SEL-787-3, -4 Transformer Protection Relay

SEL-787-3E Model

SEL-787-3S Model

SEL-787-4X Model

Major Features and Benefits

The SEL-787 Transformer Protection Relay provides unsurpassed protection, integration, and control features in a flexible, compact, and cost-effective package. The SEL-787 offers an extensive variety of protection features, depending on the model and options selected. In this document, SEL-787 refers to all the models in *Table 1*. For protection functions specific to a given MOT, the relay is referred to as SEL-787-4X, SEL-787-3E, or SEL-787-3S explicitly, where needed. Model options SEL-787-4X, SEL-787-3E, and SEL-787-3S are all considered base models. *Table 2* shows the protection features available across different models.

Table 1 Current (ACI) and Voltage (AVI) Card Selection for SEL-787 Models

Model	Description/Application	Slot Z Card (MOT Digits)	Slot Z Inputs	Slot E Card (MOT Digits)	Slot E Inputs
787-4X	4 Winding/Terminal Current Differential	6 ACI (81, 82, 85)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	6 ACI (A1, A2, A5)	IAW3, IBW3, ICW3, IAW4, IBW4, ICW4
787-3E	3 Winding/Terminal Current Differential 1 Neutral Current Input 3 Voltage Inputs (Phase)	6 ACI (81, 82, 85)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	4 ACI/3 AVI (72, 73, 76, 77)	IAW3, IBW3, ICW3, IN, VA, VB, VC
787-3S	3 Winding/Terminal Current Differential 3 Voltage Inputs (Phase) 1 Voltage Input (Vsync or Vbat)	6 ACI (81, 82, 85)	IAW1, IBW1, ICW1, IAW2, IBW2, ICW2	3 ACI/4 AVI (71, 75)	IAW3, IBW3, ICW3, VS/VBAT, VA, VB, VC

Table 2 Protection Element Table

Protection Elements		4 Windings	3 Windings With IN Channel and 3-Phase Voltages	3 Windings With VS/VBAT Channel and 3-Phase Voltages
		SEL-787-4X	SEL-787-3E	SEL-787-3S
87	Phase Differential	X	X	X
REF	Restricted Earth Fault	X[a]	X[a]	X[a]
50P	Phase Overcurrent	X	X	X
50Q	Neg.-Seq. Overcurrent	X	X	X
50G	Ground Overcurrent	X	X	X
50N	Neutral Overcurrent		X	
51P	Phase Time-Overcurrent	X	X	X
51Q	Neg.-Seq. Time-Overcurrent	X	X	X
51G	Ground Time-Overcurrent	X	X	X
51PC	Combined Winding Phase Time-Overcurrent	X	X	X
51GC	Combined Winding Ground Time-Overcurrent	X	X	X
51N	Neutral Time-Overcurrent		X	
27P	Phase Undervoltage		X	X
27PP	Phase-to-Phase Undervoltage		X	X
27S	VS Channel Undervoltage			X
59P	Phase Overvoltage		X	X
59PP	Phase-to-Phase Overvoltage		X	X
59Q	Neg.-Seq. Overvoltage		X	X
59G	Ground Overvoltage		X	X
59S	VS Channel Overvoltage			X
24	Volts/Hz		X	X
25	Synchronism Check			X
32	Directional Power		X	X
49RTD	RTDs	X	X	X
60LOP	Loss of Potential		X	X
81	Over- and Underfrequency		X	X
BF	Breaker Failure	X	X	X

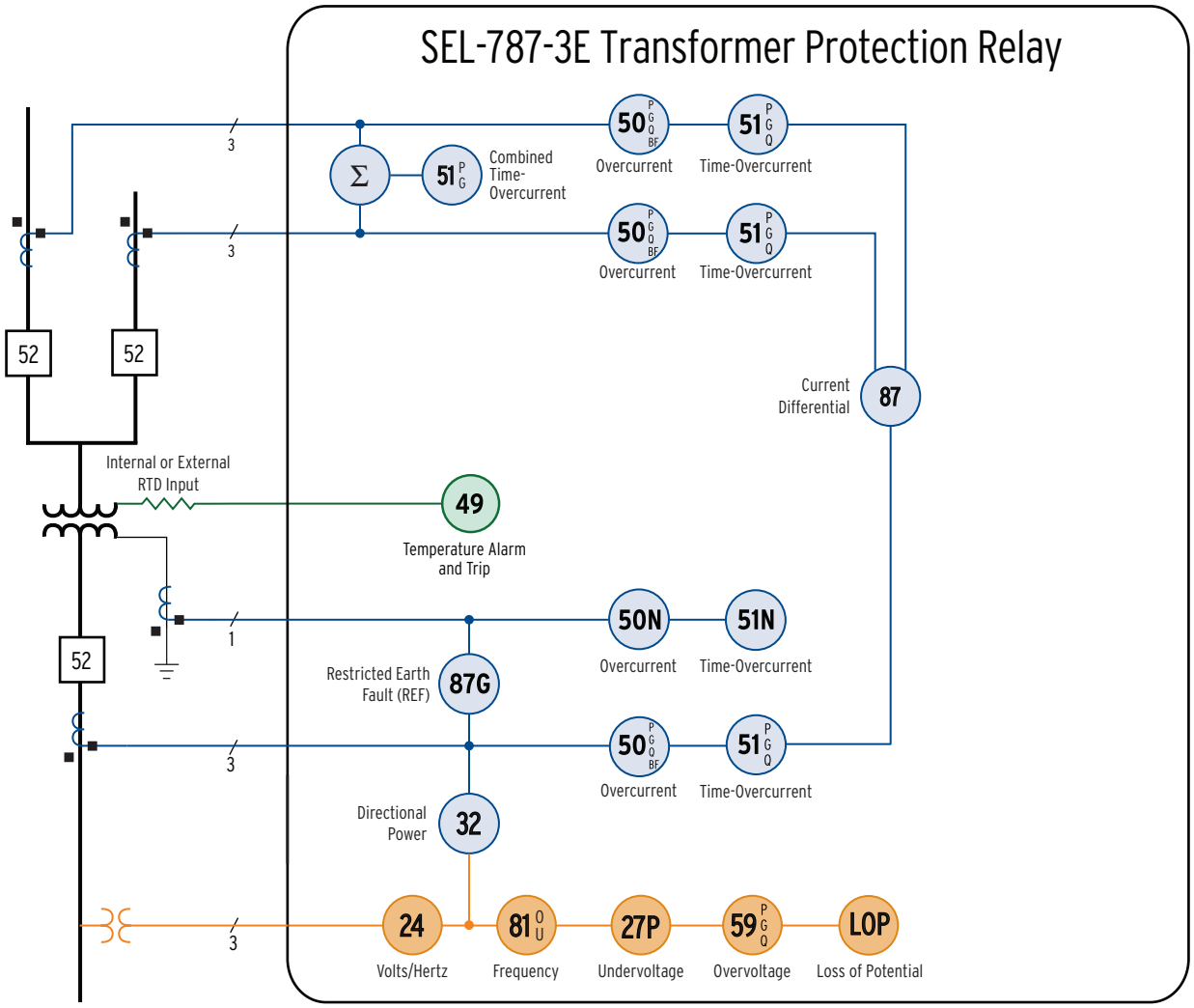
[a] Refer to Table 3 for the available REF elements based on the configuration of Winding 3.

