16 Remote Bits, the eight output contacts, and the six optoisolated inputs are shown.

Use the **EVENT 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 = Displays 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* = Displays *x* samples per cycle (4 or 8); defaults to 4 if not listed

L*y* = Displays *y* cycles of data (1 to LER); defaults to LER if not listed

L*y*- = Displays from cycle *y* to end of report

L*y*-*w* = Displays 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 and was retrieved with the **EVE DIF1 <Enter>** command.

```
XFMR 1                                   Date: 11/09/99    Time: 09:45:00.566
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228
                             Differential       Set 1  Set 2  Set 3
    Differential Quantities  87   87B HB  TR TRP     LT     LT          OUT  IN
       Multiples of TAP      R            HE 135 VVVV13 VVVV13 VVVVVVVV 1357 135
   IOP1   IRT1   I1F2   I1F5 U123 123 123 5F 24  123424 123424 12345678 246A 246
[1]
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
[2]
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
   0.17   0.92   0.00   0.00 .... ... ... .. ... ...... ...... ........ .... ...
.
.
.
 [15]
   0.44   0.71   0.00   0.00 RRRR ... ... .. .3. ...... ...... ........ .3.. ...
   0.44   0.71   0.00   0.00 RRRR ... ... .. .3. ...... ...... ........ .3.. ...
   0.44   0.71   0.00   0.00 RRRR ... ... .. .3. ...... ...... ........ .3.. ...
   0.45   0.71   0.00   0.00*RRRR ... ... .. .3. ...... ...... ........ .3.. ...
Event: TRIP3
Targets: TRIP INST 87_1 87_2 87_3 A B C
Winding 1 Currents (A Sec), ABC:   2.1   2.1   2.1
Winding 2 Currents (A Sec), ABC:   0.0   0.0   1.7
Winding 3 Currents (A Sec), ABC:   0.0   0.0   0.0
Winding 4 Currents (A Sec), ABC:   0.0   0.0   0.0
```

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 4)

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

Table 9.6 Differential Event Report Element Columns (Sheet 2 of 4)

Column	Symbol	Definition
Dif El 87-2	R U b	87R2 asserted 87U2 asserted 87R2 and 87U2 asserted
Dif El 87-3	R U b	87R3 asserted 87U3 asserted 87R3 and 87U3 asserted
Dif El 87B 1	1 .	87BL1 asserted 87BL1 not asserted
Dif El 87B 2	1 .	87BL2 asserted 87BL2 not asserted
Dif El 87B 3	1 .	87BL3 asserted 87BL3 not asserted
Dif El HB 1	2 5 b	2HB1 asserted 5HB1 asserted 2HB1 and 5HB1 asserted
Dif El HB 2	2 5 b	2HB2 asserted 5HB2 asserted 2HB2 and 5HB2 asserted
Dif El HB 3	2 5 b	2HB3 asserted 5HB3 asserted 2HB3 and 5HB3 asserted
TH5	p T	TH5 asserted TH5 asserted longer than TH5D
REF	p T 1 .	32IF*50G4*!REFP asserted (timing to trip) 32IF*50G4*REFP asserted (timed out) Timing 1 cycle to reset after REFP assertion Reset
TRP 12	1 2 b	TRIP1 asserted TRIP2 asserted TRIP1 and TRIP2 asserted
TRP 34	3 4 b	TRIP3 asserted TRIP4 asserted TRIP3 and TRIP4 asserted
TRP 5	5	TRIP5 asserted
Set 1 V1 V2 V3 V4	p T d	S1V*n* asserted (timing to output) S1ViT asserted (timed out); S1V*n* asserted S1V*n*T asserted, S1V*n* deasserted (timing to reset)
Set 1 LT 12	1 2 b	Latch Bit 1 Latched Latch Bit 2 Latched Latch Bit 1 and Latch Bit 2 Latched

Table 9.6 Differential Event Report Element Columns (Sheet 3 of 4)

Column	Symbol	Definition
Set 1 LT 34	3 4 b	Latch Bit 3 Latched Latch Bit 4 Latched Latch Bit 3 and Latch Bit 4 Latched
Set 2 V1 V2 V3 V4	p T d	S2V*n* asserted (timing to output) S2V*n*T asserted (timed out); S2V*n* asserted S2V*n*T asserted, S2V*n* deasserted (timing to reset)
Set 2 LT 12	1 2 b	Latch Bit 1 Latched Latch Bit 2 Latched Latch Bit 1 and Latch Bit 2 Latched
Set 2 LT 34	3 4 b	Latch Bit 3 Latched Latch Bit 4 Latched Latch Bit 3 and Latch Bit 4 Latched
Set 3 V1 V2 V3 V4 V5 V6 V7 V8	p T d	S3V*n* asserted (timing to output) S3V*n*T asserted (timed out); S3V*n* asserted S3V*n*T asserted, S3V*n* deasserted (timing to reset)
RB 12	1 2 b	RB1 asserted RB2 asserted RB1 and RB2 asserted
RB 34	3 4 b	RB3 asserted RB4 asserted RB3 and RB4 asserted
RB 56	5 6 b	RB5 asserted RB6 asserted RB5 and RB6 asserted
RB 78	7 8 b	RB7 asserted RB8 asserted RB7 and RB8 asserted
OUT 12	1 2 b	OUT101 asserted OUT102 asserted OUT101 and OUT102 asserted
OUT 34	3 4 b	OUT103 asserted OUT104 asserted OUT103 and OUT104 asserted
OUT 56	5 6 b	OUT105 asserted OUT106 asserted OUT105 and OUT106 asserted

Table 9.6 Differential Event Report Element Columns (Sheet 4 of 4)

Column	Symbol	Definition
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 two winding inputs as well as the status of the eight output contacts and six optoisolated inputs. The SEL-387A 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 for viewing the samples before digital filtering occurs.

Use the **EVENT R** command to retrieve raw winding event reports. There are several options to customize 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* = Displays *x* samples per cycle (4, 8, 16, 32, or 64); defaults to 16 if not listed

L*y* = Displays *y* cycles of data (1 to LER); defaults to LER if not listed

L*y*- = Displays from cycle *y* to end of report

L*y*-*w* = Displays 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 and 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

XFMR 1                                  Date: 11/09/99    Time: 09:45:00.566
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228
    Winding 1         Winding 2         Winding 3        Winding 4      OUT  IN
    Amps Sec          Amps Sec          Amps Sec         Amps Sec       1357 135
 IAW1  IBW1  ICW1  IAW2  IBW2  ICW2  IAW3  IBW3  ICW3   IN1   IN2   IN3 246A 246
[0]
 2.01 -0.76 -1.33 -1.73  0.53  1.10  0.00  0.00  0.00 -0.06 -0.05 -0.02 .... ...
-0.39  1.93 -1.58  0.30 -1.69  1.30  0.00  0.00  0.00 -0.06 -0.06 -0.02 .... ...
-2.12  0.70  1.36  1.71 -0.63 -1.16  0.00  0.00  0.00 -0.06 -0.05 -0.02 .... ...
 0.28 -1.98  1.62 -0.32  1.59 -1.35  0.00  0.00  0.00 -0.06 -0.06 -0.02 .... ...
 2.01 -0.76 -1.33 -1.73  0.54  1.10  0.00  0.00  0.00 -0.06 -0.06 -0.02 .... ...
-0.38  1.93 -1.59  0.29 -1.69  1.30  0.00  0.00  0.00 -0.06 -0.06 -0.02 .... ...
[1]
-2.12  0.71  1.35  1.70 -0.63 -1.16  0.00  0.00  0.00 -0.07 -0.05 -0.02 .... ...
 0.28 -1.98  1.62 -0.32  1.58 -1.36  0.00  0.00  0.00 -0.07 -0.06 -0.02 .... ...
 2.01 -0.77 -1.32 -1.73  0.54  1.10  0.00  0.00  0.00 -0.06 -0.06 -0.02 .... ...
-0.37  1.92 -1.59  0.28 -1.68  1.30  0.00  0.00  0.00 -0.06 -0.06 -0.02 .... ...
[2]
-2.12  0.72  1.35  1.71 -0.64 -1.15  0.00  0.00  0.00 -0.07 -0.05 -0.02 .... ...
 0.27 -1.98  1.63 -0.31  1.58 -1.36  0.00  0.00  0.00 -0.07 -0.05 -0.02 .... ...
 2.01 -0.78 -1.32 -1.73  0.54  1.10  0.00  0.00  0.00 -0.06 -0.06 -0.02 .... ...
-0.37  1.92 -1.60  0.28 -1.68  1.30  0.00  0.00  0.00 -0.07 -0.05 -0.02 .... ...
.
.
.
 [15]
-2.13  0.79  1.30 -0.02 -0.05 -1.11  0.00  0.00  0.00 -0.07 -0.06 -0.02 .3.. ...
 0.20 -1.95  1.67 -0.02 -0.06 -1.40  0.00  0.00  0.00 -0.06 -0.06 -0.02 .3.. ...
 2.02 -0.84 -1.26 -0.02 -0.05  1.04  0.00  0.00  0.00 -0.06 -0.06 -0.03 .3.. ...
-0.31  1.89 -1.64 -0.01 -0.05  1.34  0.00  0.00  0.00 -0.06 -0.05 -0.02*.3.. ...

Event: TRIP3
Targets: TRIP INST 87_1 87_2 87_3 A B C
Winding 1 Currents (A Sec), ABC:   2.1   2.1   2.1
Winding 2 Currents (A Sec), ABC:   0.0   0.0   1.7
Winding 3 Currents (A Sec), ABC:   0.0   0.0   0.0
Winding 4 Currents (A Sec), ABC:   0.0   0.0   0.0
```

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.

Table 9.7 summarizes the raw event report current columns. The column headings shown are the default headings, corresponding to the designations on terminals Z01 to Z24. 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 (A, secondary)
IBW1	Current measured by Winding 1 input channel IB (A, secondary)
ICW1	Current measured by Winding 1 input channel IC (A, secondary)
IAW2	Current measured by Winding 2 input channel IA (A, secondary)
IBW2	Current measured by Winding 2 input channel IB (A, secondary)
ICW2	Current measured by Winding 2 input channel IC (A, secondary)
IAW3	
IBW3	
ICW3	
IN1	Current measured by neutral input channel IN1 (A, secondary)

Table 9.7 Raw Winding Event Report Current Columns

Column Heading	Definition
IN2	Current measured by neutral input channel IN2 (A, secondary)
IN3	Current measured by neutral input channel IN3 (A, secondary)

Table 9.8 summarizes the raw winding event report output and input columns.

Table 9.8 Raw Winding Event Report Outputs and Inputs

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

Compressed ASCII Event Reports

The SEL-387A provides Compressed ASCII event reports to facilitate event report storage and display. The SEL-2020, SEL-2030, or SEL-2032 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 the **CEVENT** command discussion in *Appendix E: Compressed ASCII Commands* 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.

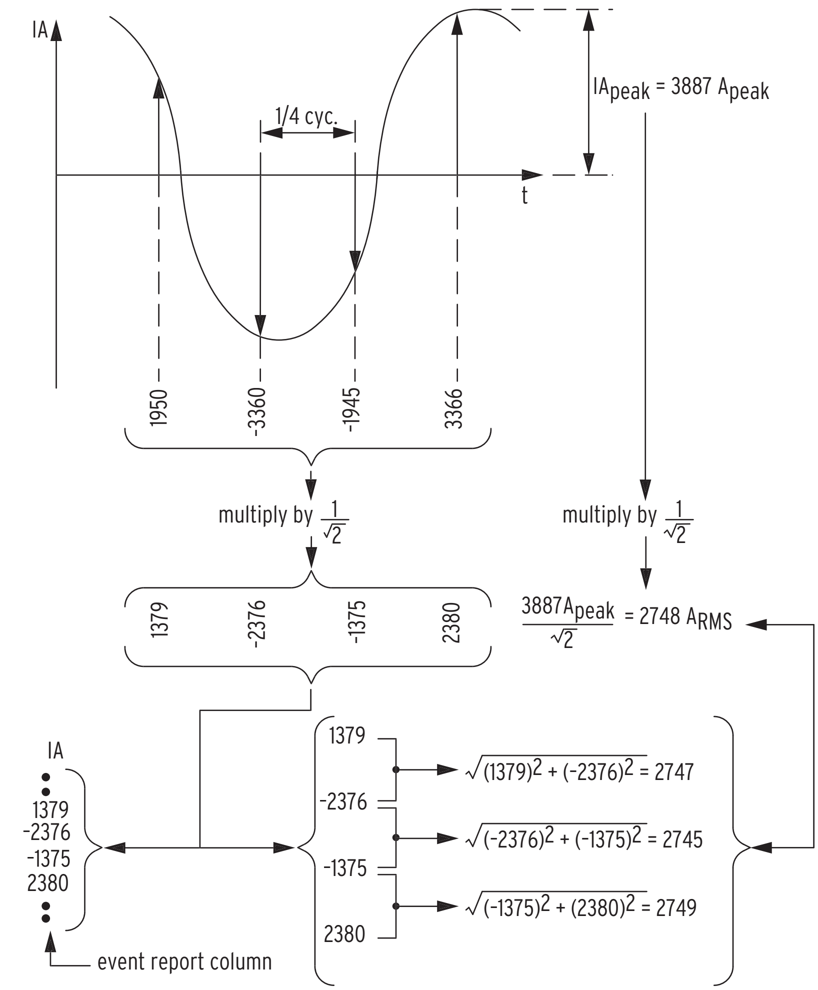


Figure 9.6 Derivation of Event Report Current Values and RMS Current Values From Sampled Current Waveform

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, hence 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.

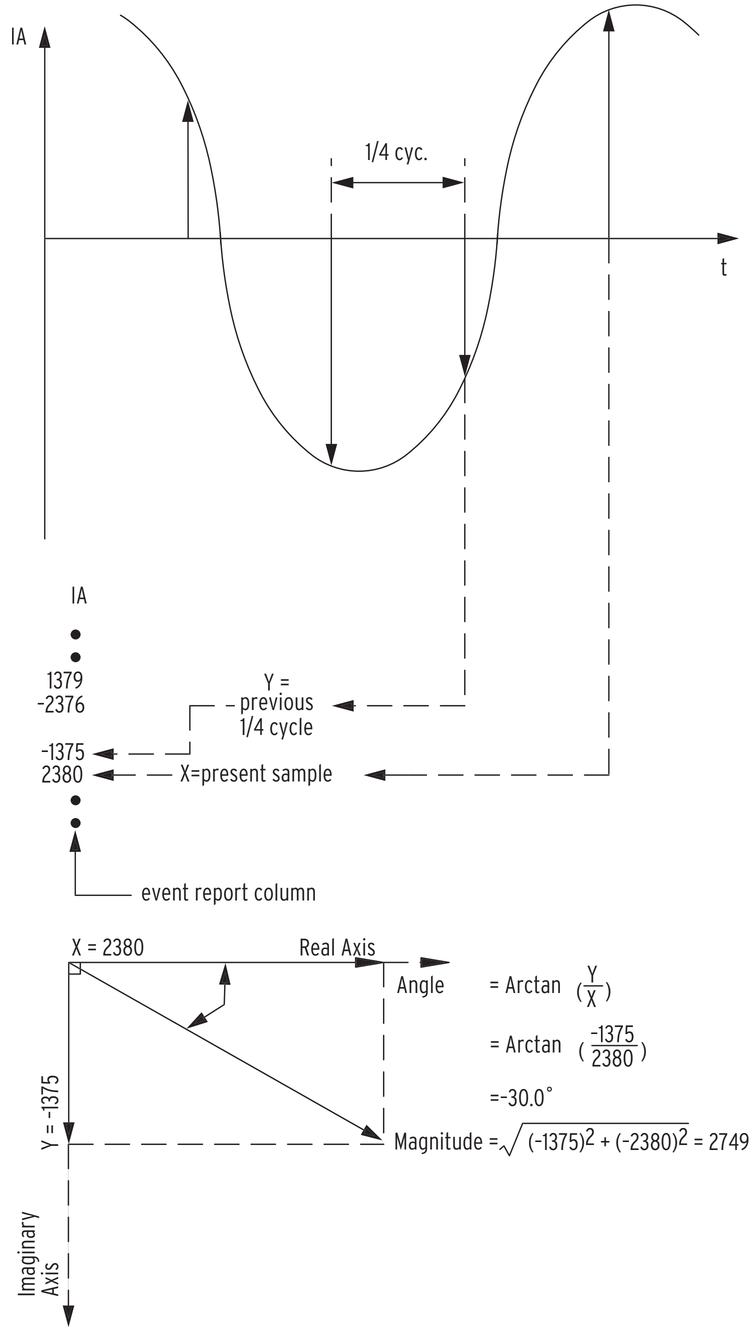


Figure 9.7 Derivation of Phasor RMS Current Values From Event Report Current Values

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:

$$2749 \text{ A} \bullet \cos(-30.0°) = 2380 \text{ A}$$

A calculation of the phasor using the previous pair, X = –1375 and Y = –2376, yields a calculation of:

$$IA = 2745 \text{ A}\angle{-120.0°}$$

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 depicts an example SER event report.

```
XFMR 1                                     Date: 11/09/99    Time: 10:04:48.485
STATION A

FID=SEL-387A-R100-V0-Z003003-D20011228
#      DATE          TIME           ELEMENT          STATE

4     11/09/99  09:11:31.610   OUT102            Deasserted
3     11/09/99  09:11:31.610   OUT103            Deasserted
2     11/09/99  09:45:00.566   OUT103            Asserted
1     11/09/99  09:45:08.287   OUT103            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 4.7* through *Table 4.9*. 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. The settings are ALIAS1 to ALIAS20. If they are not set, they are listed as, for example, ALIAS1=NA.

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; a separator, which can be one of the following characters: = ; : ' , / \ ? "; and then the desired name, which can include as many as 15 characters. 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.

NOTE: Alias names can consist of all printable characters (including spaces).

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 4.7* to *Table 4.9*). Thus, as many as 96 total elements can be monitored for SER event report row triggering.

The SER settings can be made 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.

Example SER Serial Port Commands	Format
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 up to 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

This section should be used for determining and establishing test routines for the SEL-387A Relay. Included are discussions on testing philosophies, methods, and tools. Example test procedures are shown for the overcurrent elements, differential elements, harmonic blocking functions, restricted earth fault protection, and metering. Relay troubleshooting procedures are shown 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 in the test complexity.

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 presented to the relay in primary 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: Serial Port Communications and Commands*.

Low-Level Test Interface

The SEL-387A 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 signals to the relay inputs, or, alternatively, 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).

⚠**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 relay processing module by 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.

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.

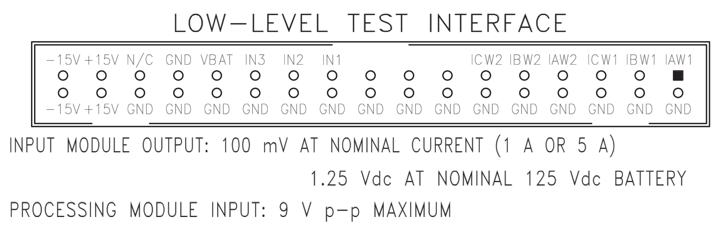


Figure 10.1 Low-Level Test Interface

Test Methods

Test the pickup and dropout of relay elements by using one of three methods: front-panel target LCD/LED indication, output contact operation, or 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. This can be done by pressing the front-panel **TARGET RESET** button or by issuing the **TAR R** command from the serial port.

Output Contact Operation

To test by 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 by 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:	a) Ensure relay meets published critical performance specifications such as operating speed and element accuracy.
	b) Ensure that the relay meets the requirements of the intended application.
	c) 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 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
- 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.

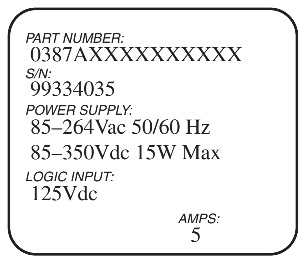


Figure 10.2 Relay Identification Sticker

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.

If the relays pull in but your terminal does not respond with the equals sign, check the terminal configuration. If neither occurs, turn off the power, and refer to *Relay Troubleshooting on page 10.28*.

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.

NOTE: If you are using a battery simulator, be sure the simulator voltage level is stabilized before turning the relay on.

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)* in *Section 7: Serial Port Communications and Commands* 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>**. The following display 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.)