Table 3 Available Differential and REF Elements Based on the Configuration of Winding 3

Elements	SEL-787-3E	SEL-787-3S	SEL-787-4X
Differential Protection Windings (Standard)	3	3	4
REF Elements (Standard)	1	0	0
Differential Protection Windings (Winding 3 Configured for REF)	2	2	3
REF Elements (Winding 3 Configured for REF)	3	2	2

- **Standard Protection Features**. Make use of standard dual-slope differential protection with harmonic blocking and restraint for as many as four windings and as many as three independent restricted earth fault (REF) elements for sensitive ground-fault detection in grounded wye-transformers. The SEL-787 Transformer Protection Relay allows configuration of Winding 3 for either differential or REF protection. Refer to *Table 3* for the available REF elements based on the configuration of Winding 3. The relay also includes phase, negative-sequence, residual ground, and neutral-ground overcurrent elements for backup protection. Breaker failure protection for as many as four three-pole breakers also comes standard.
- **Additional Protection Features.** Take advantage of SEL-787-3E/S volts/hertz protection with frequency tracking from 15 to 70 Hz for generator step-up and variable frequency applications. Use over- and underfrequency and over- and undervoltage elements to implement load shedding and other control schemes on the relay.
- **Synchronism Check/Station DC Battery Monitor.** Program the VS/VBAT voltage channel in the SEL-787-3S model to perform a synchronism check across a circuit breaker or to monitor dc voltage levels of the substation battery.
- **Transformer Monitoring.** Measure accumulated through-fault levels with the transformer through-fault monitor. Additionally, use the optional 4–20 mA or RTD thermal inputs to monitor ambient, load tap-changer (LTC) tank, and transformer oil temperature.
- **Operator Controls.** Take advantage of eight programmable front-panel pushbuttons, each with two programmable tricolor LEDs, for various uses, such as easy trip and close control and status indication for all the breakers. Use the operator control interface pushbuttons to easily implement local and remote operator control schemes using 32 local and 32 remote control bits. Use SELOGIC® control equations and slide-in, configurable front-panel labels to change the function and identification of target LEDs and operator control pushbuttons and LEDs.
- **Relay and Logic Settings Software.** Use ACSELERATOR QuickSet® SEL-5030 Software to reduce engineering costs related to relay settings and logic programming and to simplify development of SELOGIC control equations. Verify proper CT polarity and phasing through use of the built-in phasor display.
- **Metering and Reporting.** Use built-in metering functions that eliminate separately mounted metering devices. Analyze Sequential Events Recorder (SER) reports and oscillographic event reports for rapid commissioning, testing, and post-fault diagnostics. Unsolicited SER protocol allows station-wide collection of binary SER messages.
- **Additional Standard Features.** Further enhance your power system protection by taking advantage of several other SEL-787 standard features in communication, monitoring, and support. Modbus® RTU, Event Messenger support, MIRRORED BITS® communications, as well as load profile and breaker wear monitoring all come standard with the SEL-787. The relay also supports 12 additional external RTDs (SEL-2600 series module), IRIG-B input, advanced SELOGIC control equations, IEEE® C.37.118-compliant synchrophasor protocol, and an SEL-2812 compatible ST® fiber-optic serial port.
- **Optional Features.** Communicate with a number of additional optional communications protocols and ports, digital/analog I/O, and RTDs. Optional communications protocols include IEC 61850, Modbus® TCP/IP, Simple Network Time Protocol (SNTP), DNP3 LAN/WAN, DNP3 serial, and IEC 60870-5-103. Elective communications ports include EIA-232 or EIA-485, and single or dual, copper or fiber-optic Ethernet ports. Several digital/analog I/O options are available. These include 4 AI/4 AO, 4 DI/4 DO, 8 DI, 8 DO, 3 DI/4 DO/1 AO, and 4 DI/3 DO. An optional 10 internal RTD card is also available for the SEL-787 relay.
- **Language Support.** Choose English or Spanish for your serial ports, including the front-panel serial port. The standard relay front-panel overlay is in English; a Spanish overlay is available as an ordering option.

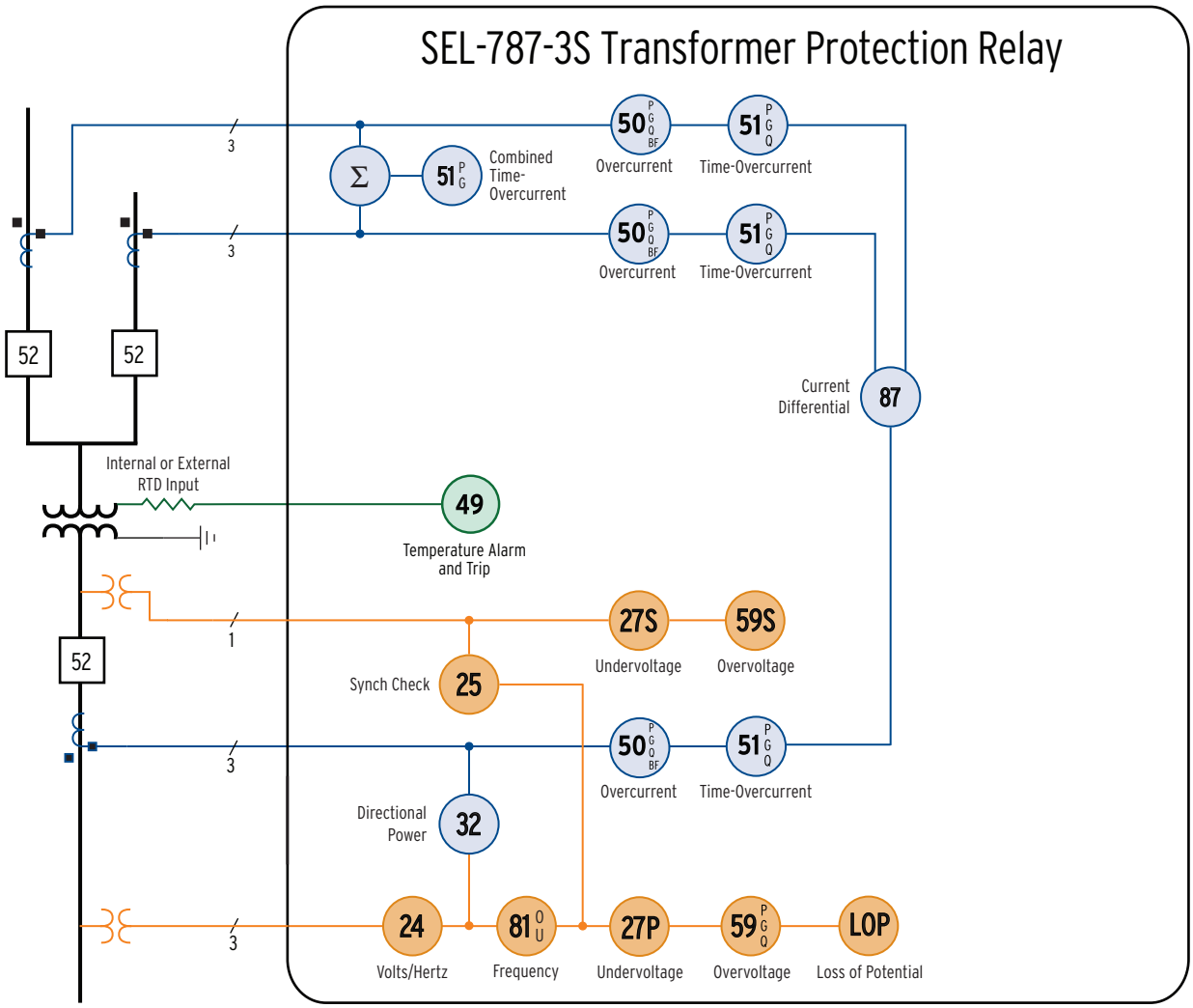
Functional Overview



- Sequential Events Recorder
- Event Reports
- SEL ASCII, Ethernet*, Modbus TCP*, IEC 61850*, DNP3 LAN/WAN*, DNP3 Serial*, 60870-5-103*, Modbus RTU, Telnet, FTP, SNTP*, and DeviceNet™ Communications*
- Synchrophasor Data and IEEE C37.118 Compliant Protocol
- Front-Panel Programmable Tricolor LED Targets
- Two Inputs and Three Outputs Standard
- I/O Expansion*--Additional Contact Inputs, Contact Outputs, Analog Inputs, Analog Outputs, and RTD Inputs
- Single or Dual Ethernet Copper or Fiber-Optic Communications Port*
- Battery-Backed Clock, IRIG-B Time Synchronization
- Instantaneous, Differential, Harmonic, and RMS Metering
- Programmable Pushbuttons and LED Indicators
- Through-Fault Monitoring
- Transformer Thermal Monitoring
- Circuit Breaker Contact Wear Monitor
- Advanced SELogic Control Equations
- 32 Programmable Display Messages
- Mirrored Bits Communications

*Optional Functions

Figure 1 SEL-787-3E Functional Diagram



- Sequential Events Recorder
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- SEL ASCII, Ethernet*, Modbus TCP*, IEC 61850*, DNP3 LAN/WAN*, DNP3 Serial*, 60870-5-103*, Modbus RTU, Telnet, FTP, SNTP*, and DeviceNet™ Communications*
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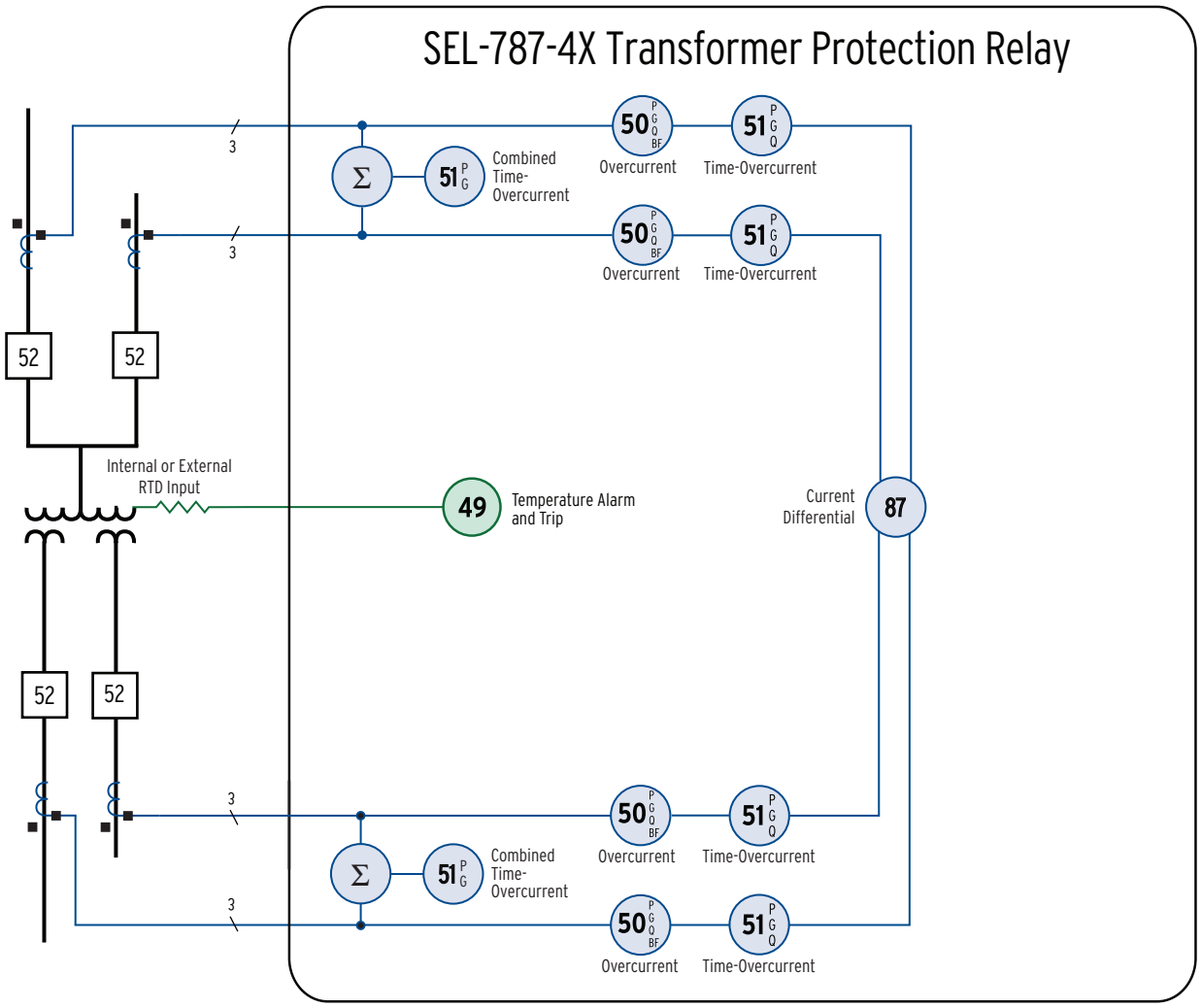
- Transformer Thermal Monitoring
- Circuit Breaker Contact Wear Monitor
- Advanced SELogic Control Equations
- 32 Programmable Display Messages
- Mirrored Bits Communications