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: Setting the Relay* includes a complete description of the settings. The terminal display should look similar to the following:

```
=>>SHO <Enter>
Group 1


RID     =XFMR 1
TID     =STATION A
E87     = Y
EOC1    = Y         EOC2    = Y         EOCN    = Y
E49A    = N         E49B    = N
ESLS1   = N         ESLS2   = N         ESLS3   = N

W1CT    = Y         W2CT    = Y
CTR1    = 120       CTR2    = 240
CTRN1   = 80        CTRN2   = 80        CTRN3   = 24
MVA     = 100.0     ICOM    = Y
W1CTC   = 11        W2CTC   = 11
VWDG1   = 230.00    VWDG2   = 138.00

TAP1    = 2.09      TAP2    = 1.74
O87P    = 0.30      SLP1    = 25        SLP2    = 50        IRS1    = 3.0
U87P    = 10.0      PCT2    = 15        PCT4    = 15        PCT5    = 35
TH5P    = OFF       DCRB    = N         HRSTR   = N         IHBL    = N


E32I1   =0

Press RETURN to continue

E32I2   =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

Press RETURN to continue
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

50NN11P = OFF       50NN11D = 10.00     50NN11TC=1
50NN12P = OFF
50NN13P = OFF       50NN14P = OFF
51NN1P  = OFF       51NN1C  = U2        51NN1TD = 1.00
51NN1RS = Y         51NN1TC =1

50NN21P = OFF       50NN21D = 10.00     50NN21TC=1
50NN22P = OFF

Press RETURN to continue
50NN23P = OFF       50NN24P = OFF
51NN2P  = OFF       51NN2C  = U2        51NN2TD = 1.00
51NN2RS = Y         51NN2TC =1

50NN31P = OFF       50NN31D = 10.00     50NN31TC=1
50NN32P = OFF
50NN33P = OFF       50NN34P = OFF
51NN3P  = OFF       51NN3C  = U2        51NN3TD = 1.00
51NN3RS = Y         51NN3TC =1

TDURD   = 9.000     CFD     = 60.000

TR1     =50P11T + 51P1T + 51Q1T + OC1 + LB3
TR2     =51P2T + 51Q2T + OC2
```

(Continued on next page)

(Continued from previous page)

```
TR3     =87R + 87U
TR4     =0
TR5     =0
ULTR1   =!50P13
ULTR2   =!50P23
ULTR3   =!(50P13 + 50P23)

Press RETURN to continue
ULTR4   =0
ULTR5   =0
52A1    =IN101
52A2    =IN102
52A3    =0
52A4    =0
CL1     =CC1 + LB4 + /IN104
CL2     =CC2 + /IN105
CL3     =0
CL4     =0
ULCL1   =TRIP1 + TRIP3
ULCL2   =TRIP2 + TRIP3
ULCL3   =0
ULCL4   =0
ER      =/50P11 + /51P1 + /51Q1 + /51P2 + /51Q2
OUT101  =TRIP1
OUT102  =TRIP2
OUT103  =TRIP3
OUT104  =0
OUT105  =CLS1

Press RETURN to continue
OUT106  =CLS2
OUT107  =0

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     45.8
GR1CHK     E740
=>>
```

Outputs

Step 1. Purpose: Verify that contact outputs 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 contact outputs by typing **TAR F OUT101 <Enter>**. The bottom row of 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 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** command to display the appropriate output elements.

Step 2. Purpose: Verify 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 contact outputs 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** 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 the corresponding target LED turns on.

c. Repeat this step for each input. Use the **TARGET F** command to display the appropriate output elements.

Metering

Step 1. Purpose: Connect simulated power system secondary current sources to the relay.

Method: Turn power off to the relay 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 percent, ±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, all three phases have the same angle. If 3I2 equals three times the applied current, the phase rotation is reversed. Turn the current sources off.

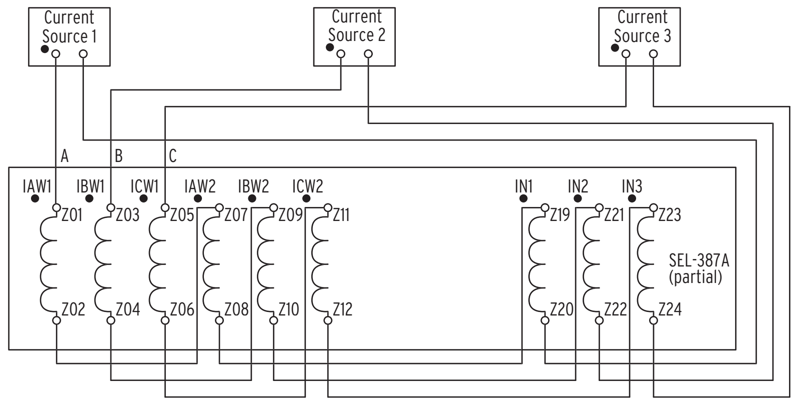


Figure 10.3 Test Connections for Balanced Load With Three-Phase Current Sources

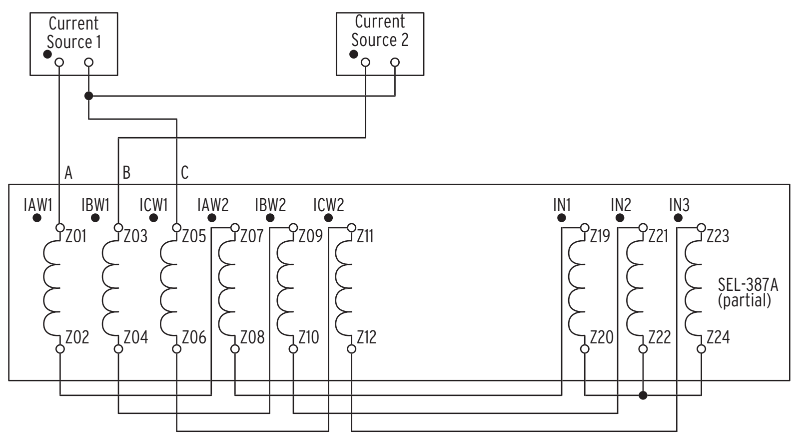


Figure 10.4 Test Connections for Balanced Load With Two-Phase Current Sources

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 EOCN settings for Windings 1 and 2 and neutral, 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.

Step 1. Purpose: Determine the expected instantaneous overcurrent element pickup value.

Method: Execute the **SHO** 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-387A 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 10.5*. 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 percent of the setting ±0.02 • I_{NOM} (negative-sequence elements are ±6 percent of the setting ±0.02 • I_{NOM}).

Step 4. Purpose: Repeat test for each instantaneous overcurrent element for both windings.

Method: Repeat steps 1 through 3 for each instantaneous overcurrent element listed in *Figure 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.

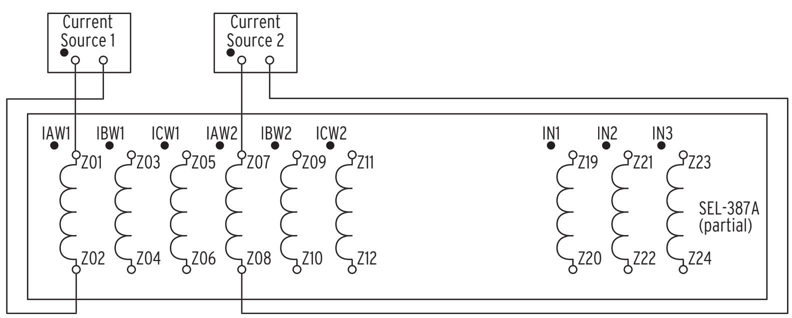


Figure 10.5 Test Connections for Two Single-Current Test Sources

Table 10.1 Instantaneous Overcurrent Elements and Corresponding Settings (Sheet 1 of 2)

	Winding 1		Winding 2		Neutral	
	Bit	Setting	Bit	Setting	Bit	Setting
Phase Level 1	50P11	50P11P	50P21	50P21P		
Phase Level 2	50P12	50P12P	50P22	50P22P		
Phase Inverse-Time	51P1	51P1P	51P2	51P2P		

Table 10.1 Instantaneous Overcurrent Elements and Corresponding Settings (Sheet 2 of 2)

	Winding 1		Winding 2		Neutral	
	Bit	Setting	Bit	Setting	Bit	Setting
A-Phase Level 3	50A13	50P13P	50A23	50P23P		
B-Phase Level 3	50B13		50B23			
C-Phase Level 3	50C13		50C23			
Phase Level 3	50P13		50P23			
A-Phase Level 4	50A14	50P14P	50A24	50P24P		
B-Phase Level 4	50B14		50B24			
C-Phase Level 4	50C14		50C24			
Phase Level 4	50P14		50P24			
Residual Level 1	50N11	50N11P	50N21	50N21P		
Residual Level 2	50N12	50N12P	50N22	50N22P		
Residual Inverse-Time	51N1	51N1P	51N2	51N2P		
Neg-Seq Level 1	50Q11	50Q11P	50Q21	50Q21P		
Neg-Seq Level 2	50Q12	50Q12P	50Q22	50Q22P		
Neg-Seq Inverse-Time	51Q1	51Q1P	51Q2	51Q2P		
Input 1 Neutral Level 2					50NN12	50NN12P
Input 1 Neutral Level 3					50NN13	50NN13P
Input 1 Neutral Level 4					50NN14	50NN14P
Input 1 Neutral Inverse-Time					51NN1	51NN1P
Input 2 Neutral Level 2					50NN22	50NN22P
Input 2 Neutral Level 3					50NN23	50NN23P
Input 2 Neutral Level 4					50NN24	50NN24P
Input 2 Neutral Inverse-Time					51NN2	51NN2P
Input 3 Neutral Level 2					50NN32	50NN32P
Input 3 Neutral Level 3					50NN33	50NN33P
Input 3 Neutral Level 4					50NN34	50NN34P
Input 3 Neutral Inverse-Time					51NN3	51NN3P

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 **SHO** 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: Differential, Restricted Earth Fault, and Overcurrent Elements*. 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):

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

$$tp = 2.33 \text{ seconds}$$

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 10.5*. 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 SER. The assertion and deassertion of each element listed in the SER1, 2, 3, and 4 settings are 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 SER records.

Step 5. Purpose: Repeat the test for each definite-time and inverse-time overcurrent element, for each winding.

Method: Repeat steps 1 through 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.

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.

Table 10.2 Time-Delayed Overcurrent Elements and Corresponding Settings

	Winding 1		Winding 2		Neutral	
	Bit	Setting	Bit	Setting	Bit	Setting
Phase Level 1	50P11	50P11P	50P21	50P21P		
Definite-Time	50P11T	50P11D	50P21T	50P21D		
Phase Inverse-Time	51P1	51P1P	51P2	51P2P		
Curve		51P1C		51P2C		
Time-Dial		51P1TD		51P2TD		
Time-Out	51P1T		51P2T			
Residual Level 1	50N11	50N11P	50N21	50N21P	50NN11	50NN11P
Definite-Time	50N11T	50N11D	50N21T	50N21D	50NN11T	50NN11D
Residual Inverse-Time	51N1	51N1P	51N2	51N2P	51NN1	51NN1P
Curve		51N1C		51N2C		51NN1C
Time-Dial		51N1TD		51N2TD		51NN1TD
Time-Out	51N1T		51N2T		51NN1T	
Neg-Seq Level 1	50Q11	50Q11P	50Q21	50Q21P		
Definite-Time	50Q11T	50Q11D	50Q21T	50Q21D		
Neg-Seq Inv-Time	51Q1	51Q1P	51Q2	51Q2P		
Curve		51Q1C		51Q2C		
Time-Dial		51Q1TD		51Q2TD		
Time-Out	51Q1T		51Q2T			

Phase Overcurrent Elements

The SEL-387A 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 (e.g., 50C14) 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 previously outlined in this section.

Negative-Sequence Overcurrent Elements

The SEL-387A 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:

3IR = 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 3IR = 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:

3IR = 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 previously outlined in this section.

Residual Overcurrent Elements

The SEL-387A 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 previously outlined in this section.

Neutral Elements

The SEL-387A has many neutral overcurrent elements. These are single-input elements, similar to the phase elements, i.e., the values are not manipulated as is the case with the residual elements. Test neutral elements in a similar manner as the phase overcurrent elements previously outlined 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). Follow the following procedure to 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. Use a digital input for the test example. Enter **SET 51P1TC <Enter>**. When prompted, set 51P1TC to IN101. Note that the 51P1TC may be set to 1 (always asserted) or 0 (always deasserted) for testing 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. 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-387A now displays the state of the six input elements in the bottom row of the front-panel LEDs. If using multiple elements in the torque-control equation, you must issue several **TARGET** commands 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-387A now displays the state of several overcurrent elements in the bottom 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. CTRnn the same overcurrent test and verify that it does not operate.

Restricted Earth Fault (REF) Function

The test for the REF function uses 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*n* = Enabling SELOGIC control equations. Set E32I*n* = 1.

32IOP*n* = Winding(s) for obtaining the Operate quantity. Set 32IOP*n* = 1.

a0*n* = Positive-sequence restraint factor. Use default setting, a0*n* = 0.1.

50GP*n* = Residual current sensitivity level. Use default setting, 50GP*n* = 0.5A.

(*n* = 1, 2)

Recall that the default CT ratio settings are: CTR1 = 120, and CTRN1 = 80.

NOTE: To use the default setting 50GP*n* = 0.5, be sure that the ratio CTR_{max}/CTRN*n* is not more than 2.0, where CTR_{max} is the CTR1 or CTR2 setting. Using the default CT ratio settings, the ratio CTR_{max}/CTRN1 = 120/80 = 1.5. Therefore, the 50GP*n* setting can remain at 0.5 A.

If the ratio CTR_{max}/CTRN*n* is greater than 2.0, set 50GPn equal to 0.25 A times the actual ratio of CTR_{max}/CTRN*n*.

Step 1. Purpose: Determine the expected time delay for the overcurrent element.

Method: Execute the **SHO** command via the relay front panel or serial port and verify the element settings (i.e., **SHO E32In <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: Differential, Restricted Earth Fault, and Overcurrent Elements*. TD is the time-dial setting, and M is the applied multiple of pickup current.

$$tp_{REF} = 0.5 \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$$

$$tp_{REF} = 0.963 \text{ seconds}$$

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., 50GN*n*, 32IF*n*, and REFP*n*). 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 10.5*, but with source current 2 connected to IN1. Set the IAW1 current magnitude to:

$$IAW1 \geq 2 \bullet\ 50GP1 \bullet\ CTRn1/CTR1$$

Using the default CT ratios, IAW1 should be set to at least 2 • 0.5 A • 80/120, or 0.67 A. Set the magnitude of IAW1 to 1 A; set the angle of IAW1 to 180 degrees.

Set the IN1 current at 1 A at zero degrees. Because the currents are opposite in phase, nothing should happen. Verify this as follows:

Execute the **TAR 50** command. Relay Word bits 50GN1, 32IR1, 32IF1, and REFP1 are all in this row. With the currents applied as above, 50GN1 should be 1, and REFP should remain at 0. Bit 32IR1 should be 1, indicating an external (reverse) fault. Bit 32IF1 should be 0.

Change the angle of IAW1 to zero degrees, or any value within about ±80 degrees of IN*n*. The REF element should function. Verify this as follows:

Execute the **TAR 50** command again. 50GN1 should still be 1, REFP1 should be 1 (indicating time-out), 32IR1 should be 0, and 32IF1 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 are recorded. Subtract the time of assertion of the directional element (32IF1) from the assertion time of the time-out bit (REFP1). This is the operate time, which should be about one second, as calculated above. (Relay Word bit 50N1 will have remained asserted from earlier in the test, because no change was made to the IN1 current.) **SER C** clears the SER records.

Repeat *Step 2–Step 4* to test REF element 2. You can use Winding 1 as reference for REF2; set 32IOP2 = 1. Alternatively, you can use Winding 2 as reference for REF2; set 32IOP2 = 2 and set pickup setting 50GP2 = 0.75. (You must change the 50GP2 pickup setting because the relay default CT ratio CTR2/CTRN2 is 3:1.)

Differential

The SEL-387A has several components to its differential element. *Figure 10.6* gives a representation of the differential characteristic and the plot of each test. Each test only uses Winding 1 and Winding 2 inputs. The differential elements must be enabled with the E87 = Y, settings.

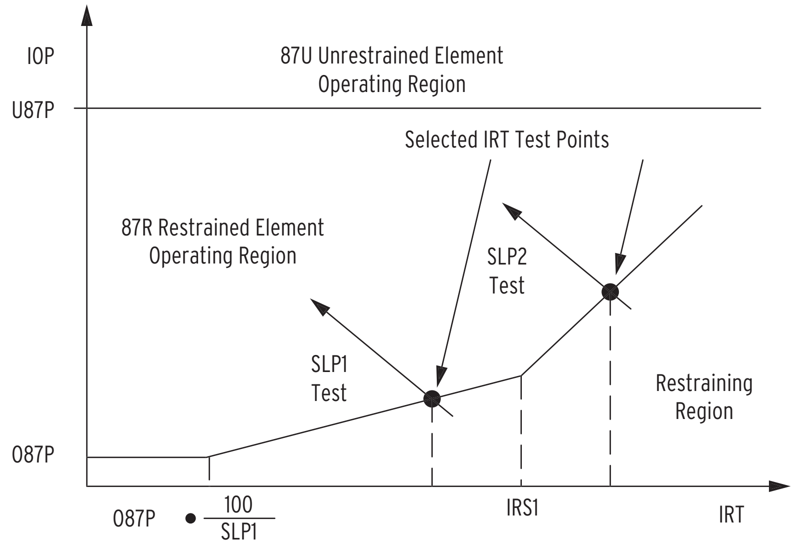


Figure 10.6 Percentage Restraint Differential Characteristic

U87P Unrestrained Differential Element

Step 1. Purpose: Verify the expected unrestrained differential element pickup setting.

Method: Execute the **SHO** command via the relay front panel or serial port and verify the setting (i.e., **SHO U87P <Enter>**). **Note:** This value is in per unit of tap.

Step 2. Purpose: Calculate the required current to pick up the unrestrained differential element.

Method: Calculate the expected pickup for the 87U element by multiplying the U87P setting by the TAP1 and TAP2 setting and the compensation constant A shown in *Figure 10.3*. The CT connection compensation settings W1CTC and W2CTC determine the A constant for the calculations. Use the corresponding TAP*n* and W*n*CTC settings for the winding under test.

⚠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 TAP*n* to limit the required test current to a safe value.

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-387A now displays the state of several differential elements in the bottom 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. 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, 6, 8, 10, 12	1.5

O87P Differential Element Pickup

Step 1. Purpose: Verify the expected restrained differential element minimum pickup setting.

Method: Execute the **SHO** command via the relay front panel or serial port and verify the setting (i.e., **SHO O87P <Enter>**). **Note:** This value is in per unit of tap.

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 and TAP2 setting and the compensation constant A shown in Table 10.3. The CT connection compensation settings W1CTC and W2CTC 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-387A now displays the state of several differential elements in the bottom 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. 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 both windings 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-387A now displays the state of several differential elements in the bottom 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 10.6*.

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 above the O87P intersection point and below IRS1. If SLP2 = OFF, IRS1 and SLP2 are not functional.

$$\mathrm{O87P} \bullet 100/\mathrm{SLP1} < \mathrm{IRT} < \mathrm{IRS1}$$

The value of IOP corresponding to the selected IRT equals the following:

$$\mathrm{IOP} = \frac{\mathrm{SLP1}}{100} \bullet \mathrm{IRT}$$

Both IRT and IOP are in multiples of tap.

Step 4. Purpose: Calculate the expected current for Winding 1 and Winding 2 at the restrained differential element SLP1 threshold for the test point selected above.

Method: Calculate the Winding 1 current for the test by using the following formula:

$$\mathrm{IAW1} = \mathrm{IRT} \bullet \left(1 + \frac{\mathrm{SLP1}}{200}\right) \bullet \mathrm{TAP1} \bullet \mathrm{A}$$

Calculate the Winding 2 current for the test by using the following formula:

$$\mathrm{IAW2} = \mathrm{IRT} \bullet \left(1 - \frac{\mathrm{SLP1}}{200}\right) \bullet \mathrm{TAP2} \bullet \mathrm{B}$$

The A and B connection compensation constants are based on *Figure 10.3*. Because the windings have the same W*n*CTC setting, the A and B constants will be the same for both windings. The constants 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.

⚠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 TAP*n* to limit the required test current to a safe value.

Step 5. Purpose: Calculate the initial current for Winding 2 for this test.

Method: Calculate the Winding 2 initial current for the test by using the following formula:

$$IAW2 = IAW1 \bullet \frac{TAP2}{TAP1} \bullet (B/A)$$

This formula determines the current necessary for zero operating current (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 10.5*. 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 87R1 element asserts. Use 87R2 when injecting current into B-Phase and 87R3 when testing C-Phase. Note the magnitude of the current applied. It should equal the value calculated in step 4 ±5% ±0.02 • I_{NOM}.

NOTE: IRS1 must be greater than 100/SLP1 • O87P if SLP2 is not set to OFF.

Step 7. Purpose: Repeat the test for each phase for both windings if desired.

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

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.

NOTE: For this test, use only W*n*CTC = 0 or W*n*CTC = 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 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-387A now displays the state of several differential elements in the bottom 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 10.6*.

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 above the IRS1 setting.

$$\mathrm{IRT} > \mathrm{IRS1}$$

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 Winding 2 at the restrained differential element SLP2 threshold for the test point selected above.

Method: Calculate the Winding 1 current for the test by using the following formula:

$$\mathrm{IAW1} = \left(\mathrm{IRT} \bullet \left(1 + \frac{\mathrm{SLP2}}{200}\right) + \mathrm{IRS1} \bullet \left(\frac{\mathrm{SLP1} - \mathrm{SLP2}}{200}\right)\right) \bullet \mathrm{TAP1} \bullet \mathrm{A}$$

Calculate the Winding 2 current for the test by 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.

⚠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 TAP*n* to limit the required test current to a safe value.

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.

$$\mathrm{IAW2\ (initial)} = (1.1 \bullet \mathrm{IAW2})\ \text{(from Step 4)}$$

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 10.5*. 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 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 **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 and that HRSTR = N. 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-387A now displays the state of several differential elements in the bottom 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 10.7*.