*Optional Functions

Figure 2 SEL-787-3S Functional Diagram



- Sequential Events Recorder
- Event Reports
- SEL ASCII, Ethernet*, Modbus TCP*, IEC 61850*, DNP3 LAN/WAN*, DNP3 Serial*, 60870-5-103*, Modbus RTU, Telnet, FTP, SNTP*, and DeviceNet™ Communications*
- Synchrophasor Data and IEEE C37.118 Compliant Protocol
- Front-Panel Programmable Tricolor LED Targets
- Two Inputs and Three Outputs Standard
- I/O Expansion*--Additional Contact Inputs, Contact Outputs, Analog Inputs, Analog Outputs, and RTD Inputs
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- Programmable Pushbuttons and LED Indicators
- Through-Fault Monitoring
- Transformer Thermal Monitoring
- Circuit Breaker Contact Wear Monitor
- Advanced SELogic Control Equations
- 32 Programmable Display Messages
- Mirrored Bits Communications

*Optional Functions

Figure 3 SEL-787-4X Functional Diagram

Protection Features

The SEL-787 Relay offers dual-slope differential characteristic for transformer differential protection. The SEL-787 includes a complete set of phase, negative-sequence, and residual overcurrent elements for each terminal (winding), as well as REF and neutral-overcurrent elements for grounded wye transformers.

Use as many as 12 independent RTD-driven thermal elements with trip and alarm levels to monitor ambient and equipment temperatures throughout the substation.

For the optional volts/hertz element, you can add three-phase voltage inputs that give the SEL-787 volts/hertz protection with definite-time and time-delay characteristics, along with directional power, over- and underfrequency, and over- and undervoltage elements with two independent pickup levels and time delay.

Transformer Differential

The SEL-787 has three restrained differential elements (87R). These elements use operate and restraint quantities calculated from as many as four winding input currents. Set the differential elements with either single- or dual-slope percentage differential characteristics. *Figure 4* illustrates a dual-slope setting. The percent-slope characteristic helps prevent undesired relay operation because of a possible unbalance between CTs during external faults. CT unbalance can result from TAP changing in the power transformer and error difference between the CTs on either side of a power transformer.

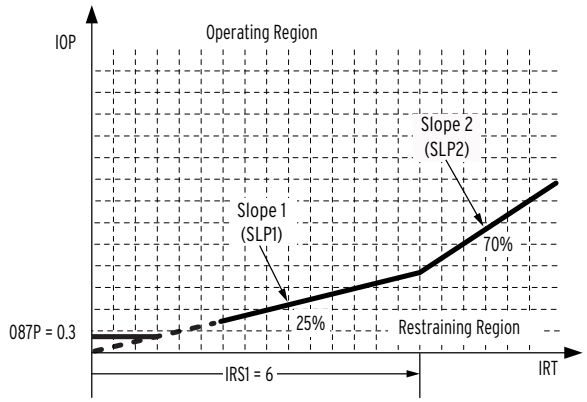


Figure 4 Dual-Slope Restrained Differential Characteristic

With the SEL-787, you can choose harmonic blocking, harmonic restraint, or both, to provide reliable differential protection during transformer inrush conditions. Even-numbered harmonics (second and fourth) provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions. Set second-, fourth-, and fifth-harmonic thresholds independently.

An additional alarm function for the fifth-harmonic current employs a separate threshold and an adjustable timer to warn of overexcitation. This may be useful for transformer applications in or near generating stations. A set of unrestrained differential current elements simply compares the differential operating current quantity to a setting value, typically about 10 times the TAP setting. This pickup setting is only exceeded for internal faults.

The three independent unrestrained differential elements (87U) provide rapid assertion without delay when differential operate current levels exceed the 87U pickup threshold that is set. Typical 87U pickup level settings are between 8 and 10 per unit of operate current.

Restricted Earth Fault (REF) Protection

Apply the REF protection feature to provide sensitive detection of internal ground faults on grounded wye-connected transformer windings and auto-transformers. Order the SEL-787-3E with the Slot **E** card containing the 1 A or 5 A neutral current input for REF protection. The single-phase 1 A or 5 A CT, provided as a Slot **E** ordering option, is used for introduction of neutral operating current. Also, across all available models, you can program Winding 3 for inclusion in differential protection or program Phase A and/or Phase B of Winding 3 for REF protection.

When Winding 3 is set for REF protection, you can apply the operate quantity (neutral current) to Phase A or Phase B of Winding 3 for REF protection. Polarizing current is derived from the residual current calculated for the protected winding(s). A sensitive directional element determines whether the fault is internal or external. Zero-sequence current thresholds supervise tripping.

Overcurrent Protection

The SEL-787 offers instantaneous overcurrent and time-overcurrent elements. All the elements can be controlled individually by means of SELOGIC torque control equations associated with the element.

Instantaneous Overcurrent Elements

The following instantaneous overcurrent elements are available in the SEL-787.

- Four instantaneous phase overcurrent (50P) elements per winding that operate on the maximum of the phase currents. A peak detection algorithm is used to enhance element sensitivity during high-fault current conditions where severe CT saturation may occur.
- Per-phase instantaneous overcurrent (50P) elements, one element per phase, that operate on the corresponding phase current of Winding 3 (only available

on Winding 3). A peak detection algorithm is used to enhance element sensitivity during high-fault current conditions where severe CT saturation may occur.

- Two instantaneous negative-sequence overcurrent (50Q) elements per winding that operate on the calculated negative-sequence current.
- Two residual instantaneous overcurrent (50G) elements per winding that operate on the calculated residual (3I0) current.
- Two neutral instantaneous overcurrent (50N) elements that operate on the neutral current associated with the neutral channel (MOT dependent).

Time-Overcurrent Elements

The time-overcurrent elements support the IEC and U.S. (IEEE) time-overcurrent characteristics shown in *Table 4*. Electromechanical disk reset capabilities are provided for all time-overcurrent elements. The following time-overcurrent elements are available in the SEL-787.

- One maximum phase time-overcurrent (51P) element per winding that operates on the maximum of the corresponding winding phase currents.
- Three per-phase (A-, B-, and C-phase) time-overcurrent (51P) elements, one element per phase, that operate on the corresponding phase current of Winding 3 (only available on Winding 3).
- One negative-sequence time-overcurrent (51Q) element per winding that operates on the calculated negative-sequence current.
- One residual time-overcurrent (51G) element per winding that operates on the calculated residual (3I0) current.
- One neutral time-overcurrent (51N) element that operates on the neutral current associated with the neutral channel (MOT dependent).

Combined Time-Overcurrent Elements

The combined time-overcurrent elements can be used for transformers connected to ring-bus or breaker and one-half systems. The relay only allows you to combine Winding 1 and Winding 2 and/or Winding 3 and Winding 4 currents. The combined time-overcurrent elements support the IEC and U.S. (IEEE) time-overcurrent characteristics shown in *Table 4*. Electromechanical disk reset capabilities are provided for all combined time-overcurrent elements. The following combined time-overcurrent elements are available in SEL-787.

- Two phase time-overcurrent (51P) elements, one each for combined Windings 1 and 2 and Windings 3 and 4, that operate on the maximum of the corresponding combined phase currents.
- Two zero-sequence time-overcurrent (51G) elements, one each for combined Windings 1 and 2 and Windings 3 and 4, that operate on the calculated zero-sequence current of the corresponding combined currents.

Table 4 Time-Overcurrent Curves

U.S. (IEEE)	IEC
Moderately Inverse	Standard Inverse
Inverse	Very Inverse
Very Inverse	Extremely Inverse
Extremely Inverse	Long-Time Inverse
Short-Time Inverse	Short-Time Inverse

Breaker Failure Protection

The SEL-787 offers breaker failure protection for as many as four three-pole breakers. Use breaker failure detection to issue re-trip commands to the failed breaker or to trip adjacent breakers using the relays contact output logic or communications-based tripping schemes.

Breaker failure is initiated by the breaker failure initiate (BFI) SELOGIC input. The BFI input is typically driven by local and remote open/trip commands to the breaker. Once the BFI input is received, the breaker failure element monitors positive- and negative-sequence current magnitudes and the breaker auxiliary contacts to determine when to initiate the breaker failure delay timer. If current or breaker auxiliary contact status does not indicate an open breaker condition within the time set by the breaker failure delay timer, the element issues a breaker failure trip output.

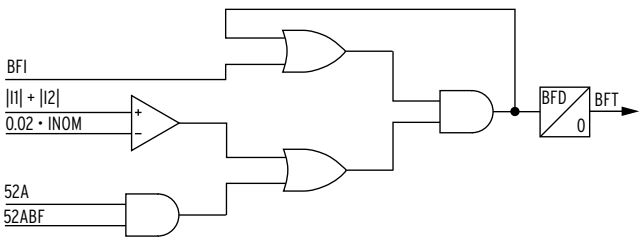


Figure 5 Breaker Failure Protection

Volts/Hertz Protection

Overexcitation occurs when the magnetic core of a power apparatus becomes saturated. When saturation occurs, stray flux is induced in nonlaminated components, which can result in overheating. By ordering the voltage option for the SEL-787, you can add a volts/hertz element to detect overexcitation. An SEL-787 with optional voltage inputs provides a sensitive definite-time delayed element, plus a tripping element with a composite operating time.

For example, the relay calculates the present transformer volts/hertz as a percentage of nominal, based on present measured values and the nominal voltage and frequency settings. The relay starts a timer when the system voltage causes an excursion that exceeds the volts/hertz overexcitation setting. If the condition remains for the set time delay, the relay asserts and typically provides an

alarm function. The element is supervised by the SELOGIC torque control equation, which enables or disables the element as required by the application.

Use the SEL-5806 Volts/Hertz User Curve Design Software to set the user-defined curve (see *Figure 6*). For tripping, the relay provides a time-integrating element with a settable operating characteristic. You can set the relay element to operate as an inverse-time element; a user-defined curve element; a composite element with an inverse-time characteristic and a definite-time characteristic; or a dual-level, definite-time element.

For any of these operating characteristics, the element provides a linear reset characteristic with a settable reset time. The torque control setting also supervises this element. The tripping element has a percent-travel operating characteristic similar to that used by an induction-disk, time-overcurrent element. This characteristic emulates the heating effect of overexcitation on transformer components.