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 $\pm 0.02 \cdot I_{NOM}$.

$$\text{IAW1 (second harmonic)} = \frac{\text{PCT2}}{100} \cdot \text{IAW1(fund.)}, \pm 5\% \pm 0.02 \cdot I_{NOM}$$

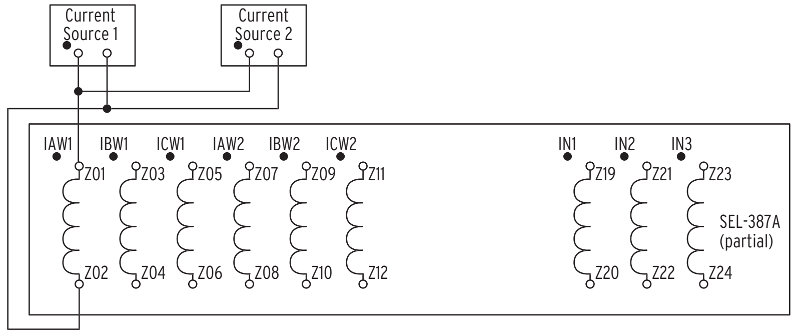


Figure 10.7 Test Connections for Parallel Current Sources

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 **SHOW** 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-387A now displays the state of several differential elements in the bottom 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 10.7*.

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, multiplied by the magnitude of the fundamental current source, ±5% and ±0.02 • I_{NOM}.

$$\text{(fifth harmonic)} = \frac{PCT5(2)}{100} \bullet IAW1(\text{fundamental}), \pm 5\% \pm I_{NOM}$$

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 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-387A now displays the state of several differential elements in the bottom 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 10.7*.

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 harmonic current to drop out the 87R element.

Method: 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:

$$I1F2 = (IOP1 - (IRT1 \bullet f(SLP))) \bullet \frac{PCT2}{100}$$

(±5%±0.10 A (5 A relay) or ±5%±0.02 A (1 A relay))

$$\% \text{ harmonic } = \frac{\mathrm{I1F2}}{\mathrm{IOP1}} \bullet 100 \text{ (percent)}$$

For inrush conditions, current normally is applied to one side of the transformer, and the equation simplifies to the following:

$$\% \text{ harmonic } = \mathrm{PCT2}\left(1 - \frac{\mathrm{SLP1}}{200}\right)$$

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:

$$\% \text{ harmonic } = \left(\frac{\mathrm{PCT2}}{200}\right) \bullet \left(200 - \mathrm{SLP2} - \frac{\mathrm{IRS1}}{\mathrm{IRT}}(\mathrm{SLP1} - \mathrm{SLP2})\right)$$

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

$$\% \text{ harmonic } = \left(\frac{20}{200}\right) \bullet \left(200 - 60 - \frac{3}{6}(25 - 60)\right) = 15.75 \text{ percent}$$

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:

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.
2. Execute the **IRIG** command. Make sure the relay clock displays the correct date and time.
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

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.

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

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-387A Commissioning Test Worksheet, located at the end of this section, to verify correct CT connections and settings when placing the relay in service. The worksheet shows how using software commands or the front-panel display can replace the need for the traditional phase angle meter and ammeter.

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 the utility’s 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 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 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 the *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.
6. If the serial port or front-panel interface that does not respond was working before, you have tried Step 1 through Step 5, and the **MET** command was the last issued command, the Digital Signal Processor may have failed, and you should call the factory.

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.

SELBOOT on Front Display at When Turning On; Serial Port Warning to Remove Link

1. A jumper has been installed at position JMP6D.
2. Turn off the relay, remove the jumper, and turn the relay on again.

No Prompting Message Issued to Terminal Upon Relay Turning 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: Serial Port Communications and Commands*.

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) 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) on page 7.34*.
2. A/D converter failure.

Self-Test Failure: +12 V PS

1. Power supply +12 V output out-of-tolerance. See *STA (Status Report) on page 7.34*.
2. A/D converter failure.

Self-Test Failure: –12 V PS

1. Power supply –12 V output out-of-tolerance. See *STA (Status Report) on page 7.34*.
2. A/D converter failure.

Self-Test Failure: +15 V PS

1. Power supply +15 V output out-of-tolerance. See *STA (Status Report) on page 7.34*.
2. A/D converter failure.

Self-Test Failure: –15 V PS

1. Power supply –15 V output out-of-tolerance. See *STA (Status Report) on page 7.34*.
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 two interface boards.
3. Interface board failure.

Self-Test Failure: CR_RAM, EEPROM, and IO_BRD

1. Self-test detected setting location movement due to Flash firmware upgrade. Execute the **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 After R_S Command

1. Issue the **STA** command and record the state of all outputs.
2. Call the factory. Powering down the relay will reset the logic.

Relay Calibration

The SEL-387A 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-387A Relay Commissioning Test Worksheet

System Information

System Settings

RID (Relay identification) = ____________________

TID (Terminal identification) = ____________________

MVA (Maximum transformer rating) = ____________________

	Winding 1	Winding 2	Neutral Current		
Current transformer connection:	W1CT = _________	W2CT = _________			
Current transformer ratio:	CTR1 = _________	CTR2 = _________	CTRN1=____	CTRN2 =____	CTRN3 =____
Connection compensation	W1CTC =________	W2CTC =________			
Nominal line-to-line voltage (kV):	VWDG1=________	VWDG2=________			
TAP calculation:	TAP1=________	TAP2=________			

Differential Settings

O87P = __________ SLP1 = __________ SLP2 = __________ IRS1 = __________ U87P = __________

Metered Load (Data taken from substation panel meters, not the SEL-387A Relay)

± Readings from meters	Winding 1	Winding 2
Megawatts:	MW1 = ______________________	MW2 = ______________________
Megavars:	MVAR1 = ____________________	MVAR2 = ____________________
MVA calculation: $\mathrm{MVA}n = \sqrt{\mathrm{MW}n^2 + \mathrm{MVAR}n^2}$	MVA1 = _____________________	MVA2 = _____________________

Calculated Relay Load

	Winding 1	Winding 2
Primary amperes calculation: $\mathrm{Inpri} = \frac{\mathrm{MVA}n \bullet 1000}{\sqrt{3} \bullet \mathrm{VWDG}n}$	I1pri = ______________________	I2pri = ______________________
Secondary amperes calculation: $\mathrm{W}n\mathrm{CT} = \mathrm{Y}, \mathrm{Insec} = \frac{\mathrm{Inpri}}{\mathrm{CTR}n}$ $\mathrm{W}n\mathrm{CT} = \mathrm{D}, \mathrm{Insec} = \frac{\mathrm{Inpri} \bullet \sqrt{3}}{\mathrm{CTR}n}$	I1sec = ____________________	I2sec = ____________________

Settings Check

The following check ensures zero-sequence current filtering is applied to all necessary transformer windings.

It is essential to use a non-zero Winding CT Connection Compensation (WnCTC) setting for all grounded-WYE-connected transformer windings with WYE-connected CTs.

Please verify that no grounded-WYE transformer windings with WYE-connected CTs has setting WnCTC = 0. Use a setting of 12 instead of 0 for proper zero-sequence current filtering.

Please note the following commissioning checks will not detect the failure to properly filter zero-sequence current. Failure to adhere to this check will result in a differential operation for external faults involving ground.

Proper zero-sequence filtering verified? ________________

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. A setting of 0.5 A secondary is recommended for the best results.

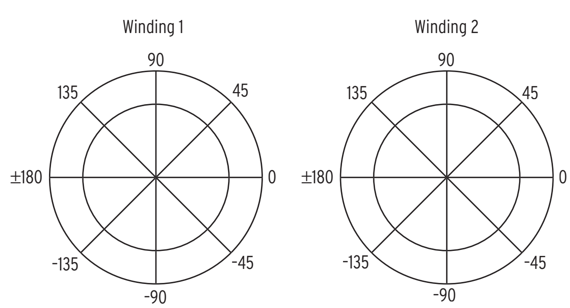
Operate Current:	IOP1 = ______________	IOP2 = ______________	IOP3 = ______________
Restraint Current:	IRT1 = ______________	IRT2 = ______________	IRT3 = ______________
Mismatch Calculation: $MMn = IOPn/IRTn$	MM1 = ______________	MM2 = ______________	MM3 = ______________

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		
A-Phase Secondary Amperes:	IAW1 = _______	IAW2 = _______		IN1 = _________
A-Phase Angle:	_______	_______	IN1 Angle:	_______
B-Phase Secondary Amperes:	IBW1 = _______	IBW2 = _______		IN2 = _________
B-Phase Angle:	_______	_______	IN2 Angle:	_______
C-Phase Secondary Amperes:	ICW1 = _______	ICW2 = _______		IN3 = _________
C-Phase Angle:	_______	_______	IN3 Angle:	_______



1. Calculated relay amperes match MET SEC amperes?
2. Phase rotation is as expected for each winding?
3. Do angular relationships among windings correspond to expected results? (Remember that secondary current values for load current flowing out of a winding will be 180° out-of-phase with the reference phase position for that winding. The reason is that CT polarity marks normally face away from the transformer on all windings.)

Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

To find the firmware revision number in your relay, view the status report by using the serial port **STATUS** command or the front-panel **STATUS** pushbutton. For firmware versions with the date code of February 21, 2002, or later, the FID label will appear as follows with the Part/Revision number in bold:

FID=**SEL-387A-Rxxx-Vx-Z001001-Dxxxxxxxx**

For example:

FID=**SEL-387A-R605-V0-Z003003-D20020304**

is SEL-387A Relay firmware revision number 605, which was released on March 4, 2002.

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

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-387A-R611-V0-Z004004-D20120124	➤ Improved accuracy of DNP Delay Measurement response. In previous firmware, the Delay Measurement response could be incorrect by as much as 150 ms. ➤ Revised relay so that the password characters are not echoed as they are entered. ➤ Increased the maximum number of allowed password characters from six to twelve.	20140124
SEL-387A-R610-V0-Z004004-D20100324	➤ Corrected problem with incorrect assertion of Relay Word bit COMFLG when receiving RTD temperature data from an SEL-2600 RTD module.	20100324
SEL-387A-R609-V0-Z004004-D20071025	➤ Modified A5C1 Fast Message header to properly indicate Delta CT connections when Group Setting W*n*CT = D (Delta). ➤ Corrected CHSG Relay Word Bit so that it will maintain the correct state through a relay setting group transition. ➤ Set the default event record length equal to relay LER setting.	20071025
SEL-387A-R608-V0-Z004003-D20050919	➤ Fixed ability to properly process SEL Fast Message data with corrupted length field.	20050919
SEL-387A-R607-V0-Z004003-D20050614	➤ Fixed DNP3 Index 216, 217, 218 Fault Time data types to provide DNP3 Type 30, default variation 2 data (16 bit signed analog input).	20050614
SEL-387A-R606-V0-Z004003-D20040628	➤ Added Through-Fault Monitor.	20040628
SEL-387A-R605-V0-Z003003-D20020304	➤ Initial version.	20020208

Table A.2 lists the firmware versions, a description of settings modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.2 Settings Change History

Firmware Part/Revision No.	Settings Change Description	Manual Date Code
SEL-387-A-R606-V0-Z004003-D20040628	➤ Added ETHRU Enable Through-Fault Monitor Setting. ➤ Added THRU Through-Fault Event Trigger Setting. ➤ Added ISQT Through-Fault Alarm Threshold Setting.	20040628

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

This manual covers SEL-387A Relays that contain firmware bearing the following part numbers and revision numbers (most recent firmware listed at top):

Table A.3 Instruction Manual Revision History

Date Code	Summary of Revisions
20250127	Appendix B ➤ Removed references to CD throughout**.**
20221103	Section 1 ➤ Added UKCA Marks in *Specifications*.
20211203	Section 1 ➤ Updated *Type Tests* in *Specifications*.
20190809	List of Tables ➤ Added *List of Tables*. List of Figures ➤ Added *List of Figures*. Section 7 ➤ Updated the definition for **CEV** in *Command Definitions*. ➤ Updated the definition for **EVE** in *Command Definitions*. Section 9 ➤ Updated *Compressed ASCII Event Reports* in *Standard 15-, 30-, or 60-Cycle Event Reports.* Appendix I ➤ Added *Appendix I: PC Software***.**
20170505	Section 3 ➤ Updated *Setting Calculation* in *Differential Element*. Appendix H ➤ Added *Appendix H: Protection Application Examples*.
20160122	Section 1 ➤ Updated *General Specifications*.
20150126	Preface ➤ Added *Preface.* Section 1 ➤ Updated *General Specifications.*

Table A.3 Instruction Manual Revision History

Date Code	Summary of Revisions
20140124	**Section 4** ➤ Removed Relay Word bits that are not available in *Table 4.7: SEL-387A Word Bits and Locations*, *Table 4.8: Relay Word Bit Definitions*, and *Table 4.9: Relay Word Bits Sorted Alphabetically.* **Section 7** ➤ Modified **PASsword** command description to reflect relay behavior. **Appendix A** ➤ Updated for firmware version R611. **Appendix G** ➤ Expand fault current description in *Table G.3: SEL-387A Wye/Delta DNP Data Map* (index values 203–215). ➤ Removed Relay Word bits that are not available in *Table G.4: SEL-387A Binary Input Lookup Table*.
20120127	**Section 3** ➤ Updated *Figure 3.30: U.S. Short-Time Inverse Curve: U5*. **Section 7** ➤ Added *CAL (Calibration Access Level)* section. **Command Summary** ➤ Added CAL (Calibration Access Level) command to Access Level 2 table. **Appendix A** ➤ Updated Firmware Revision History and Manual Revision History.
20100324	**Appendix A** ➤ Updated for firmware version R610.
20071025	**Appendix A** ➤ Updated for firmware version R609.
20050919	**Appendix A** ➤ Updated Firmware Revision History and Manual Revision History.
20050614	**Appendix A** ➤ Updated Firmware Revision History and Manual Revision History.
20040628	**Section 1** ➤ Stylistic changes. ➤ Revised *Figure 1.1*. ➤ Added Through-Fault Event Monitor description. ➤ Added discussion of projection rack mounting and projection panel mounting. **Section 3** ➤ Stylistic changes. ➤ Added through-fault event monitor description. ➤ Added to description of CT Connection (W1CT and W2CT). ➤ Added discussion of projection rack mounting and projection panel mounting. **Section 4** ➤ Revised *Table 4.7*, *Table 4.8*, and *Table 4.9* to add through-fault information. **Section 5** ➤ Added through-fault event monitor information. **Section 6** ➤ Added through-fault event monitor settings to Settings Sheets. ➤ Modified screen captures depicting default settings for 5 A and 1 A relays. ➤ Modified screen capture depicting **SHO G** command settings. **Section 7** ➤ Revised *Figure 7.2*. ➤ Added description of the **TFE** (through-fault event report) command. ➤ Added description of the **TFE** command to the Command Summary.

Table A.3 Instruction Manual Revision History

Date Code	Summary of Revisions
	Section 10 ➤ Added Zero-Sequence Filter Check to the Commissioning Test Worksheet. Appendix G ➤ Revised *Table G.3*.
20020208	➤ Initial version.

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 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 Cable SEL-C234A (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 Cable SEL-C234A (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*).

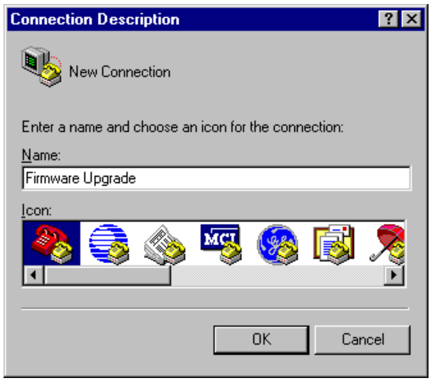


Figure B.1 Establishing a Connection

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**.

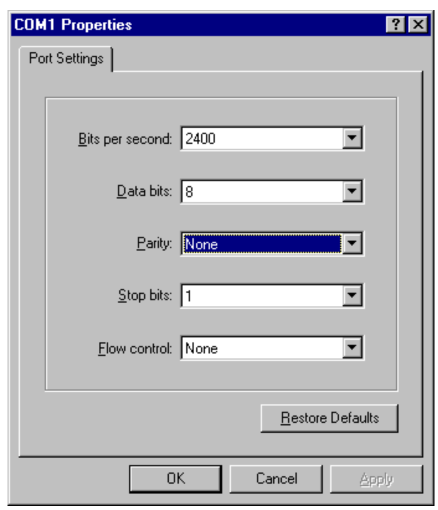


Figure B.3 Determining Communications Parameters for the Computer

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**.

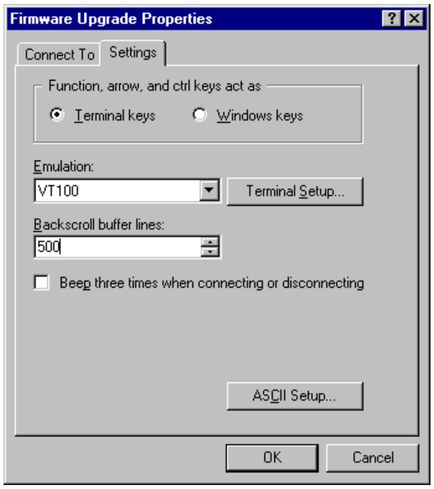


Figure B.4 Setting Terminal Emulation

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*.

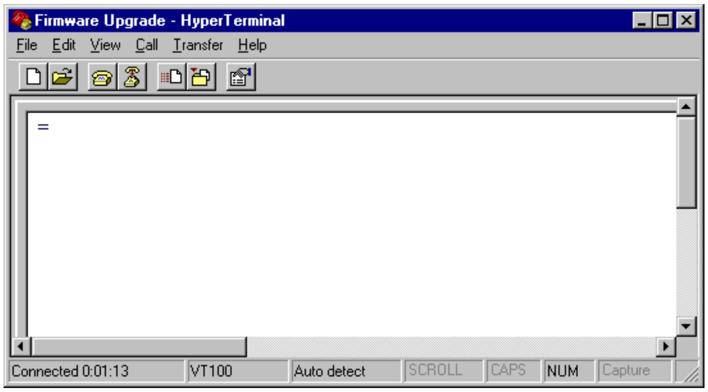


Figure B.5 Terminal Emulation Startup Prompt

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.

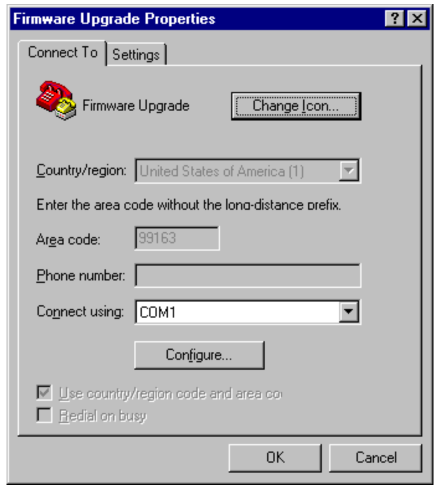


Figure B.6 Correcting the Port Setting

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.6*.

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.

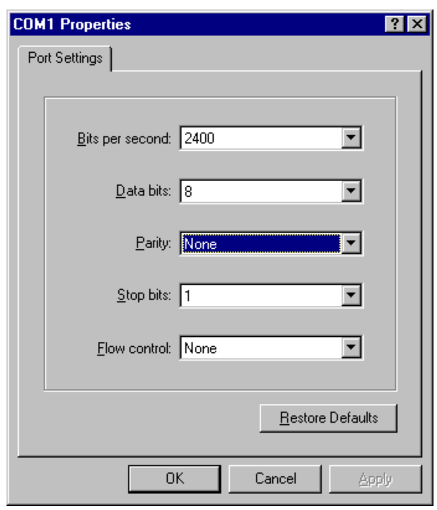


Figure B.7 Correcting the Communications Parameters

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 on page B.7*. 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*.

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**.

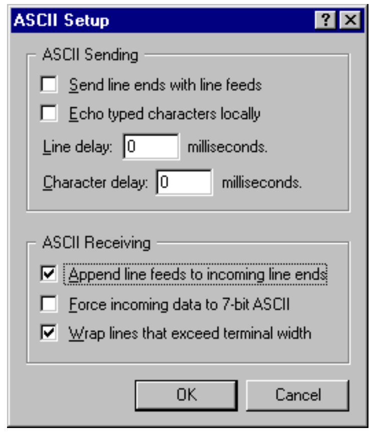


Figure B.8 Preparing HyperTerminal for ID Command Display

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.

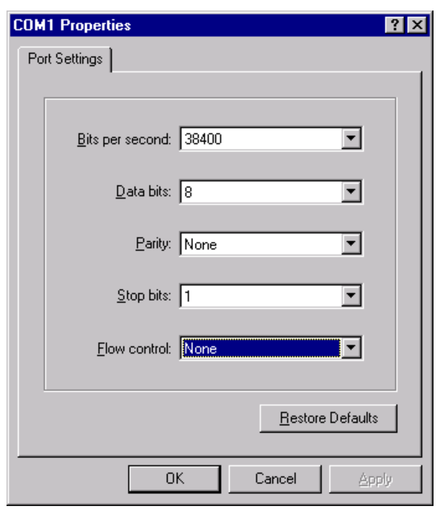


Figure B.10 Matching Computer to Relay Parameters

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**.