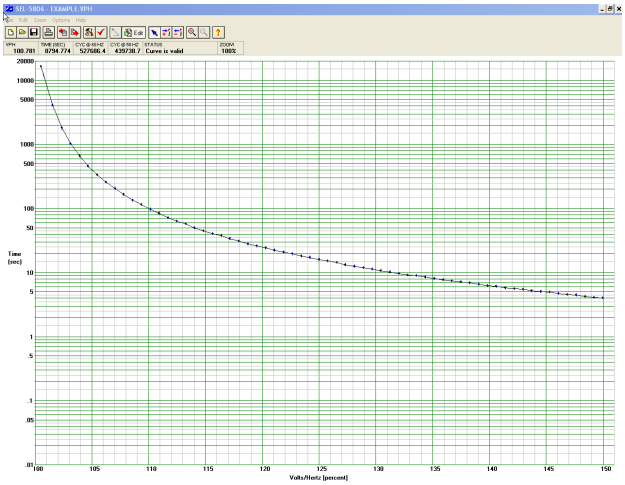


Figure 6 SEL-5806 Volts/Hertz User Curve Design Example

Over- and Undervoltage Protection

The SEL-787 with voltage inputs contains phase over- and undervoltage, and sequence overvoltage elements that help create protection and control schemes, such as undervoltage load shedding or standby generation start/stop commands. All voltage elements provide two pickup levels with definite-time delay settings. The following over- and undervoltage elements are available:

- Phase undervoltage (27P) and overvoltage (59P) elements that operate on the measured phase-to-neutral voltages.
- Phase-to-phase undervoltage (27PP) and overvoltage (59PP) elements that operate on the measured phase-to-phase voltages.
- Negative-sequence overvoltage (59Q) and residual-ground overvoltage (59G) elements that operate on the calculated negative-sequence and residual-ground voltage, respectively.
- Phase undervoltage (27S) and phase overvoltage (59S) elements that operate on VS channel voltage.

Loss-of-Potential Detection

The SEL-787 with optional voltage inputs contains loss-of-potential (LOP) detection logic on the three-phase voltage input to the relay. The LOP logic detects open voltage transformer fuses or other conditions that cause a loss of relay secondary voltage input. The SEL-787 with optional voltage inputs includes LOP logic that detects one, two, or three potentially open fuses. This patented LOP logic is unique, because it does not require settings and is universally applicable. The LOP feature allows for the blocking of protection elements to add security during voltage transformer fuse failure.

Synchronism Check/Station DC Battery Monitor

The SEL-787 with the voltage option allows you to program the VS/Vbat voltage channel for use as either synchronism check or station dc battery monitor. When programmed as a synchronism-check channel, single-phase voltage (phase-to-neutral or phase-to-phase) can be connected to the voltage input for synchronism check or hot/dead line check across the circuit breaker to which the three-phase voltages are assigned. When the channel is programmed for battery monitor, the station dc battery voltage can be monitored. The relay also allows you to program over- and undervoltage elements on the voltage channel.

Over- and Underfrequency Protection

The SEL-787 with optional voltage inputs contains four frequency elements. Each element operates as either an over- or underfrequency element with or without time delay, depending on the element pickup setting.

If the element pickup setting is less than the nominal system frequency setting, the element operates as an underfrequency element, picking up if the measured frequency is less than the set point. If the pickup setting exceeds the nominal system frequency, the element operates as an overfrequency element, picking up if the measured frequency exceeds the set point.

The SEL-787 with optional voltage inputs uses the positive-sequence voltage to determine system frequency. All frequency elements are disabled if the positive-sequence voltage is less than the minimum voltage threshold.

Directional Power Element Protection

The SEL-787 with optional voltage inputs provides two directional power elements for detecting real (WATTS) or reactive (VARS) directional power flow levels for the transformer winding(s) associated with the three-phase voltage input. Each directional power element has a definite-time delay setting.

RTD Thermal Protection

When the SEL-787 is equipped with either the optional 10 RTD input expansion card or an external SEL-2600 RTD module with as many as 12 RTD inputs, as many as 12 thermal elements in the relay can be programmed for two levels of thermal protection per element. Each RTD input provides an alarm and trip thermal pickup setting in degrees C, provides open and shorted RTD detection, and is compatible with the following three-wire RTD types:

- PT100 (100 Ω platinum)
- NI100 (100 Ω nickel)
- NI120 (120 Ω nickel)
- CU10 (10 Ω copper)

Operator Controls

Operator controls eliminate traditional panel control switches. Eight conveniently sized operator controls are located on the relay front panel (see *Figure 7* and *Figure 8*). The SER can be set to track operator controls. Use SELOGIC control equations to change operator control functions. It is possible to use configurable labels to change all text in *Figure 7* and *Figure 8*.

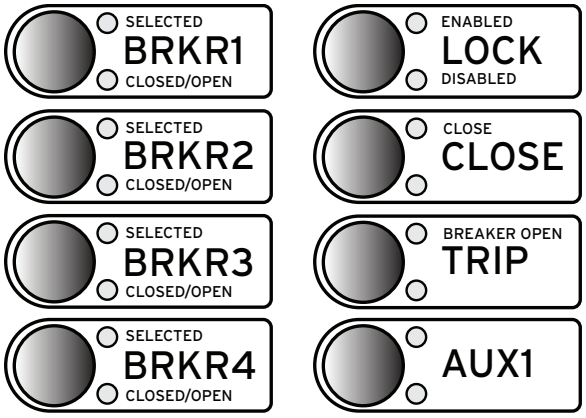


Figure 7 Operator Controls (787-4X Model)

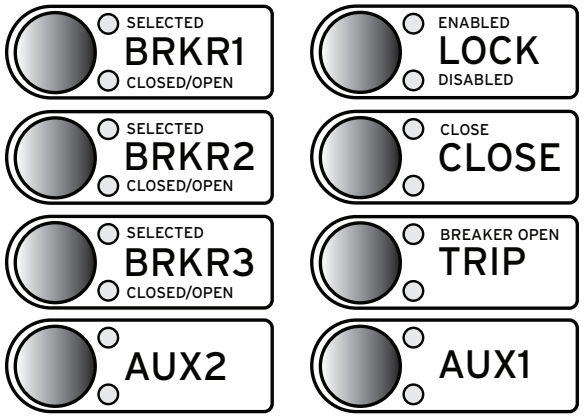


Figure 8 Operator Controls (787-3S/3E Models)

The following operator control descriptions are for factory-set logic.

LOCK: The LOCK operator control blocks selected functions. Press it for at least three seconds to enable or disable the lock function. When the LOCK pushbutton is enabled, the CLOSE operator control is blocked.

BRKRn (n = 1, 2, 3, or 4): Each of these pushbuttons allows you to select the breaker on which a CLOSE or TRIP control operation is to be performed. Only one breaker can be selected at any given time. Breaker select status for a given breaker is indicated by the upper pushbutton LED. The lower pushbutton LED indicates CLOSED/OPEN (RED/GREEN, respectively) status of the corresponding breaker.

CLOSE and TRIP: Use the CLOSE and TRIP operator controls to close and open the circuit breaker. You can program these controls with intentional time delays to support operational requirements for breaker-mounted relays. This allows you to press the CLOSE or TRIP pushbutton, then move to an alternate location before the breaker command executes.

AUXn (n = 1, 2): The AUXn pushbutton is available for you to program additional control for your specific application.

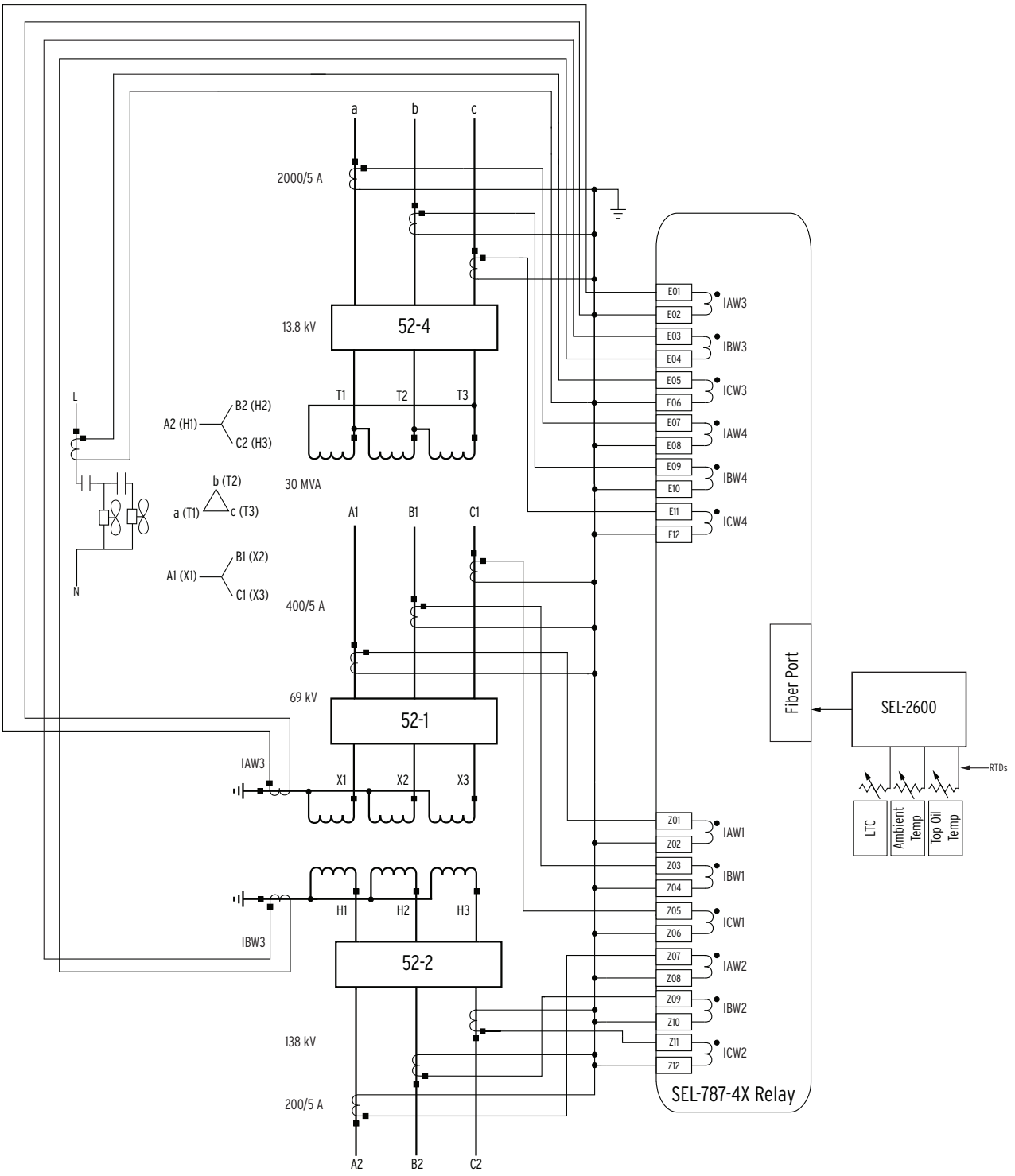
SEL-787 Application

The SEL-787 is designed to provide differential and overcurrent protection for power transformers, generator step-up transformers, and autotransformers with as many as four windings/terminals. In addition, the SEL-787 contains advanced integration and control features that will allow its application in a wide variety of automation and control schemes. Refer to *Section 2: Installation* and *Section 4: Protection and Logic Functions* of the instruction manual for more details.

Figure 9 shows the application of an SEL-787-4X Relay for protection of a three-winding transformer. You can configure windings 1, 2, and 4 on the relay for differential protection, and you can apply the 50/51 elements associated with each winding towards overcurrent protection. You can configure A-phase and B-phase of Winding 3 on the relay for REF protection for windings 1 and 2, respectively. You can configure C-phase of Winding 3, along with the RTD thermal elements, to provide fan bank control and protection. Use additional RTD thermal elements to monitor load tap changer (LTC) tank temperatures and SELOGIC programming to indicate temperature differential alarms between transformer and LTC tank temperatures.