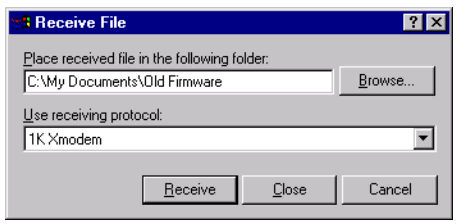


Figure B.11 Example Receive File Dialog Box

Step 6. Enter a filename that clearly identifies the existing firmware version (*Figure B.12*), using the version number from the FID you recorded in *Step 1 on page B.7* and click **OK**.

SEL lists the firmware revision number first, then the product number.

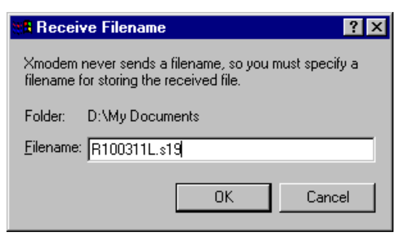


Figure B.12 Example Filename Identifying Old Firmware Version

If Xmodem times out before the download completes, repeat the process from *Step 1 on page B.10*.

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.

For a successful download, you should see a dialog box similar to *Figure B.13*. After the transfer, the relay responds with the following:

```
Download completed successfully!
```

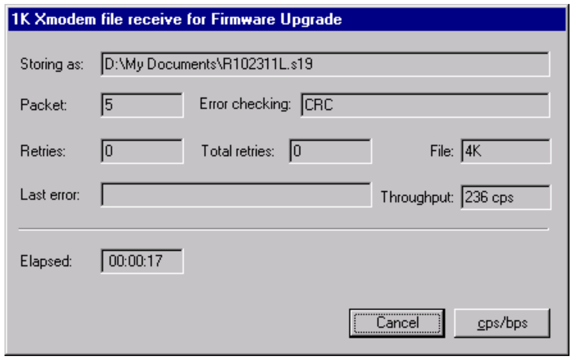


Figure B.13 Downloading Old Firmware

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.15*. 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.

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.

After the transfer completes, the relay displays the following:

```
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.

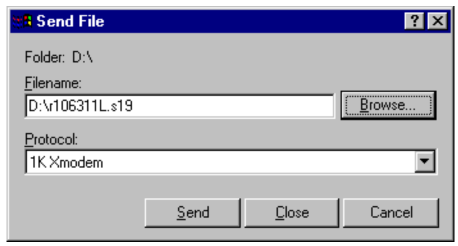


Figure B.14 Selecting New Firmware to Send to the Relay

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*.

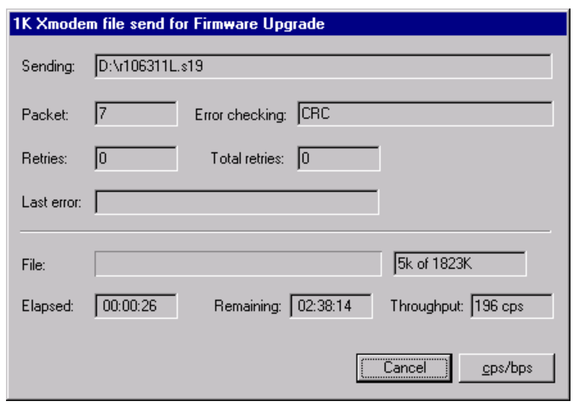


Figure B.15 Transferring New Firmware to the Relay

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.14*.

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 on page B.2* (see *Match Computer Communications Speed to the Relay on page B.9*). Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to the values you recorded in *A. Prepare the Relay on page B.2*. Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 **=** prompt indicating that serial communication is successful. Step 5. If you get no response, proceed to *Match Computer Communications Speed to the Relay on page B.9*.
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. Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. 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 on page B.9*). Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 **=** prompt indicating successful serial communication. If you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. Check for the Access Level 0 **=** prompt. If you see the Access Level 0 **=** prompt, proceed to *G. Check Relay Self-Tests on page B.14*.
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.16*.

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.15*.

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 on page B.15*.

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 the SEL-5010 or QuickSet, restore 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 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 on page B.16*.

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>**.

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the EN LED illuminates.

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).

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 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 10: 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.15*).

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**.

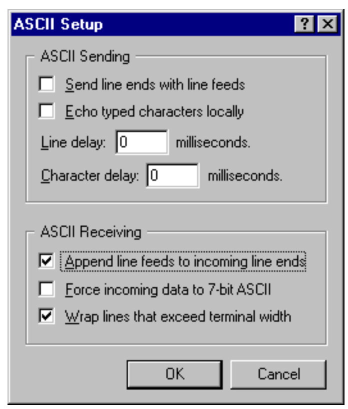


Figure B.16 Preparing HyperTerminal for ID Command Display

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 port.

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)
- 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:

NOTE: Use IP settings (IPADDR, SUBNETM, DEFRTR) that are compatible with your PC's network settings.

IPADDR = 10.201.0.213

SUBNETM = 255.255.0.0

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.

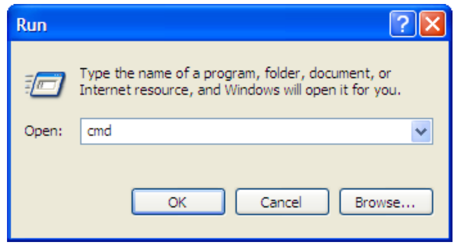
Step 2. Copy the firmware upgrade file to the root directory of the primary drive (usually C:\).

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 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 (LMD)

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.

NOTE: You can use the front-panel SET pushbutton to change the port settings to return to SEL protocol.

5. The **QUIT** command terminates the connection. If no data are sent to the relay before the port timeup 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.

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. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. 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-387A Relay.

Message Lists

Binary Message List

Table D.1 Binary Message List (Sheet 1 of 2)

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

Table D.1 Binary Message List (Sheet 2 of 2)

Request to Relay (hex)	Response From Relay
A5ED	Fast Operate Reset Command
A5CD	Fast Reset Configuration Block

ASCII Configuration Message List

Table D.2 ASCII Configuration Message List

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 (Sheet 1 of 2)

Data	Description
A5C0	Command
40	Message length (64 bytes)
42	Message length (66 bytes (DNP versions only))
xx	Non-DNP versions = 02
xx	DNP versions = 03
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 Global settings
0300	SEL protocol, Fast Meter, and Fast Message

Table D.3 A5C0 Relay Definition Block (Sheet 2 of 2)

Data	Description
0301	LMD protocol, Fast Meter, and Fast Message
0005	DNP protocol (DNP versions only)
00	Reserved
xx	Checksum

A5C1 Fast Meter Configuration Block

In response to the A5C0 request, the relay sends the following block:

Table D.4 A5C1 Fast Meter Configuration Block (Sheet 1 of 3)

Data	Description
A5C1	Fast Meter configuration response
C8	Message length (200 bytes)
01	One status flag byte
01	Scale factors in config message
06	# scale factors
0D	# analog input channels
02	# samples per channel
3F	# digital banks (63 bytes)
02	# 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)
00AE	Scale factor offset (winding 1)
494257310000 (IBW1)	
00	
01	
00AE	
494357310000 (ICW1)	
00	
01	
00AE	
494157320000 (IAW2)	
00	
01	
00B2	(Winding 2)

Table D.4 A5C1 Fast Meter Configuration Block (Sheet 2 of 3)

Data	Description
494257320000 (IBW2)	
00	
01	
00B2	
494357320000 (ICW2)	
00	
01	
00B2	
494157330000 (IAW3)	
00	
FF	
0000	(Winding 3)
494257330000 (IBW3)	
00	
FF	
0000	
494357330000 (ICW3)	
00	
FF	
0000	

With REF/Neutral Current Option	**Without REF/Neutral Current Option**
494E31000000 (IN1)	494157340000 (IAW4)
00	00
01	FF
00B6	0000
494E32000000 (IN2)	494257340000 (IBW4)
00	00
01	FF
00BA	0000
494E33000000 (IN3)	494357340000 (ICW4)
00	00
01	FF
00BE	0000
564443000000 (VDC)	
00	
01	
00C2	

Data	Description
xx	Connection byte—Based on PHROT and W1CT settings
	(Calc block #1)
03	Current calculation only
FFFF	No skew adjustment

Table D.4 A5C1 Fast Meter Configuration Block (Sheet 3 of 3)

Data	Description	
FFFF	No RS offset	
FFFF	No XS offset	
00	IAW1	
01	IBW1	
02	ICW1	
FF	NA	
FF	NA	
FF	NA	
xx	Connection byte—Based on PHROT and W2CT settings	
	(Calc block #2)	
03	Current calculation only	
FFFF	No skew adjustment	
FFFF	No RS offset	
FFFF	No XS offset	
03	IAW2	
04	IBW2	
05	ICW2	
FF	NA	
FF	NA	
FF	NA	
xxxxxxxx	Winding 1 scale factor (NCurr/1000) • CTR1	
xxxxxxxx	Winding 2 scale factor (NCurr/1000) • CTR2	
With REF/Neutral Current Option		**Without REF/Neutral Current Option**
xxxxxxxx	IN1 scale factor (NCurr/1000) • CTRN1	00000000
xxxxxxxx	IN2 scale factor (NCurr/1000) • CTRN2	00000000
xxxxxxxx	IN3 scale factor (NCurr/1000) • CTRN3	00000000
3C23D70A	Scale factor (1/100)	
00	Reserved	
xx	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 (Sheet 1 of 2)

Data	Description
A5D1	Fast Meter message
80	Message length (128 bytes)
xx	Status byte
52 bytes	Inst for the following: IAW1, IBW1, ICW1, IAW2, IBW2, ICW2, IAW3, IBW3, IN1, IN2, IN3, VDC (Imaginaries first, followed by Reals)

Table D.5 A5D1 Fast Meter Data Block (Sheet 2 of 2)

Data	Description
8 bytes	Time stamp
63 bytes	Digital banks—targets 0 through 62
xx	Checksum

A5B9 Fast Meter Status Acknowledge Message

In response to the A5B9 request, the SEL-387A 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)
DA	Message length (218 bytes)
00	No status byte
01	Scale factors in Fast Meter configuration
00	No scale factors used
14	20 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
0000	No scale factor offset
494257310000 (IBW1)	
02	
FF	
0000	
494357310000 (ICW1)	
02	
FF	
0000	
334932573100 (3I2W1)	
02	

Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 2 of 3)

Data	Description
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	
0000	
494257330000 (IBW3)	
02	
FF	
0000	
494357330000 (ICW3)	
02	
FF	
0000	
334932573300 (3I2W3)	
02	

Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 3 of 3)

Data	Description
FF	
0000	
495257330000 (IRW3)	
02	
FF	
0000	
494157340000 (IAW4)	
02	
FF	
0000	
494257340000 (IBW4)	
02	
FF	
0000	
494357340000 (ICW4)	
02	
FF	
0000	
334932573400 (3I2W4)	
02	
FF	
0000	
495257340000 (IRW4)	
02	
FF	
0000	
00	Reserved
xx	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
A6	Message length (166 bytes)
00	Reserved
160 bytes	Demand meter values in double floats in the same order as channel listings in A5C2
00	Reserved
xx	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 2)

Data	Description
A5CE	Command
42	Message length, #bytes (66)
04	# circuit breakers supported
0010	16 remote bits
01	Remote bit pulse supported
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
34	Open breaker 4
14	Close breaker 4
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

Table D.8 A5CE Fast Operate Configuration Block (Sheet 2 of 2)

Data	Description
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
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
00	Reserved pad
xx	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
xx	Operate code (0-F, 20-2F, 40-4F for remote bit clear, set or pulse)
xx	Operate validation: 4 • operate code + 1
xx	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
xx	Operate code (hex 31–34 open, hex 11–14 close breakers 1 through 4)
xx	Operate validation: 4 • operate code + 1
xx	Checksum

A5CD Fast Operate Reset Definition Block

In response to the A5CD request, the relay sends the following block:

Table D.11 A5CD Fast Operate Reset Definition Block (Sheet 1 of 2)

Data	Description
A5CD	Command
9E	Length
13	Support nineteen Fast Resets
00	Reserved
00	Reset Code, Reset Targets
54415220520000	Fast Operate Reset Description (TAR R)
01	Reset Code, Reset Peak Demand for Winding 1
4D455420525031	Fast Operate Reset Description (MET RP1)
02	Reset Code, Reset Peak Demand for Winding 2
4D455420525032	Fast Operate Reset Description (MET RP2)
03	Reset Code, Reset Peak Demand for Winding 3
4D455420525033	Fast Operate Reset Description (MET RP3)
04	Reset Code, Reset Peak Demand for Winding 4
4D455420525034	Fast Operate Reset Description (MET RP4)
05	Reset Code, Reset Peak Demand for all Windings
4D455420525041	Fast Operate Reset Description (MET RPA)
06	Reset Code, Reset Demand for Winding 1
4D455420524431	Fast Operate Reset Description (MET RD1)
07	Reset Code, Reset Demand for Winding 2
4D455420524432	Fast Operate Reset Description (MET RD2)
08	Reset Code, Reset Demand for Winding 3
4D455420524433	Fast Operate Reset Description (MET RD3)
09	Reset Code, Reset Demand for Winding 4
4D455420524434	Fast Operate Reset Description (MET RD4)
0A	Reset Code, Reset Demand for all Windings
4D455420524441	Fast Operate Reset Description (MET RDA)
0B	Reset Code, Reset Breaker Monitor for Breaker 1
42524520522031	Fast Operate Reset Description (BRE R 1)

Table D.11 A5CD Fast Operate Reset Definition Block (Sheet 2 of 2)

Data	Description
0C	Reset Code, Reset Breaker Monitor for Breaker 2
42524520522032	Fast Operate Reset Description (BRE R 2)
0D	Reset Code, Reset Breaker Monitor for Breaker 3
42524520522033	Fast Operate Reset Description (BRE R 3)
0E	Reset Code, Reset Breaker Monitor for Breaker 4
42524520522034	Fast Operate Reset Description (BRE R 4)
0F	Reset Code, Reset Breaker Monitor for all Breakers
42524520522041	Fast Operate Reset Description (BRE R A)
10	Reset Code, Reset all Inverse-Time O/C Elements
52455300000000	Fast Operate Reset Description (RES)
11	Reset Code, Clear the Summary
48495320430000	Fast Operate Reset Description (HIS C)
12	Reset Code, Clear the SER
53455220430000	Fast Operate Reset Description (SER C)
DA	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”)
01	Operate Validation—(4 + Operate Code) + 1
xx	Checksum

A546 Temperature Data Block

The SEL-387A understands the contents of the following binary data packet from an external SEL-2600 RTD module:

Table D.13 A546 Temperature Data Block (Sheet 1 of 2)

Data	Description
0xA546	Header code to flag the beginning of message
74h	Message length (116 bytes)
0000000000h	Routing value: 0 for point-to-point communication
00h	Status byte
12h	Function code: unsolicited read response
00h	Sequence byte
00h	Pad byte
xxxxxxxx	Internal time since the relay turned on or rollover at 86400000 milliseconds

Table D.13 A546 Temperature Data Block (Sheet 2 of 2)

Data	Description
xxxx	External RTD Unit Status: Bit 0 indicates the state of the external RTD power supply (0 = good, 1 = fail). Bit 1 indicates the state of the external RTD RAM (0 = good, 1 = fail). Bits 2–14 are 0. Bit 15 indicates the state of the external RTD's digital input (0 = deasserted, 1 = asserted).
xxxx * 4 * 12	Temperature Data (°C) in 12 data sets of 4 words. Word One—16 bit representation of a PT100 RTD. Word Two—16 bit representation of a NI100 RTD. Word Three—16 bit representation of a NI120 RTD. Word Three—16 bit representation of a CU10 RTD. This set is repeated 12 times. Open / Shorted RTDs are processed by the RTD diagnostic module.
yyyy	CRC-16 Block Check Code.

ID Command

In response to the **ID** command, the relay sends the firmware ID, the relay TID setting, and the Modbus device code, as shown below.

```
<STX>
"FID=FID string","yyyy"
"CID=XXXX","yyyy"
"DEVID=TID setting","yyyy"
"DEVCODE=32","yyyy"
"PARTNO=0387AXXXXXXXXXX","yyyy"
"CONFIG=111100","yyyy"
```

where:

yyyy	Is the 4-byte ASCII hex representation of the checksum for the message.
FID	Reports the FID string.
CID	Reports the checksum of the ROM code.
DEVID	Reports the terminal ID as set by the TID setting.
DEVCODE	Reports the Modbus code (32).
PARTNO	Reports the part number.
CONFIG	The phase input current and neutral input current scaling are both set to the same value since the SEL-387A does not differentiate. Both the voltage and current input connection (wye vs. delta) are reported as N/A.

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>
... (62 more, where xxxxxx is a Relay Word element name)
<ETX>(ETX character, 03)
```

where:

xxxxxx is 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 is 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 is the 4-byte ASCII representation of the hex checksum for the line.

The bits named are defined as follows:

- STSET: Set when a restart 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 is in a FAIL state.
- STWARN: One or more of the monitored status quantities is 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. **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 32IF1; SER3 = OUT102 52A, SER4 = 0; the name string will be "50P11","OUT101","87U1","32IF1","OUT102","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 less 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: Setting the Relay*.

SNS message for the SEL-387A 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`	is a string from the settings in SER (SER1, SER2, SER3, and SER4)
`yyyy`	is the 4-byte ASCII representation of the checksum

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Appendix E

Compressed ASCII Commands

Introduction

The SEL-387A Relay provides Compressed ASCII versions of some of the relay's ASCII commands. The Compressed ASCII commands allow an external device to obtain data from the relay, in a format that directly imports into spreadsheet or database programs, and which can be validated with a checksum.

The SEL-387A provides the following Compressed ASCII commands:

Table E.1 Compressed ASCII Commands

Command	Description
CASCII	Configuration message
CBREAKER	Breaker report
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 <Enter>

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` is the number of Compressed ASCII command descriptions to follow.
- `COMMAND` is 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.
- `ll` is the minimum access level (e.g., 1, or 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` is 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 ASCII representation of the hex checksum for the line.

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

Display the SEL-387A Compressed ASCII configuration message by sending:

CAS <Enter>

The SEL-387A sends:

```
<STX>
"CAS",7,"yyyy"<CR>
"CST",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","40S","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","IN1",
"IN2","IN3","+5V_PS","+5V_REG","-5V_REG","+12V_PS","-12V_PS","+15V_PS",
"-15V_PS","TEMP","RAM","ROM","A/D","CR_RAM","EEPROM","IO_BRD","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","yyyy"<CR>
"CBR",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","40S","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>
"4D","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","40S","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>
"80D","I","I","I","I","I","I","I","I","7S","I","52S","yyyy"<CR>
"CEV",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","40S","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>
"15H","IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","IN1",
"IN2","IN3","VDC","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","1S","96S","yyyy"<CR>
"CEV C",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","40S","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>
"15H","IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","IN1",
"IN2","IN3","VDC","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","1S","96S","yyyy"<CR>
"CEV S64 R",1,"yyyy"<CR>
"1H","FID","yyyy"<CR>
"1D","40S","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>
"15H","IAW1","IBW1","ICW1","IAW2","IBW2","ICW2","IAW3","IBW3","ICW3","IN1",
"IN2","IN3","VDC","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","1S","96S","yyyy"<CR>
"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 is 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 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.

#D identifies a data format line, "#"is the maximum number of subsequent data lines, each format field contains 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-387A Compressed ASCII breaker report by sending:

CBR <Enter>

The relay sends:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387A-RXXX-VO-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>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
    xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx"yyyy"<CR>
<ETX>
```

The data are a summation of breaker information collected since the last summary clear where:

xxxx are the data values corresponding to the first line labels.

yyyy is the 4-byte ASCII representation of the hex checksum for the line.

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>

NOTE: If S*x* and/or L*y* 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.

The command parameters, all optional, can be entered in any order. They are as follows:

Report Types:	
DIF	Display differential information for all elements
R	Displays raw (unfiltered) analog data and raw station battery Displays preceding 1.5 cycles (including reports with 'L' options) Allows S4, S8, S16, S32, and S64 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) Defaults to 4 if S*x* not specified
L*y*	Display first y cycles of event report (*y* = 1 – LER) 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	Defaults to 8 samples/cycle (same as **EVE C**)

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-387A-RXXX-VO-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","IN1",
"IN2","IN3","VDC","TRIG","DIGITAL_ELEMENT_NAMES","yyyy"<CR>
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>
```

where:

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.

`xxxx` are the data values corresponding to the first line labels.

`yyyy` is the 4-byte ASCII representation of the hex checksum for the line.

z is “>” 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 *Section 9: Event Reports and SER*.

CEVENT Differential Report

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 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-387A-RXXX-V0-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,xxxx,"z","RLY_BITS","yyyy"
<CR> ... (previous line repeated for SAM/CYC_A*NUM_OF_CYC)
"SETTINGS","yyyy"<CR>
"SETTINGS text","yyyy"<CR>
<ETX>
```

where:

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.

xxxx are the data values corresponding to the first line labels.

yyyy is the 4-byte ASCII representation of the hex checksum for the line.

z is “>” 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 *Section 9: Event Reports and SER*.

CHISTORY Command

Display the SEL-387A Compressed ASCII history report by sending:

CHI <Enter>

or display the last *n* items in the SEL-387A Compressed ASCII history report by sending:

CHI *n* <Enter>

The relay responds to the **CHI <Enter>** command by sending the following:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387A-RXXX-VO-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 80)
<ETX>
```

where:

The data are a list of all events since the last history clear.

`xxxx` are the data values corresponding to the first line labels.

`yyyy` is the 4-byte ASCII representation of the hex checksum for the line.

CSTATUS Command

Display the SEL-387A Compressed ASCII status report by sending:

CST <Enter>

The relay sends:

```
<STX>
"FID","yyyy"<CR>
"FID=SEL-387A-RXXX-VO-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","IN1",
"IN2","IN3","+5V_PS","+5V_REG","-5V_REG","+12V_PS","-12V_PS","+15V_PS",
"-15V_PS","TEMP","RAM","ROM","A/D","CR_RAM","EEPROM","IO_BRD","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","yyyy"<CR>
<ETX>
```

where:

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.

`xxxx` are the data values corresponding to the first line labels.

`yyyy` is the 4-byte ASCII representation of the hex checksum for the line.

CTARGET Command

Display the SEL-387A 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 are the labels for the given target.

x is 0 or 1 corresponding to the first line labels.

yyyy is the 4-byte 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: Event Reports and SER* of the instruction manual. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary SER messages from the SEL-387A 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 use of a single communications channel 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 at the other end of the link requires software that uses the separate data streams. A device that does not interleave the data streams can also access the binary commands and ASCII commands.

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 stores the latest 512 rows of the SER event report so they can be retained during power loss. The nonvolatile memory stores a finite number of “writes.” Exceeding the limit can result in an EEPROM self-test failure. An average of one state change every three minutes 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-387A:

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-387A to transmit unsolicited binary SER messages.
2. When SER records are triggered in the SEL-387A, 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 that contained in the original message. The relay will wait about 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

Upon turning on, the SEL-387A disables its own unsolicited transmissions. This function enables the SEL-387A to begin sending unsolicited data to the device that sent the enable message, if the SEL-387A has such data to transfer. *Table F.1* shows the message format for function code 0x01.

Table F.1 Function Code 0X01 Message Format

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-387A 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 result from settings changes and power being applied to the relay. If the SER1, SER2, SER3, or SER4 settings subsequently change to any non-NA value and SER entries trigger, unsolicited SER messages will generate with the new SER records.

0x02—Function Code: Disable Unsolicited Data Transfer

This function disables the SEL-387A from transferring unsolicited data. *Table F.2* shows the message format for function code 0x02.

Table F.2 Function Code 0X02 Message Format

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-387A 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 Sequence-of-Events Response

The function 0x18 is used for the transmission of unsolicited Sequential Events Recorder (SER) data from the SEL-387A. 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. *Table F.3* shows the message format for function code 0x18.

Table F.3 Function Code OX18 Message Format

Data	Description
A546	Message header
ZZ	Message length (As many as 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
.	
.	
.	
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 up to 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

Data	Description
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
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 that contains a status byte with the LSB set (except another acknowledge message) and which passes all other checks, including the CRC. *Table F.4* shows the acknowledge message format.

Table F.4 Acknowledge Message Format

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-387A 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 due to 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 message 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

Optional Distributed Network Protocol (DNP3) Level 2 Slave protocol provides access to metering data, protection elements (Relay Word), contact I/O, targets, Sequential Events Recorder, breaker monitor, relay summary event reports, settings groups, time synchronization, and SCADA information. The SEL-387A Relay 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
TIMERQ	Time-set request interval (0–32767 minutes)	0
STIMEO	Select/operate time-out (0.0–30.0 seconds)	1.0
DTIMEO	Data-link time-out (0–5 seconds)	1
MINDLY	Minimum time from DCD to TX (0.00–1.00 seconds)	0.05
MAXDLY	Maximum time from DCD to TX (0.00–1.00 seconds)	0.10
PREDLY	Settle time from RTS on to TX (OFF, 0.00–30.00 seconds)	0

Label	Description	Default
PSTDLY	Settle time after TX to RTS off (0.00–30.00 seconds)	0
ANADBA	Analog reporting deadband (0–32767 counts)	100
ETIMEO	Event data confirmation time-out (0.1–50.0 seconds)	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 seconds)	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-387A monitors received data and treats receipt of data as a DCD indication. When the SEL-387A 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-387A 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-387A 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. This allows RTS to be looped back to CTS in cases where the external transceiver does not support DCD. 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-387A decides to transmit on the DNP link, it has to wait if the physical connection is in use. The SEL-387A 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-387A 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. *Table G.1* 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-387A Settings
Polled Static	The master polls for static (Class 0) data only.	Set CLASS = 0, 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, 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, Set UNSOL = Y, 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, Set UNSOL = Y, 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-387A DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-387A 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. Supports Virtual Terminal
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

Table G.2 SEL-387A DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
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 rollover	16 bits
Sends multifragment responses	Yes

In all cases of a configurable item within the device profile, the item is controlled by SEL-387A settings.

Object Table

Table G.3 lists supported objects, functions, and qualifier code combinations.

Table G.3 SEL-387A 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				
21	2	16-Bit Frozen Counter				

Table G.3 SEL-387A DNP Object List (Sheet 2 of 5)

Obj.	Var.	Description	Request[a] Funct. Codes[c]	Request[a] Qual. Codes[d]	Response[b] Funct. Codes[c]	Response[b] Qual. Codes[d]
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter With Time of Freeze				
21	6	16-Bit Frozen Counter With Time of Freeze				
21	7	32-Bit Frozen Delta Counter With Time of Freeze				
21	8	16-Bit Frozen Delta Counter With Time of Freeze				
21	9	32-Bit Frozen Counter Without Flag				
21	10	16-Bit Frozen Counter Without Flag				
21	11	32-Bit Frozen Delta Counter Without Flag				
21	12	16-Bit Frozen Delta Counter Without Flag				
22	0	Counter Change Event—All Variations	1	6,7,8		
22	1	32-Bit Counter Change Event Without Time	1	6,7,8	129	17,28
22	2[e]	16-Bit Counter Change Event Without Time	1	6,7,8	129,130	17,28
22	3	32-Bit Delta Counter Change Event Without Time				
22	4	16-Bit Delta Counter Change Event Without Time				
22	5	32-Bit Counter Change Event With Time	1	6,7,8	129	17,28
22	6	16-Bit Counter Change Event With Time	1	6,7,8	129	17,28
22	7	32-Bit Delta Counter Change Event With Time				
22	8	16-Bit Delta Counter Change Event With Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event Without Time				
23	2	16-Bit Frozen Counter Event Without Time				

Table G.3 SEL-387A 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	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
32	4	16-Bit Analog Change Event With Time	1	6,7,8	129	17,28

Table G.3 SEL-387A 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]
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		
70	1	File Identifier				

Table G.3 SEL-387A 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]
80	1	Internal Indications	2	0,1 index = 7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				
101	1	Small Packed Binary—Coded Decimal				
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

The following is the default object map supported by the SEL-387A (see *Appendix A: Firmware and Manual Versions*).

Table G.4 SEL-387A Wye/Delta DNP Data Map (Sheet 1 of 5)

DNP Object Type	Index	Description
01,02	000–799	Relay Word, where OCA is 0 and TRIP1 is 319
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 LED16, 1607 is EN, and 1600 is 51
01,02	1616	Relay Disabled
01,02	1617	Relay diagnostic failure
01,02	1618	Relay diagnostic warning
01,02	1619	New relay event available

Table G.4 SEL-387A Wye/Delta DNP Data Map (Sheet 2 of 5)

DNP Object Type	Index	Description
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	Pulse Open Breaker 4 command OC
10,12	23	Pulse Close Breaker 4 command CC
10,12	24–31	Remote bit pairs RB1–RB16
10,12	32	Open/Close pair for Breaker 1
10,12	33	Open/Close pair for Breaker 2
10,12	34	Open/Close pair for Breaker 3
10,12	35	Open/Close pair for Breaker 4
10,12	36	Reset demands
10,12	37	Reset demand peaks
10,12	39	Reset breaker monitor
10,12	40	Reset front-panel targets
10,12	41	Read next relay event
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	Internal breaker Trips 4
20,22	05	External breaker Trips 1
20,22	06	External breaker Trips 2
20,22	07	External breaker Trips 3
20,22	08	External breaker Trips 4
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

Table G.4 SEL-387A Wye/Delta DNP Data Map (Sheet 3 of 5)

DNP Object Type	Index	Description
30,32	24,25	IA magnitude and angle for Wdg. 3, always reads zero
30,32	26,27	IB magnitude and angle for Wdg. 3, always reads zero
30,32	28,29	IC magnitude and angle for Wdg. 3, always reads zero
30,32	30,31	3I1 magnitude and angle for Wdg. 3, always reads zero
30,32	32,33	3I2 magnitude and angle for Wdg. 3, always reads zero
30,32	34,35	IRW magnitude and angle for Wdg. 3, always reads zero
30,32	36,37	IA magnitude and angle for IN1
30,32	38,39	IB magnitude and angle for IN2
30,32	40,41	IC magnitude and angle for IN3
30,32	42,43	3I1 magnitude and angle for Wdg. 4, always reads zero
30,32	44,45	3I2 magnitude and angle for Wdg. 4, always reads zero
30,32	46,47	IRW magnitude and angle for Wdg. 4, always reads zero
30,32	48	IOP1 Operate Current
30,32	49	IOP2 Operate Current
30,32	50	IOP3 Operate Current
30,32	51	IRT1 Restraint Current
30,32	52	IRT2 Restraint Current
30,32	53	IRT3 Restraint Current
30,32	54	I1F2 Second-Harmonic Current
30,32	55	I2F2 Second-Harmonic Current
30,32	56	I3F2 Second-Harmonic Current
30,32	57	I1F5 Fifth-Harmonic Current
30,32	58	I2F5 Fifth-Harmonic Current
30,32	59	I3F5 Fifth-Harmonic Current
30,32	60	VDC
30,32	61–65	Demand A, B, C, IR, and 3I2 magnitudes for Wdg. 1
30,32	66–70	Demand A, B, C, IR, and 3I2 magnitudes for Wdg. 2
30,32	71–75	Demand A, B, C, IR, and 3I2 magnitudes for Wdg. 3, always reads zero
30,32	76–78	Demand for IN1, IN2, IN3 always reads zero
30,32	79–80	Demand IN1, IN2, IN3, IR, and 3I2 magnitudes for Wdg. 4, always reads zero
30,32	81	Peak demand IA mag. for Wdg. 1
30	82–84	Peak demand IA time in DNP format for Wdg. 1
30,32	85	Peak demand IB mag. for Wdg. 1
30	86–88	Peak demand IB time in DNP format for Wdg. 1
30,32	89	Peak demand IC mag. for Wdg. 1
30	90–92	Peak demand IC time in DNP format for Wdg. 1
30,32	93	Peak demand 312 mag. for Wdg. 1
30	94–96	Peak demand 312 time in DNP format for Wdg. 1
30,32	97	Peak demand IR mag. for Wdg. 1
30	98–100	Peak demand IR time in DNP format for Wdg. 1
30,32	101	Peak demand IA mag. for Wdg. 2

Table G.4 SEL-387A Wye/Delta DNP Data Map (Sheet 4 of 5)

DNP Object Type	Index	Description
30	102–104	Peak demand IA time in DNP format for Wdg. 2
30,32	105	Peak demand IB mag. for Wdg. 2
30	106–108	Peak demand IB time in DNP format for Wdg. 2
30,32	109	Peak demand IC mag. for Wdg. 2
30	110–112	Peak demand IC time in DNP format for Wdg. 2
30,32	113	Peak demand 312 mag. for Wdg. 2
30	114–116	Peak demand 312 time in DNP format for Wdg. 2
30,32	117	Peak demand IR mag. for Wdg. 2
30	118–120	Peak demand IR time in DNP format for Wdg. 2
30,32	121	Peak demand IA mag. for Wdg. 3, always reads zero
30	122–124	Peak demand IA time in DNP format for Wdg. 3, always reads zero
30,32	125	Peak demand IB mag. for Wdg. 3, always reads zero
30	126–128	Peak demand IB time in DNP format for Wdg. 3, always reads zero
30,32	129	Peak demand IC mag. for Wdg. 3, always reads zero
30	130–132	Peak demand IC time in DNP format for Wdg. 3, always reads zero
30,32	133	Peak demand 312 mag. for Wdg. 3, always reads zero
30	134–136	Peak demand 312 time in DNP format for Wdg. 3, always reads zero
30,32	137	Peak demand IR mag. for Wdg. 3, always reads zero
30	138–140	Peak demand IR time in DNP format for Wdg. 3, always reads zero
30,32	141	Peak demand IN1 mag. for Wdg. 4, always reads zero
30	142–144	Peak demand IN1 time in DNP format for Wdg. 4, always reads zero
30,32	145	Peak demand IN2 mag. for Wdg. 4, always reads zero
30	146–148	Peak demand IN2 time in DNP format for Wdg. 4, always reads zero
30,32	149	Peak demand IN3 mag. for Wdg. 4
30	150–152	Peak demand IN3 time in DNP format for Wdg. 4, always reads zero
30,32	153	Peak demand 312 mag. for Wdg. 4
30	154–156	Peak demand 312 time in DNP format for Wdg. 4, always reads zero
30,32	157	Peak demand IR mag. for Wdg. 4, always reads zero
30	158–160	Peak demand IR time in DNP format for Wdg. 4
30,32	161–163	Breaker contact wear percentage (A, B, C) for Wdg. 1
30,32	164–166	Breaker contact wear percentage (A, B, C) for Wdg. 2
30,32	167–169	Breaker contact wear percentage (A, B, C) for Wdg. 3, always reads zero
30,32	170–172	Breaker contact wear percentage (A, B, C) for Wdg. 4, always reads zero
30,32	173	Reserved
30,32	174–176	Reserved
30,32	177–179	Reserved
30,32	180–182	Reserved
30,32	183–185	Reserved
30,32	186–188	Reserved
30,32	189–191	Reserved
30,32	192–194	Reserved

Table G.4 SEL-387A Wye/Delta DNP Data Map (Sheet 5 of 5)

DNP Object Type	Index	Description
30,32	195–197	Reserved
30,32	198–200	Reserved
30,32	201	Event Type (see the following table of event causes)
30,32	202	Fault Targets (bit 15:EN, bit 8:51, and bit 7:A-bit 0:W4)
30,32	203–205	Fault currents Wdg. 1 (A, B, C)
30,32	206–208	Fault currents Wdg. 2 (A, B, C)
30,32	209–211	Reserved
30,32	212–214	Reserved
30,32	215	Fault settings group
30	216–218	Fault time in DNP format (high, middle, and low 16 bits)
30,32	219–230	Measured RTD temperatures (RTD 1A–RTD 12A)
30,32	231–242	Measured RTD temperatures (RTD 1B–RTD 12B)
40,41	00	Active settings group

Binary inputs (Objects 1 and 2) are supported as defined by *Table G.3*. 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 bit 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 *Table G.3*. The values are reported in primary units. Current magnitudes are scaled according to the DECPLA setting. If DECPLA is 3, then its value is multiplied by 1000. VDC is not scaled. Event-class messages are generated whenever an input changes beyond the value given by the ANADBA setting. 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 ANADBA setting. Analog inputs are scanned at approximately a half-second rate, except for analogs 201–218. During a scan, all events generated will use the time the scan was initiated. Analogs 201–218 are derived from the history queue data for the most recently read fault and do not generate event messages. Analog 201 is defined as follows:

Value	Event Cause
1	Trigger command
2	Pulse command
4	ER element
8	Trip 5
16	Trip 4
32	Trip 3
64	Trip 2
128	Trip 1

If Analog 201 is 0, fault information has not been read and the related analogs (202–218) do not contain valid data.

If Analog 201 is 0, no more new events are available (i.e., all events have been read).

Analogs 219–242 are temperature values in F or C, depending on TMPREFA and TMPREFB settings. The valid values can be in the range of 0–250°C (32–482°F). The invalid values will be set as follows:

RTD Failure Mode	Error Code
Open (Temp < –50°C)	7FFFh
Short (Temp > 250°C)	8000h
Fiber-Optic Communications Failure	7FFCh
External RTD Unit Status Failure	7FF8h
RTD Channel Not Used	7FF0h

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 as follows:

Table G.5 Object 12 Trip/Close Pair Operation (Sheet 1 of 2)

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
16–23	Pulse	Do nothing	Pulse	Do nothing	Pulse	Do nothing
24	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3	Pulse RB4	Pulse RB3	Pulse RB4	Pulse RB3
26	Pulse RB6	Pulse RB5	Pulse RB6	Pulse RB5	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7	Pulse RB8	Pulse RB7	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9	Pulse RB10	Pulse RB9	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11	Pulse RB12	Pulse RB11	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13	Pulse RB14	Pulse RB13	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15	Pulse RB16	Pulse RB15	Pulse RB16	Pulse RB15
32	Pulse CC1	Pulse OC1	Pulse CC1	Pulse OC1	Pulse CC1	Pulse OC1
33	Pulse CC2	Pulse OC2	Pulse CC2	Pulse OC2	Pulse CC2	Pulse OC2
34	Pulse CC3[a]	Pulse OC3[a]	Pulse CC3[a]	Pulse OC3[a]	Pulse CC3[a]	Pulse OC3[a]

Table G.5 Object 12 Trip/Close Pair Operation (Sheet 2 of 2)

Index	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
35	Pulse CC4[a]	Pulse OC4[a]	Pulse CC4[a]	Pulse OC4[a]	Pulse CC4[a]	Pulse OC4[a]
36–41	Pulse	Do nothing	Pulse	Do nothing	Pulse	Do nothing

[a] Not available in the SEL-387A Relay.

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 *Table G.3*. 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-387A Binary Input Lookup Table (Sheet 1 of 2)

Row	SEL-387A 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	*	*	*	*	*	*	*	OCC	71–64
11	*	*	*	*	*	*	*	*	79–72
12	*	*	*	*	*	*	*	*	87–80
13	*	*	*	*	*	*	*	*	95–88
14	*	*	*	*	*	*	*	*	103–96
15	*	*	*	*	*	*	*	*	111–104
16	*	*	*	*	*	*	*	*	119–112
17	*	*	*	*	*	*	*	*	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	*	151–144
21	87O1	87O2	87O3	*	*	*	*	*	159–152
22	*	*	*	*	*	*	DC1	DC2	167–160
23	*	*	*	*	*	*	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

Table G.6 SEL-387A Binary Input Lookup Table (Sheet 2 of 2)

Row	SEL-387A Relay Word Bits								Binary Input Point
26	SG1	SG2	SG3	SG4	SG5	SG6	CHSG	*	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	*	*	*	*	*	*	*	*	295–288
39	BCWA1	BCWB1	BCWC1	BCW1	BCWA2	BCWB2	BCWC2	BCW2	303–296
40	*	*	*	*	*	*	*	*	311–304
41	TRIP1	TRIP2	TRIP3	TRIP4	TRIP5	TRIPL	*	TRGTR	319–312
42	CLS1	CLS2	CLS3	CLS4	CF1T	CF2T	CF3T	CF4T	327–320
43	NOTALM	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101	335–328
44	OUT201	OUT202	OUT203	OUT204	OUT205	OUT206	OUT207	OUT208	343–336
45	OUT209	OUT210	OUT211	OUT212	OUT213	OUT214	OUT215	OUT216	351–344
46	*	*	*	*	*	*	*	*	359–352
47	*	*	*	*	*	*	*	*	367–360
48	LB1	LB2	LB3	LB4	LB5	LB6	LB7	LB8	375–368
49	LB9	LB10	LB11	LB12	LB13	LB14	LB15	LB16	383–376
50	50GC1	50GN1	32IE1	32IR1	32IF1	REFP1	CTS1	*	391–384
51	50GC2	50GN2	32IE2	32IR2	32IF2	REFP2	CTS2	*	399–392
52	*	*	*	*	*	*	*	*	407–400
53	49A01A	49T01A	49A02A	49T02A	49A03A	49T03A	49A04A	49T04A	415–408
54	49A05A	49T05A	49A06A	49T06A	49A07A	49T07A	49A08A	49T08A	423–416
55	49A09A	49T09A	49A10A	49T10A	49A11A	49T11A	49A12A	49T12A	431–424
56	49A01B	49T01B	49A02B	49T02B	49A03B	49T03B	49A04B	49T04B	439–432
57	49A05B	49T05B	49A06B	49T06B	49A07B	49T07B	49A08B	49T08B	447–440
58	49A09B	49T09B	49A10B	49T10B	49A11B	49T11B	49A12B	49T12B	455–448
59	COMFLA	RTDINA	COMFLB	RTDINB	*	*	*	ISQTAL	463–456
60	50NN11	50NN1T	50NN12	50NN13	50NN14	51NN1	51NN1T	51NN1R	471–464
61	50NN21	50NN2T	50NN22	50NN23	50NN24	51NN2	51NN2T	51NN2R	479–472
62	50NN31	50NN3T	50NN32	50NN33	50NN34	51NN3	51NN3T	51NN3R	487–480

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 201–218) to be loaded with information from the next oldest relay event summary. Since 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 201) 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
```

Custom Scaling

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 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

Upon turning on the relay and a 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-387A, the SEL-387A 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 a C220 or 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 SEL-387A Command Summary. 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.

SEL-387A 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**	=
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**	=
Event Data Confirmation time-out (0.1–50.0 seconds)	**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**	=

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Appendix H
Protection Application Examples

Overview

This section provides instructions for setting the SEL-387A 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-387A 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: Differential, Restricted Earth Fault, and Overcurrent Elements* (*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 H.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 H.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: Differential, Restricted Earth Fault, and Overcurrent Elements* (*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 H.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.

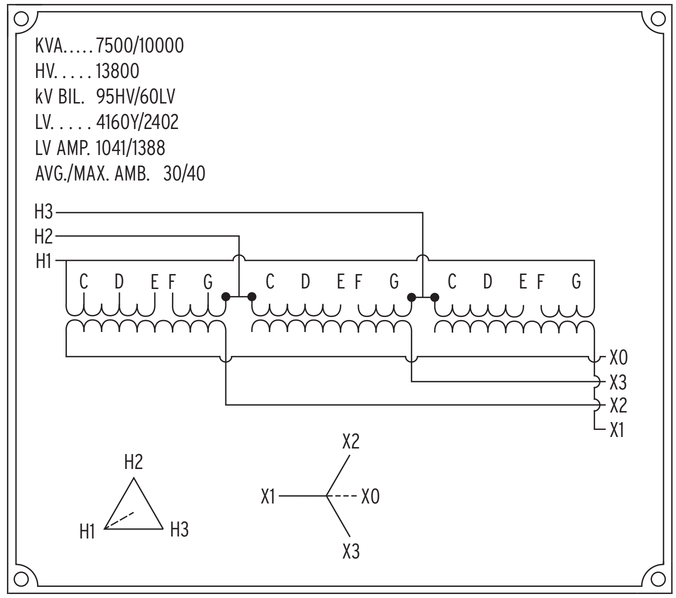

Figure H.1 Transformer Nameplate

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 H.2 shows a three-line connection diagram with the transformer shown in *Figure H.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 H.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.

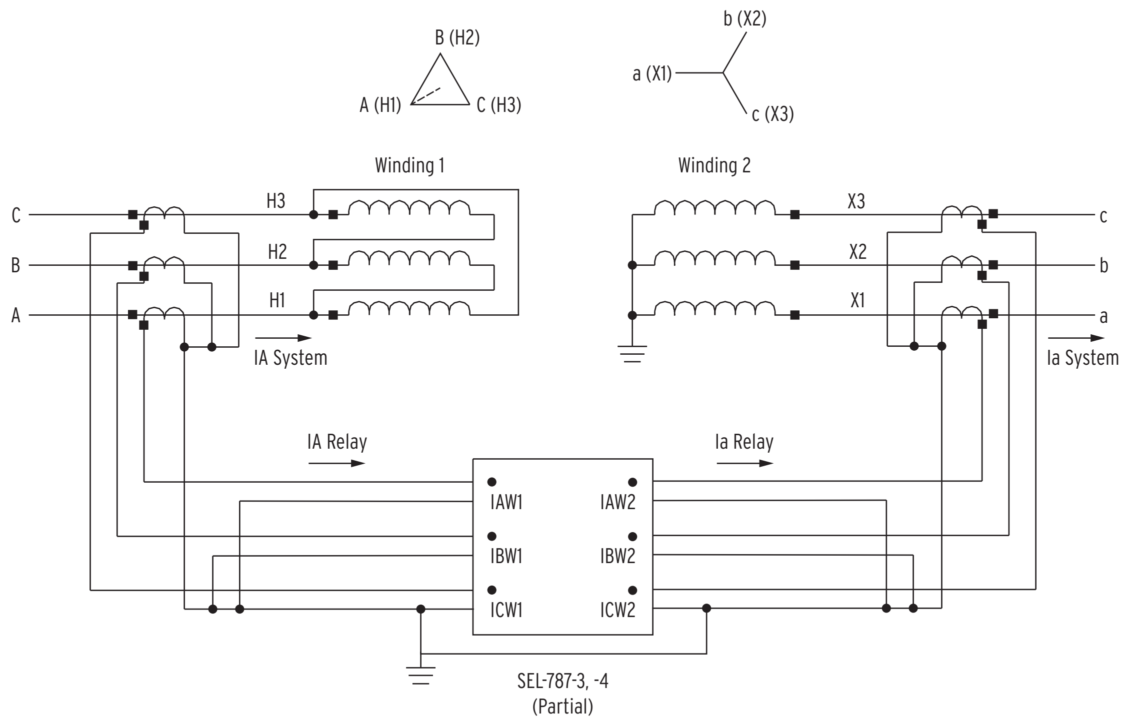

Figure H.2 Three-Line Diagram Showing System Phase-to-Transformer Bushing, CT, and CT-to-Relay Connections

If all the connections are standard as shown in *Figure H.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 H.3* (Ia lags IA by 30 degrees) and *Figure H.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.

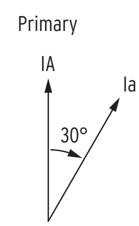

Figure H.3 Primary Current Phasors

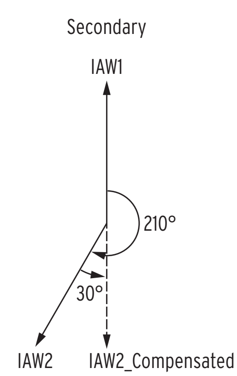

Figure H.4 Current at the Relay Terminals

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 zig-zag 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 H.1* and the phase-to-bushing connections in *Figure H.2*. Assume balanced X-side (wye-winding) three-phase currents Ia, Ib, and Ic, as shown in *Figure H.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.

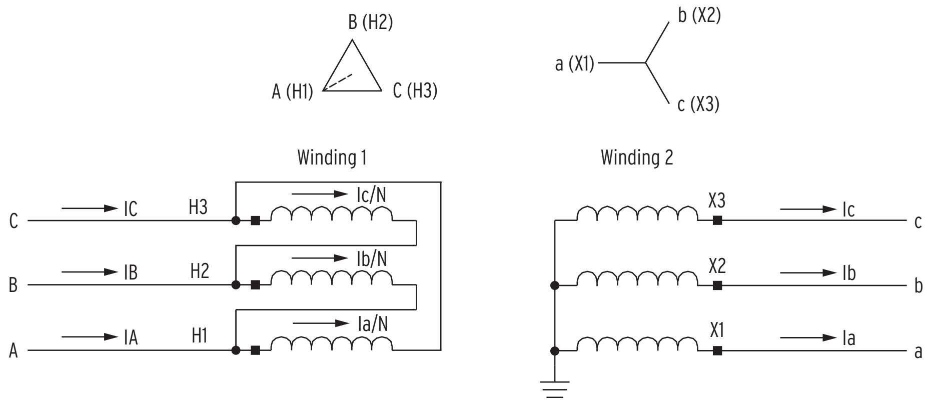

Figure H.5 Standard System Phase-to-Transformer Bushing Connections

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 H.6* shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 30 degrees.

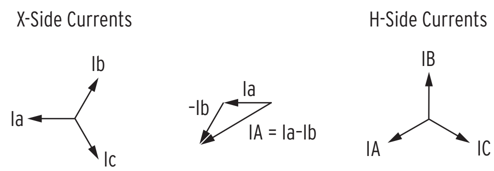

Figure H.6 X- and H-Side Current Phasors for Figure H.5

The primary load phase shift determined in *Figure H.6* applies for the phase-to-bushing connections shown in *Table H.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 H.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 H.7*. This is the same transformer discussed in *Figure H.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.

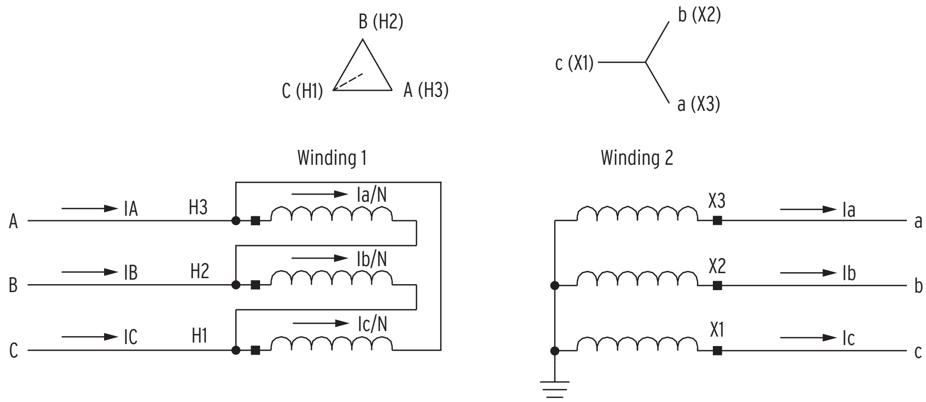

Figure H.7 Non-Standard System Phase-to-Transformer Bushing Connections

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 H.8 shows that system primary current Ia (X-side) leads the system primary current IA (H-side) by 30 degrees.

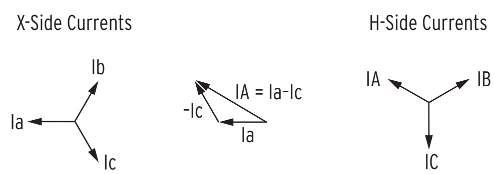

Figure H.8 X- and H-Side Current Phasors for Figure H.7

The primary load phase shift determined in *Figure H.8* applies for the phase-to-bushing connections shown in *Table H.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 H.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 H.5* and *Figure H.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 H.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.

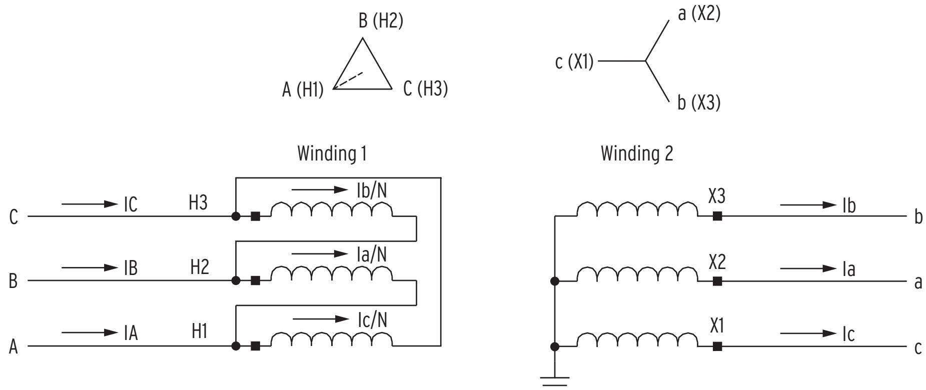

Figure H.9 Combination of Standard and Non-Standard Phase-to-Bushing Connection Diagram

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 H.10 shows that system primary current Ia (X-side) lags the system primary current IA (H-side) by 150 degrees.

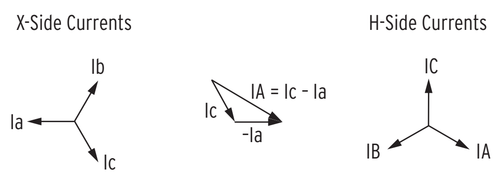

Figure H.10 X- and H-Side Current Phasors for Figure H.9

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 H.11 shows the transformer of *Figure H.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.

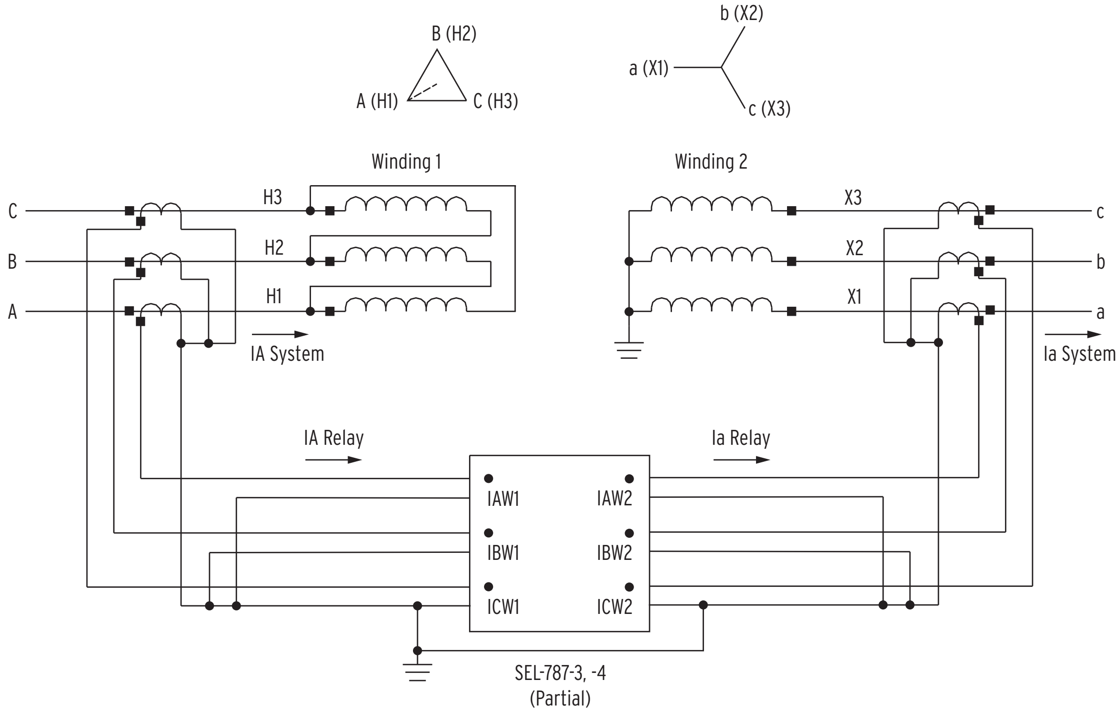

Figure H.11 Standard CT Connections

Standard CT Connections. In *Figure H.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 H.11* represents the standard connections for the transformer, CTs, and relay.

Figure H.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 H.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 H.12*. B- and C-Phases follow this relationship. Only A-Phase is discussed for simplicity, but the concept is the same.

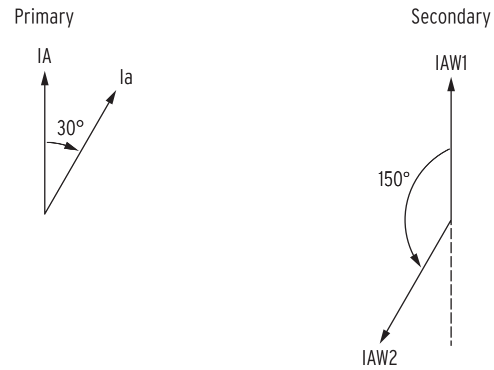

Figure H.12 Primary System Currents and Currents as seen by the Relay

Non-Standard CT Connections: Reversed CT Polarity. *Figure H.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 H.12*. No additional adjustments need to be made because of this type of non-standard CT connection.

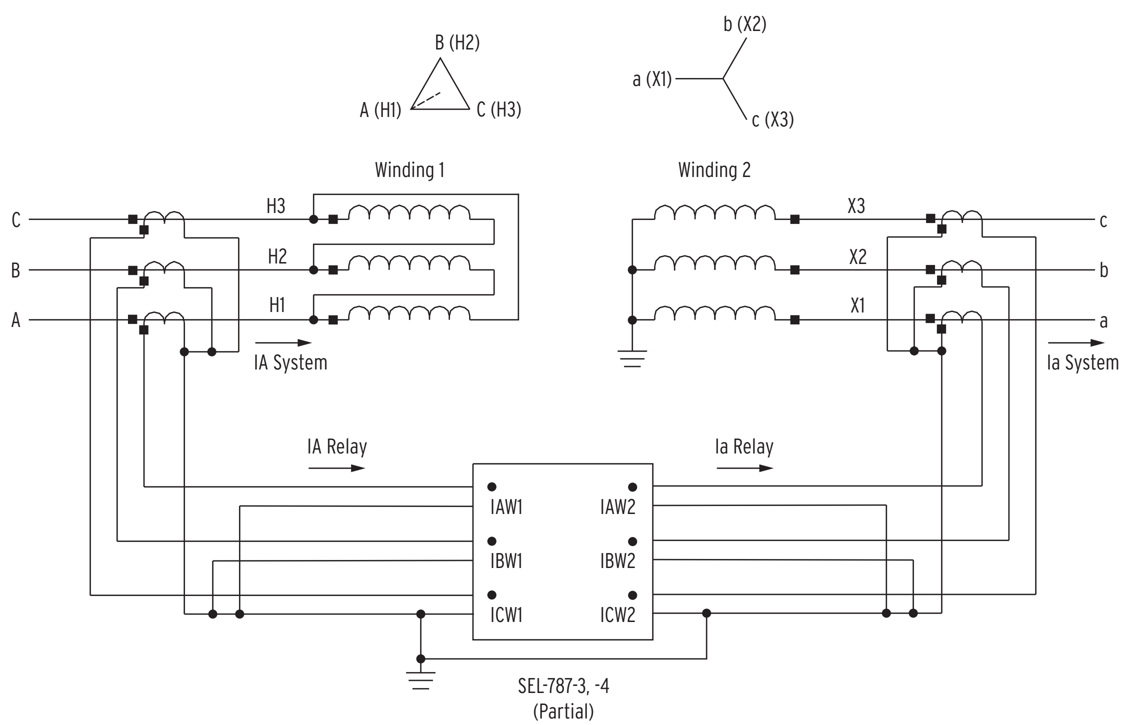

Figure H.13 Current Flow With Reversed X-Side CT Polarity

Non-Standard CT Connections: Reversed CT Polarity and Reversed Connections. In *Figure H.14*, the polarity marks of the X-side CTs are toward the transformer, as in *Figure H.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.

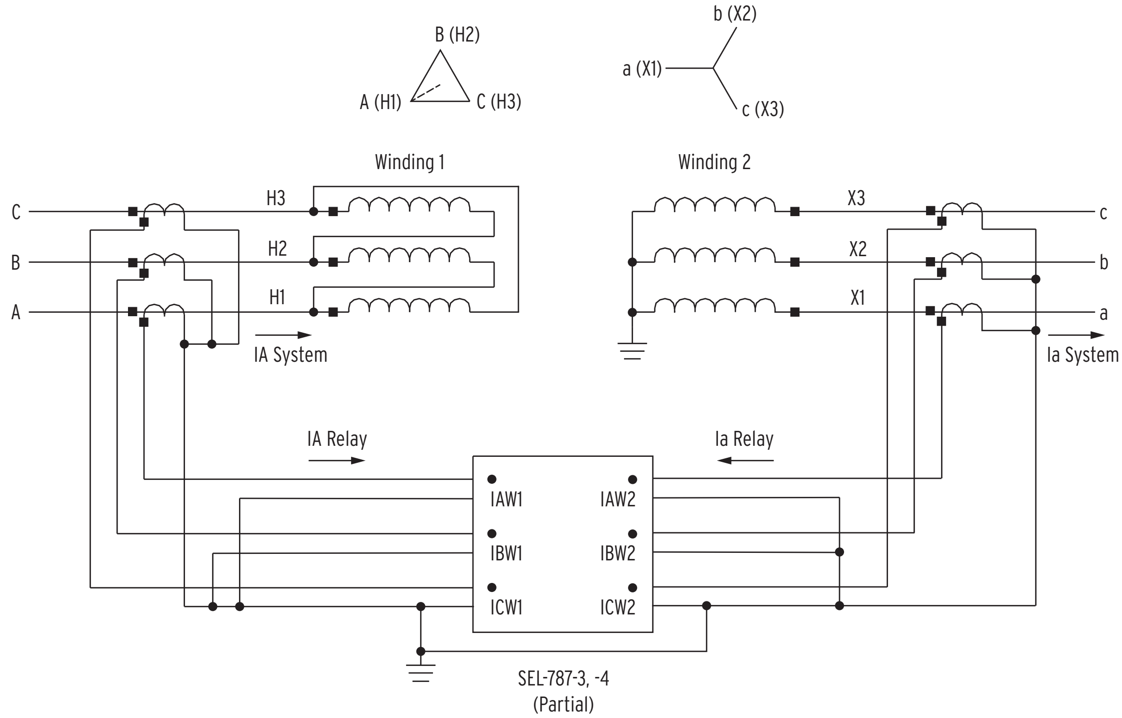

Figure H.14 Current Flow With Reversed X-Side CT Polarity and Reversed Connections

As shown in *Figure H.15*, the resulting IAW2 current measured by the relay is now shifted 180 degrees, as compared to *Figure H.12*.

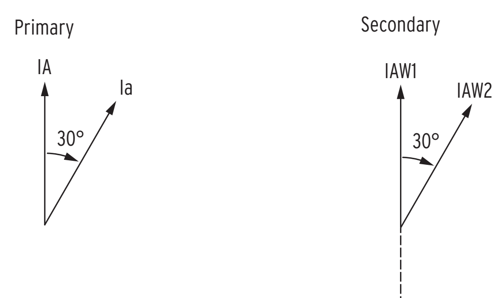

Figure H.15 Results of Reversed X-Side CT Polarity and Reversed Connections

One method to correct this is to reverse the current connections at the relay. Connect the non-polarity terminal of the CT to the polarity terminal of the relay current input and the polarity terminal of the CT to the non-polarity terminal of the relay current input. These changes result in the connections shown in *Figure H.13*.

An alternate method to correct the phase shift is to use the CT compensation setting, W*n*CTC. As shown in *Table H.1*, each CTC setting results in a counterclockwise 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 H.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 H.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 H.16. The primary current phase shift for these connections was determined in Figure H.6. Figure H.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.

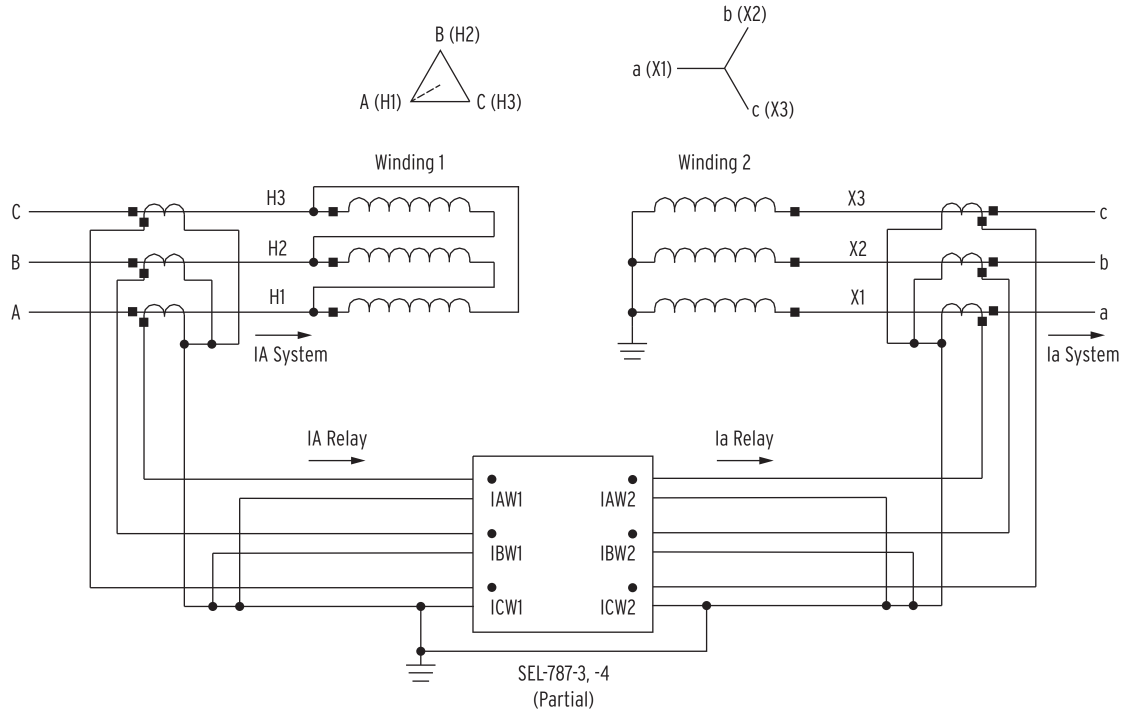

Figure H.16 Delta-Wye Transformer With Standard Phase-to-Bushing Connections

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-387A Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2 of the SEL-387A Relay, so W2CTC must be determined.

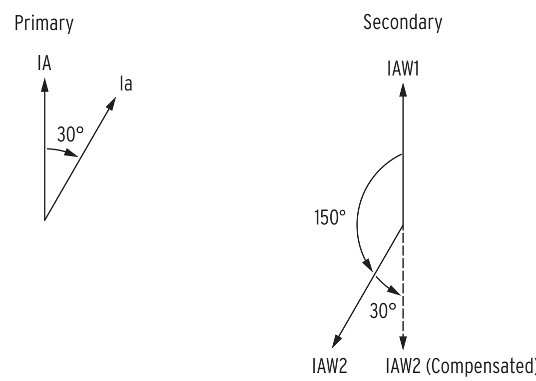

Figure H.17 Primary Currents and Secondary Currents as Measured by the Relay

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 H.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 H.18. This is the same transformer as in Example H.1, but with non-standard phase-to-bushing connections. Figure H.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 H.19 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

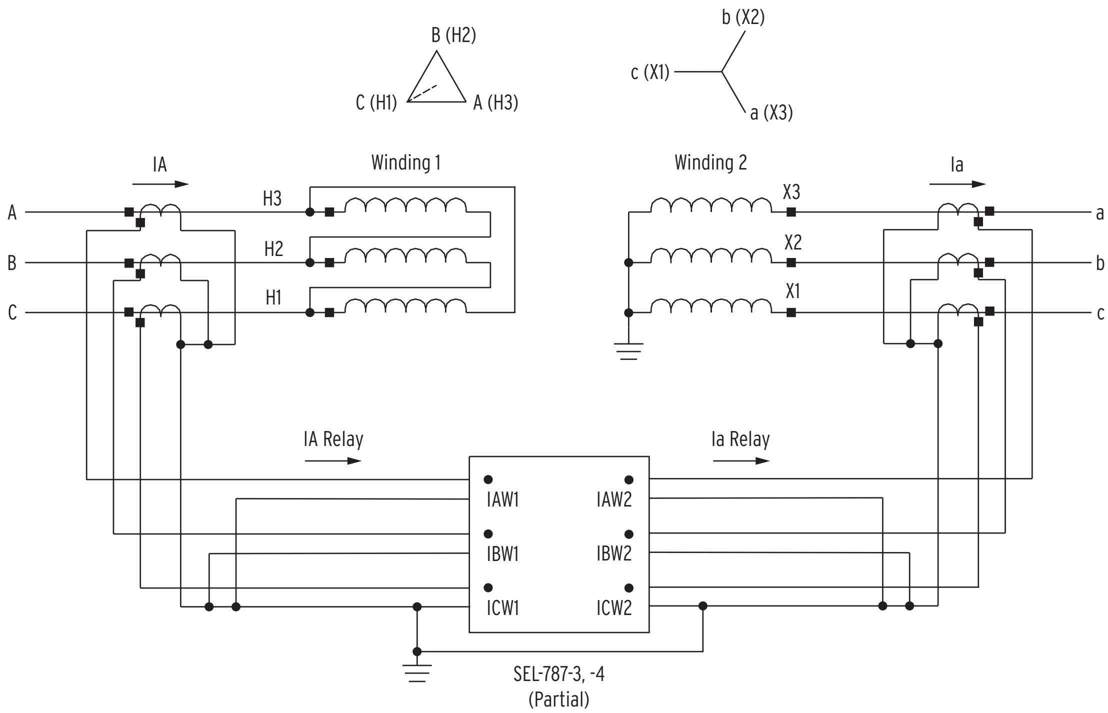

Figure H.18 Delta-Wye Transformer With Non-Standard Phase-to-Bushing Connections

Select the delta winding as the reference winding. The H-side delta current is connected to Terminal W1 of the SEL-387A Relay. Therefore, set W1CTC = 0. The X-side currents are connected to Terminal W2, so W2CTC must be determined.

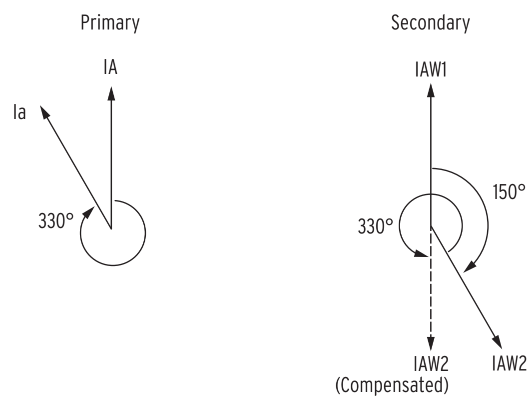

Figure H.19 Primary Currents and Secondary Currents as Measured by the Relay

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 H.1 and Example H.2, notice that the non-standard phase-to-bushing connections affect the compensation settings in both examples.

EXAMPLE H.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 H.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.

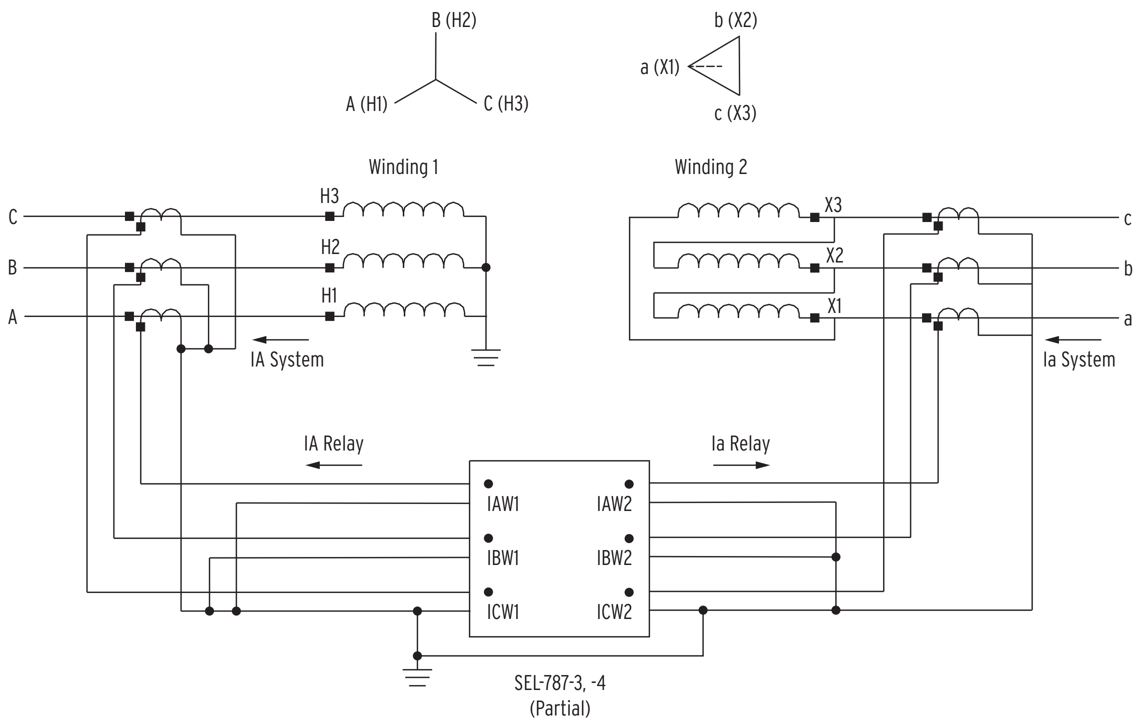

Figure H.20 Wye-Delta Transformer With Non-Standard CT Connections on the X-Side

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 H.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.

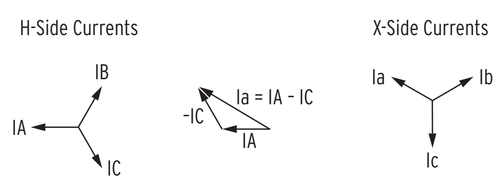

Figure H.21 X- and H-Side Current Phasors for Figure H.20

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 H.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 H.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.

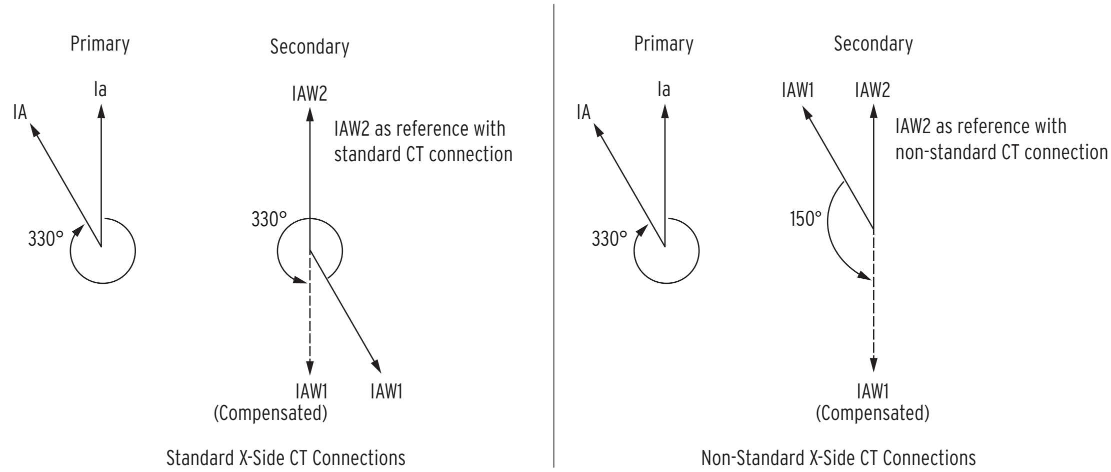

Figure H.22 Comparison of Standard and Non-Standard CT Connections on the X-Side of the Transformer

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 H.4 Autotransformer, Standard Phase-to-Bushing Connections, Standard CT Connections, and an ABC System Phase Rotation

Consider the autotransformer shown in Figure H.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 H.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-387A Relay. Therefore, set W1CTC = 11. The X-side currents are connected to Terminal W2, so W2CTC must be determined. Figure H.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.

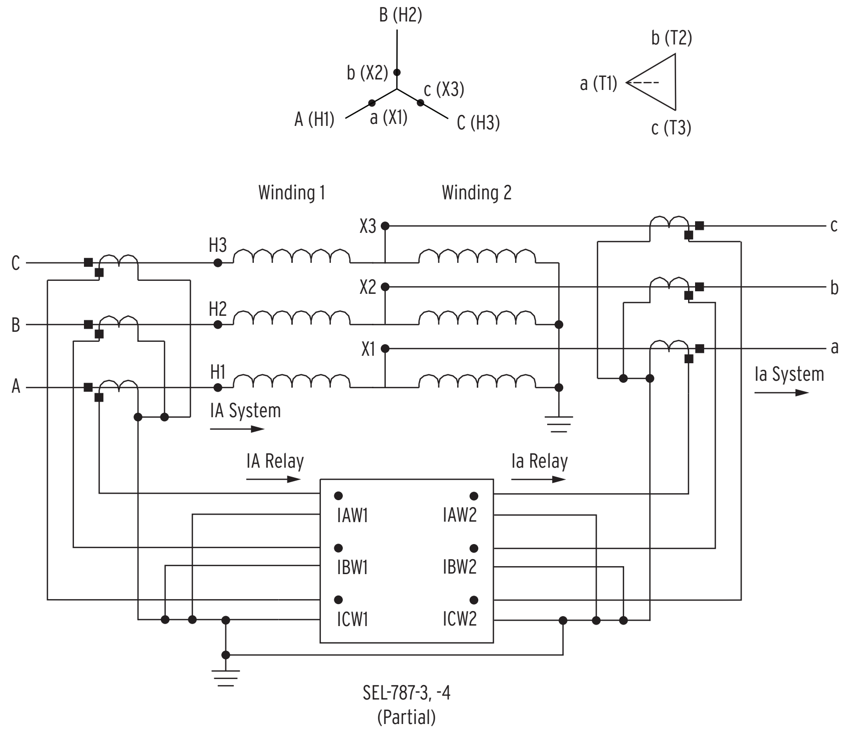

Figure H.23 Autotransformer With Standard Phase-to-Bushing Connections

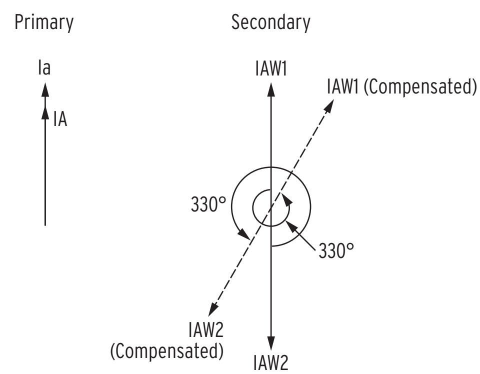

Figure H.24 Primary Currents and Secondary Currents as Measured by the Relay

Special Cases

EXAMPLE H.5 Delta-Wye Transformer With Standard Phase-to-Bushing Connections, Standard CT Connections, and an ACB System Phase Rotation

Consider the application in Figure H.25 with standard phase-to-bushing connections, standard CT connections, and an ACB system phase rotation.

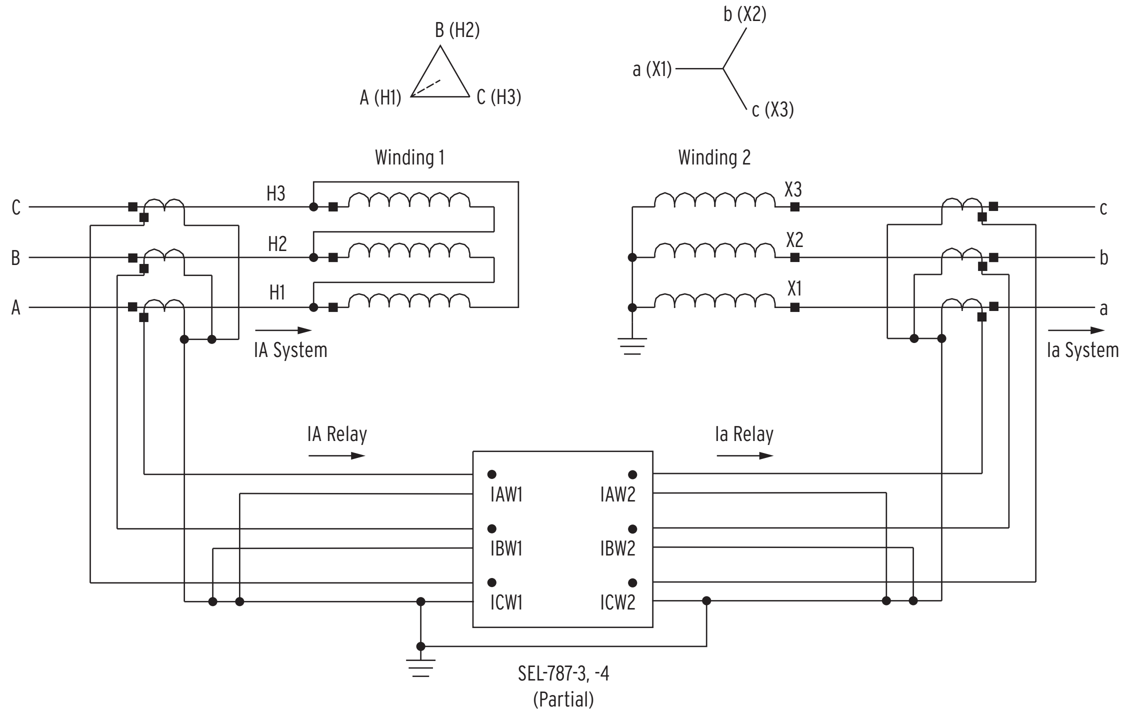

Figure H.25 Delta-Wye Transformer With Standard Phase-to-Bushing Connections With an ACB Phase Rotation

The H-side currents are:

IA = Ia – Ib
IB = Ib – Ic
IC = Ic – Ia

Figure H.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 H.1, even with the same transformer and the same connections, Figure H.26 shows that Ia (X-side) now leads IA (H-side) by 30 degrees because of the system phase rotation. Note that in Example H.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 H.28 shows the phase relationship of both the primary system phase currents and the secondary phase currents as seen by the relay.

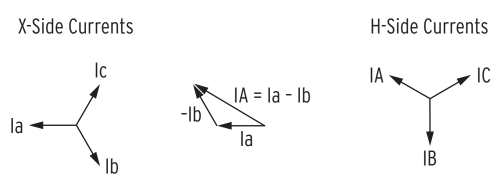

Figure H.26 X- and H-Side Current Phasors for Figure H.25

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 H.1 (also shown in Figure H.27) indicate that the matrix causes the compensated currents to rotate in the opposite direction depending on the system phase rotation.

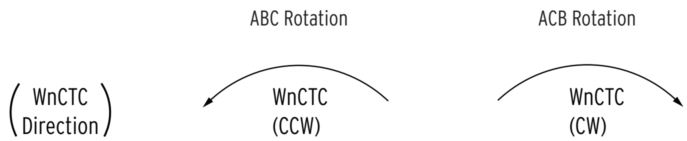

Figure H.27 Direction of Compensation Based on System Phase Rotation

Thus, the compensation settings required for Example H.1 and Example H.5 are the same. Following the settings guideline, the delta side of the transformer is selected as the reference, so W1CTC = 0. Figure H.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.

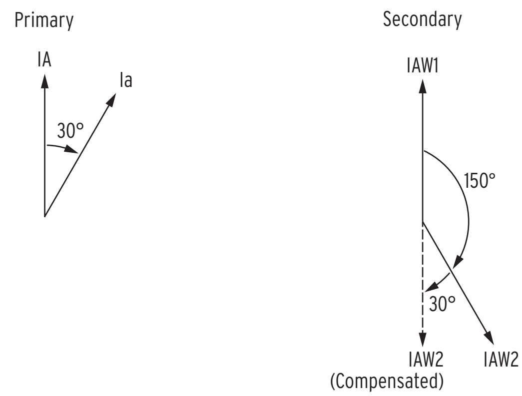

Figure H.28 Primary Currents and Secondary Currents as Measured by the Relay

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 H.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 H.1, except that it includes a zig-zag 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 H.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 H.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 H.29 shows examples of common transformer connections. *Table H.4* is a quick reference guide to be used when all standard phase-to-bushing, CT, and relay connections are present. *Table H.4* is applicable to both ABC and ACB system phase rotations.

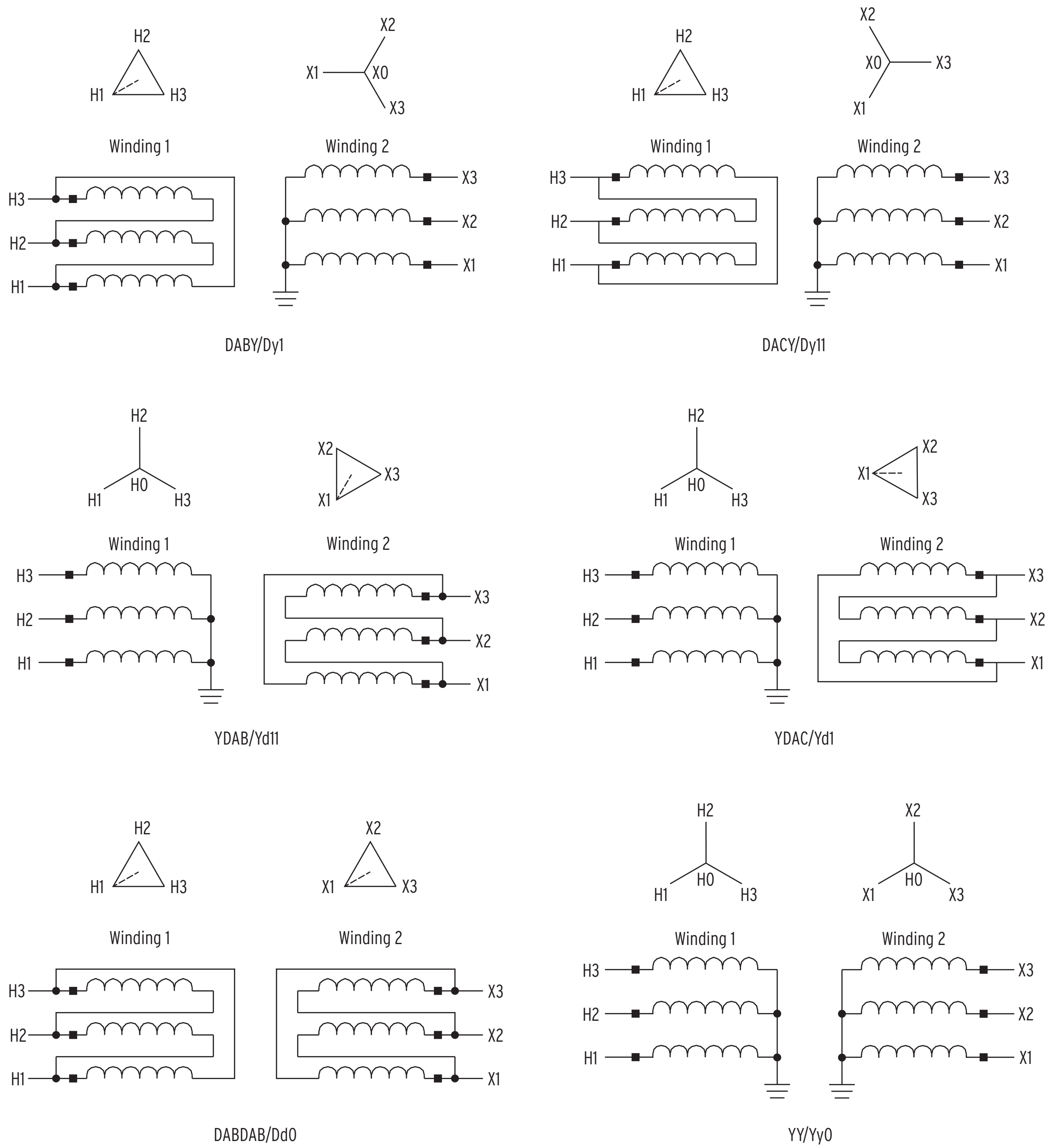

Figure H.29 Common Transformer Connections

Table H.4 Quick Settings Guide for Common Transformer Configurations and Standard Connections

XFMR Connection	W1CTC (Winding 1)	W2CTC (Winding 2)
DABY/Dy1	0	1
DACY/Dy11	0	11
YDAC/Yd1	11	0
YDAB/Yd11	1	0
DABDAB/Dd0 DACDAC/Dd0	0	0
YY/Yy0	11	11

The compensation settings of *Table H.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 H.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 I
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 I.1*.

Visit selinc.com to obtain the latest versions of the software listed in *Table I.1*.

Table I.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. 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-387A does not support the freeform logic described in the QuickSet instruction manual.

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SEL-387A Command Summary

Command	Description
Access Level 0 Commands	
ACC	Enter Access Level 1. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
Access Level 1 Commands	
2AC	Enter Access Level 2. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
BAC	Enter Access Level B. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level B password in order to enter Access Level B.
BRE	Breaker report shows trip counters, trip currents, and wear data for two breakers.
CEV *n*	Show compressed winding event report number *n*, at l/4-cycle resolution. Attach DIF for compressed differential element report, at 1/4-cycle resolution. Attach R for compressed raw winding data report, at 1/16-cycle resolution. 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 presently in the relay.
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. Attach S8 for 1/8-cycle resolution.
EVE D *n*	Show digital data event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF1 *n*	Show differential element 1 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF2 *n*	Show differential element 2 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF3 *n*	Show differential element 3 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE R *n*	Show raw analog data event report number *n*, with 1/16-cycle resolution. Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64)
EVE T	Show event summary.
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.
ID	Display variety of identification and configuration information about the relay.
INI	**INITIO** command reports the number and type of I/O 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 amperes. Enter number *k* to scroll metering *k* times on screen.
MET D *k*	Display demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET DIF *k*	Display differential metering data, in multiples of TAP. Enter number *k* to scroll metering *k* times on screen.
MET H	Generate harmonic spectrum report for all input currents, showing first to fifteenth harmonic levels in secondary amperes.

Command	Description
MET P *k*	Display peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET RD *n*	Reset demand metering values. (*n* = 1, 2, A)
MET RP *n*	Reset peak demand metering values. (*n* = 1, 2, A)
MET SEC *k*	Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen.
MET T	Report temperature values of up to 24 RTD inputs.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
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 the Sequential Events Recorder (SER) event reports 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	Show relay self-test status.
STA C	Clear relay status report from memory and restart the relay.
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 A	Displays cumulative and individual through-fault event data. All the most recent individual events are displayed, up to 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.
Access Level B Commands	
ACC	Enter Access Level 1. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
2AC	Enter Access Level 2. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
BRE	Breaker report shows trip counters, trip currents, and wear data for two breakers.
BRE R *n*	Reset trip counters, trip currents, and wear data for breaker *n* (*n* = 1, 2, A).
BRE W *n*	Pre-set the percent contact wear for each pole of breaker *n* (*n* = 1, 2).
CEV *n*	Show compressed winding event report number *n*, at 1/4-cycle resolution. Attach DIF for compressed differential element report, at 1/4-cycle resolution. Attach R for compressed raw winding data report, at 1/16-cycle resolution. 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).
CLO *n*	Assert the CC*n* Relay Word bit. Used to close breaker *n* if CC*n* is assigned to an output contact. **JMP6B** must be in place to enable this command.
DAT	Show date presently in the relay.

Command	Description
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. Attach S8 for 1/8-cycle resolution.
EVE D *n*	Show digital data event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF1 *n*	Show differential element 1 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF3 *n*	Show differential element 3 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE R *n*	Show raw analog data event report number *n*, with 1/16-cycle resolution. Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64)
EVE T	Show event summary.
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.)
HIS *n*	Show brief summary of the *n* latest event reports.
HIS C	Clear the brief summary and corresponding standard event reports.
ID	Display variety of identification and configuration information about the relay.
INI	**INITIO** command reports the number and type of I/O 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 amperes. Enter number *k* to scroll metering *k* times on screen.
MET D *k*	Display demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET H	Generate harmonic spectrum report for all input currents, showing first to fifteenth harmonic levels in secondary amperes.
MET DIF *k*	Display differential metering data, in multiples of TAP. Enter number *k* to scroll metering *k* times on screen.
MET P *k*	Display peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET RD *n*	Reset demand metering values. (*n* = 1, 2, A)
MET RP *n*	Reset peak demand metering values. (*n* = 1, 2, A)
MET SEC *k*	Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen.
MET T	Report temperature values of the 24 RTD inputs.
OPE *n*	Assert the OCn Relay Word bit. Used to open breaker *n* if OC*n* is assigned to an output contact. **JMP6B** must 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** must be in place to enable this command.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
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 the Sequential Events Recorder (SER) event reports from memory.
SHO *n*	Show relay group *n* settings. Shows active group if *n* is not specified.

Command	Description
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	Show relay self-test status.
TAR R	Return front-panel LED targets to regular operation and reset the tripping front-panel targets.
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. Append F to display targets on the front-panel second row of LEDs.
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, up to 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	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.
Access Level 2 Commands	
ACC	Enter Access Level 1. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Access Level B. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level B password in order to enter Access Level B.
BRE	Breaker report shows trip counters, trip currents, and wear data for two breakers.
BRE R *n*	Reset trip counters, trip currents, and wear data for breaker *n* (*n* = 1, 2, A).
BRE W *n*	Preset the percent contact wear for each pole of breaker *n* (*n* = 1, 2).
CAL	Moves from Access Level 2 to Access Level C.
CEV *n*	Show compressed winding event report number *n*, at 1/4-cycle resolution. Attach DIF for compressed differential element report, at 1/4-cycle resolution. Attach R for compressed raw winding data report, at 1/16-cycle resolution. 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)
CLO *n*	Assert the CC*n* Relay Word bit. Used to close breaker *n* if CC*n* is assigned to an output contact. **JMP6B** must be in place to enable this command.
CON *n*	Control Relay Word bit RBn (Remote Bit *n*; *n* = 1 through 16). Execute **CON *n*** and the relay responds: `CONTROL RBn`. Reply with one of the following: SRB *n*—set Remote Bit *n* (assert RB*n*) CRB *n*—clear Remote Bit n (deassert RB*n*) PRB *n*—pulse Remote Bit *n* [assert RB*n* for one processing interval (1/8 cycle)].
COPY *m n*	Copy settings and logic from setting Group *m* to Group *n*.
DAT	Show date presently in the relay.
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. Attach S8 for 1/8-cycle resolution.

Command	Description
EVE D *n*	Show digital data event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF1 *n*	Show differential element 1 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF2 *n*	Show differential element 2 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF3 *n*	Show differential element 3 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE R *n*	Show raw analog data event report number *n*, with 1/16-cycle resolution. Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64)
EVE T	Show event summary.
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.)
HIS *n*	Show brief summary of the *n* latest event reports.
HIS C	Clear the brief summary and corresponding standard event reports.
ID	Display variety of identification and configuration information about the relay.
INI	**INITIO** command reports the number and type of I/O boards in the relay. In Access Level 2, confirms that I/O boards are correct.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
MET *k*	Display metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET D *k*	Display demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET H	Generate harmonic spectrum report for all input currents, showing first to fifteenth harmonic levels in secondary amperes.
MET DIF *k*	Display differential metering data, in multiples of TAP. Enter number *k* to scroll metering *k* times on screen.
MET P *k*	Display peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET RD *n*	Reset demand metering values. (*n* = 1, 2, A)
MET RP *n*	Reset peak demand metering values. (*n* = 1, 2, A)
MET SEC *k*	Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen.
MET T	Report temperature values of up to 24 RTD inputs.
OPE *n*	Assert the OC*n* Relay Word bit. Used to open breaker *n* if OC*n* is assigned to an output contact. JMP6B must be in place to enable this command.
PAS	Show existing Access Level 1, B, and 2 passwords.
PAS 1 *xxxxxx*	Change Access Level 1 password to *xxxxxx*.
PAS B *xxxxxx*	Change Access Level B password to *xxxxxx*.
PAS 2 *xxxxxx*	Change Access Level 2 password to *xxxxxx*. If *xxxxxx* is DISABLE (uppercase), password for selected level is disabled.
PAS C *xxxxxx*	Change Access Level C password to *xxxxxx*. If *xxxxxx* is DISABLE (uppercase), password for selected level is disabled.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
RES	**RESET51** command resets all inverse-time O/C elements for both windings and the neutral elements.
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.

Command	Description
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 the Sequential Events Recorder (SER) event reports from memory.
SET *n*	Change relay group settings (overcurrent, differential, etc.). 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.
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*	Change port settings.
SHO R	Show Sequential Events Recorder (SER) settings.
STA	Show relay self-test status.
TAR R	Return front-panel LED targets to regular operation and reset the tripping front-panel targets.
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. Append F to display targets on the front-panel second row of LEDs.
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, up to 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	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.

SEL-387A Command Summary

Command	Description
Access Level 0 Commands	
ACC	Enter Access Level 1. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
Access Level 1 Commands	
2AC	Enter Access Level 2. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
BAC	Enter Access Level B. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level B password in order to enter Access Level B.
BRE	Breaker report shows trip counters, trip currents, and wear data for two breakers.
CEV *n*	Show compressed winding event report number *n*, at l/4-cycle resolution. Attach DIF for compressed differential element report, at 1/4-cycle resolution. Attach R for compressed raw winding data report, at 1/16-cycle resolution. 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 presently in the relay.
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. Attach S8 for 1/8-cycle resolution.
EVE D *n*	Show digital data event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF1 *n*	Show differential element 1 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF2 *n*	Show differential element 2 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF3 *n*	Show differential element 3 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE R *n*	Show raw analog data event report number *n*, with 1/16-cycle resolution. Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64)
EVE T	Show event summary.
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.
ID	Display variety of identification and configuration information about the relay.
INI	**INITIO** command reports the number and type of I/O 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 amperes. Enter number *k* to scroll metering *k* times on screen.
MET D *k*	Display demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET DIF *k*	Display differential metering data, in multiples of TAP. Enter number *k* to scroll metering *k* times on screen.
MET H	Generate harmonic spectrum report for all input currents, showing first to fifteenth harmonic levels in secondary amperes.

Command	Description
MET P *k*	Display peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET RD *n*	Reset demand metering values. (*n* = 1, 2, A)
MET RP *n*	Reset peak demand metering values. (*n* = 1, 2, A)
MET SEC *k*	Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen.
MET T	Report temperature values of up to 24 RTD inputs.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
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 the Sequential Events Recorder (SER) event reports 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	Show relay self-test status.
STA C	Clear relay status report from memory and restart the relay.
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 A	Displays cumulative and individual through-fault event data. All the most recent individual events are displayed, up to 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.
Access Level B Commands	
ACC	Enter Access Level 1. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
2AC	Enter Access Level 2. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
BRE	Breaker report shows trip counters, trip currents, and wear data for two breakers.
BRE R *n*	Reset trip counters, trip currents, and wear data for breaker *n* (*n* = 1, 2, A).
BRE W *n*	Pre-set the percent contact wear for each pole of breaker *n* (*n* = 1, 2).
CEV *n*	Show compressed winding event report number *n*, at 1/4-cycle resolution. Attach DIF for compressed differential element report, at 1/4-cycle resolution. Attach R for compressed raw winding data report, at 1/16-cycle resolution. 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).
CLO *n*	Assert the CC*n* Relay Word bit. Used to close breaker *n* if CC*n* is assigned to an output contact. **JMP6B** must be in place to enable this command.
DAT	Show date presently in the relay.

Command	Description
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. Attach S8 for 1/8-cycle resolution.
EVE D *n*	Show digital data event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF1 *n*	Show differential element 1 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF3 *n*	Show differential element 3 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE R *n*	Show raw analog data event report number *n*, with 1/16-cycle resolution. Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64)
EVE T	Show event summary.
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.)
HIS *n*	Show brief summary of the *n* latest event reports.
HIS C	Clear the brief summary and corresponding standard event reports.
ID	Display variety of identification and configuration information about the relay.
INI	**INITIO** command reports the number and type of I/O 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 amperes. Enter number *k* to scroll metering *k* times on screen.
MET D *k*	Display demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET H	Generate harmonic spectrum report for all input currents, showing first to fifteenth harmonic levels in secondary amperes.
MET DIF *k*	Display differential metering data, in multiples of TAP. Enter number *k* to scroll metering *k* times on screen.
MET P *k*	Display peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET RD *n*	Reset demand metering values. (*n* = 1, 2, A)
MET RP *n*	Reset peak demand metering values. (*n* = 1, 2, A)
MET SEC *k*	Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen.
MET T	Report temperature values of the 24 RTD inputs.
OPE *n*	Assert the OCn Relay Word bit. Used to open breaker *n* if OC*n* is assigned to an output contact. **JMP6B** must 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** must be in place to enable this command.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
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 the Sequential Events Recorder (SER) event reports from memory.
SHO *n*	Show relay group *n* settings. Shows active group if *n* is not specified.

Command	Description
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	Show relay self-test status.
TAR R	Return front-panel LED targets to regular operation and reset the tripping front-panel targets.
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. Append F to display targets on the front-panel second row of LEDs.
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, up to 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	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.
Access Level 2 Commands	
ACC	Enter Access Level 1. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Access Level B. If the main board password jumper (**JMP6A**) is not in place, the relay prompts for the entry of the Access Level B password in order to enter Access Level B.
BRE	Breaker report shows trip counters, trip currents, and wear data for two breakers.
BRE R *n*	Reset trip counters, trip currents, and wear data for breaker *n* (*n* = 1, 2, A).
BRE W *n*	Preset the percent contact wear for each pole of breaker *n* (*n* = 1, 2).
CAL	Moves from Access Level 2 to Access Level C.
CEV *n*	Show compressed winding event report number *n*, at 1/4-cycle resolution. Attach DIF for compressed differential element report, at 1/4-cycle resolution. Attach R for compressed raw winding data report, at 1/16-cycle resolution. 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)
CLO *n*	Assert the CC*n* Relay Word bit. Used to close breaker *n* if CC*n* is assigned to an output contact. **JMP6B** must be in place to enable this command.
CON *n*	Control Relay Word bit RBn (Remote Bit *n*; *n* = 1 through 16). Execute **CON *n*** and the relay responds: `CONTROL RBn`. Reply with one of the following: SRB *n*—set Remote Bit *n* (assert RB*n*) CRB *n*—clear Remote Bit n (deassert RB*n*) PRB *n*—pulse Remote Bit *n* [assert RB*n* for one processing interval (1/8 cycle)].
COPY *m n*	Copy settings and logic from setting Group *m* to Group *n*.
DAT	Show date presently in the relay.
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. Attach S8 for 1/8-cycle resolution.

Command	Description
EVE D *n*	Show digital data event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF1 *n*	Show differential element 1 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF2 *n*	Show differential element 2 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE DIF3 *n*	Show differential element 3 event report number *n*, with 1/4-cycle resolution. Attach S8 for 1/8-cycle resolution.
EVE R *n*	Show raw analog data event report number *n*, with 1/16-cycle resolution. Attach S*m* for 1/*m*-cycle resolution. (*m* = 4, 8, 32, 64)
EVE T	Show event summary.
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.)
HIS *n*	Show brief summary of the *n* latest event reports.
HIS C	Clear the brief summary and corresponding standard event reports.
ID	Display variety of identification and configuration information about the relay.
INI	**INITIO** command reports the number and type of I/O boards in the relay. In Access Level 2, confirms that I/O boards are correct.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
MET *k*	Display metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET D *k*	Display demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET H	Generate harmonic spectrum report for all input currents, showing first to fifteenth harmonic levels in secondary amperes.
MET DIF *k*	Display differential metering data, in multiples of TAP. Enter number *k* to scroll metering *k* times on screen.
MET P *k*	Display peak demand metering data, in primary amperes. Enter number *k* to scroll metering *k* times on screen.
MET RD *n*	Reset demand metering values. (*n* = 1, 2, A)
MET RP *n*	Reset peak demand metering values. (*n* = 1, 2, A)
MET SEC *k*	Display metering data (magnitude and phase angle), in secondary amperes. Enter number *k* to scroll metering *k* times on screen.
MET T	Report temperature values of up to 24 RTD inputs.
OPE *n*	Assert the OC*n* Relay Word bit. Used to open breaker *n* if OC*n* is assigned to an output contact. JMP6B must be in place to enable this command.
PAS	Show existing Access Level 1, B, and 2 passwords.
PAS 1 *xxxxxx*	Change Access Level 1 password to *xxxxxx*.
PAS B *xxxxxx*	Change Access Level B password to *xxxxxx*.
PAS 2 *xxxxxx*	Change Access Level 2 password to *xxxxxx*. If *xxxxxx* is DISABLE (uppercase), password for selected level is disabled.
PAS C *xxxxxx*	Change Access Level C password to *xxxxxx*. If *xxxxxx* is DISABLE (uppercase), password for selected level is disabled.
QUI	Quit. Returns to Access Level 0. Returns front-panel LEDs to the default targets.
RES	**RESET51** command resets all inverse-time O/C elements for both windings and the neutral elements.
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.

Command	Description
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 the Sequential Events Recorder (SER) event reports from memory.
SET ***n***	Change relay group settings (overcurrent, differential, etc.). 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.
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***	Change port settings.
SHO R	Show Sequential Events Recorder (SER) settings.
STA	Show relay self-test status.
TAR R	Return front-panel LED targets to regular operation and reset the tripping front-panel targets.
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. Append F to display targets on the front-panel second row of LEDs.
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, up to 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	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.