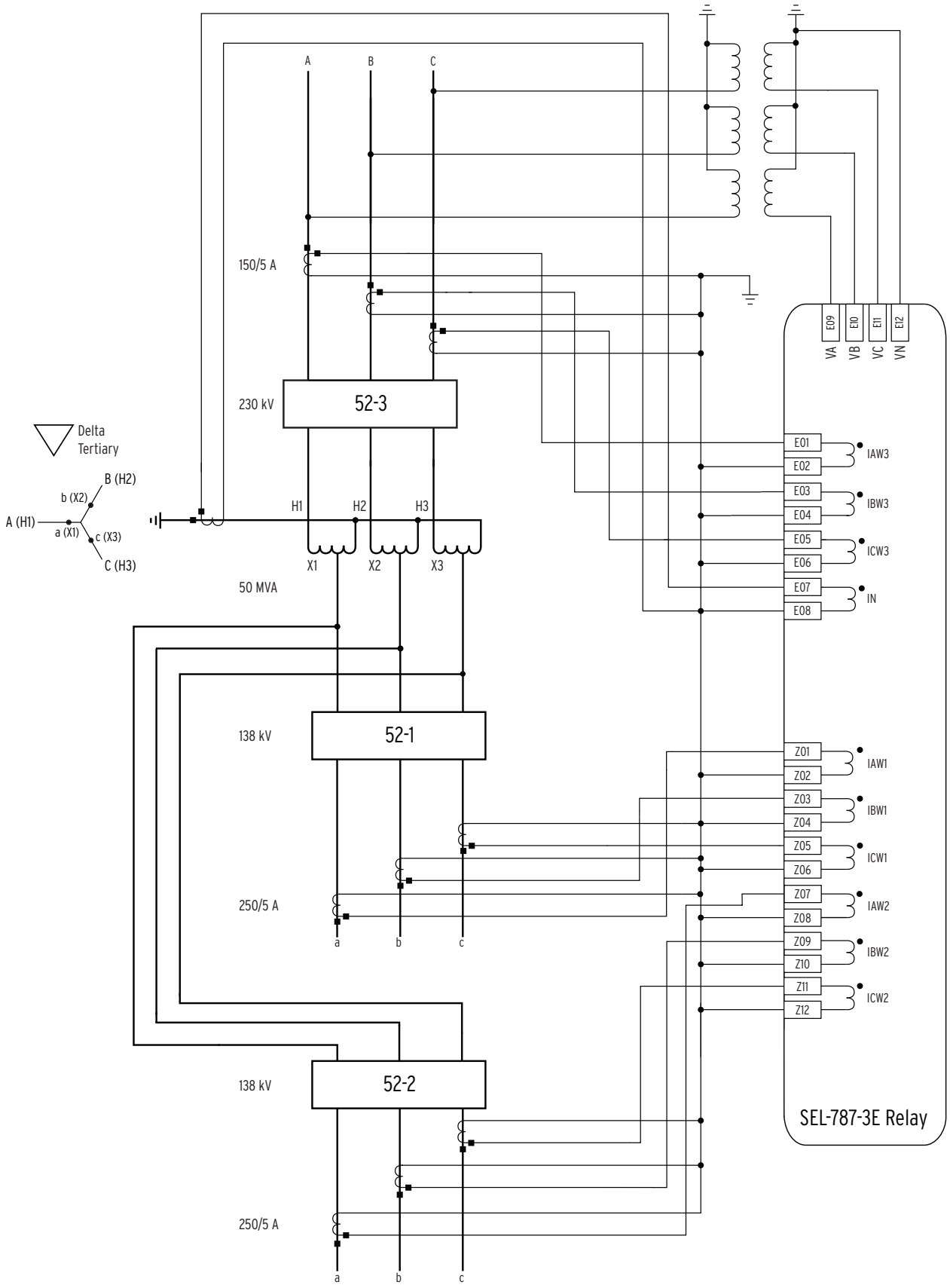
Figure 10 shows an SEL-787-3E Relay protecting an autotransformer with three terminals. You can configure windings 1, 2, and 3 on the relay for differential protection, and you can apply the 50/51 elements associated with each winding towards overcurrent protection. You can configure Channel IN on the relay for REF protection. You can use the three-phase voltage inputs for V/Hz, over- and undervoltage, over- and underfrequency, and directional power protection.

Apply the transformer through-fault monitoring of the SEL-787 to keep track of accumulated through-fault I^2t values. Monitor the number of through faults, accumulated I^2t, and fault duration times to determine the frequency (through-fault events per day, week, month, or year) and impact of external faults on the transformer.



Note: The CT secondary circuit should be grounded in the relay cabinet.

Figure 9 SEL-787-4X Provides 3-Winding Transformer Differential Protection, REF Protection, Overcurrent Protection, and Fan Bank Control With LTC Monitoring



Note: The CT secondary circuit should be grounded in the relay cabinet.

Figure 10 SEL-787-3E Provides Auto-Transformer Differential Protection, REF Protection, Overcurrent Protection, and Voltage-Based Protection

Relay and Logic Settings Software

ACSELERATOR QuickSet simplifies settings and provides analysis support for the SEL-787. There are several ways to create and manage relay settings with ACSELERATOR QuickSet.

- Develop settings offline with an intelligent settings editor that only allows valid settings.
- Create SELOGIC control equations with a drag-and-drop text editor.
- Use online help to configure proper settings.
- Organize settings with the relay database manager.
- Use a simple PC communications link to load and retrieve settings.

With ACSELERATOR QuickSet, you can verify settings and analyze power system events with the integrated waveform and harmonic analysis tools.

You can use the following features of ACSELERATOR QuickSet to monitor, commission, and test the SEL-787.

- Use the human-machine interface (HMI) to monitor meter data, Relay Word bits, and output contacts status during testing.
- Use the PC interface to remotely retrieve power system data.
- Use the Event Report Analysis tool for easy retrieval and visualization of ac waveforms and digital inputs and outputs the relay processes.
- Use the graphical current phasor displays in the HMI for visualizing differential current relationships.

Metering and Monitoring

The SEL-787 provides extensive metering capabilities. See *Specifications* for metering and power measurement accuracies. As shown in *Table 5*, metered quantities include phase voltages and currents; neutral current; sequence voltages and currents; harmonics, power, frequency, and energy; and maximum/minimum logging of selected quantities.

Table 5 SEL-787 Metered Values (Model Dependent)

Quantity	Description
I*x*W*n* (*x* = A, B, C, *n* = 1, 2, 3, 4)	Winding phase current magnitude and angle, primary A
IN1	Neutral current magnitude and angle, primary A
IGW*n* (*n* = 1, 2, 3, 4)	Residual-ground fault current and angle per winding, primary A
3I2W*n* (*n* = 1, 2, 3, 4)	Negative-sequence current and angle per winding, primary A
IOP*z* (*z* = 1, 2, 3)	Differential operate current, scaled to TAP
IRT*z* (*z* = 1, 2, 3)	Differential restraint current, scaled to TAP
I*n*F2, I*n*F4, I*n*F5 (*n* = 1, 2, 3, 4)	Current harmonics, I*n*F2/IOP*n* (%) for 2nd, 4th, 5th harmonics
VA, VB, VC	Phase voltages and angles, primary volts, for wye-connected potential transformers
VAB, VBC, VCA	Phase-to-phase voltages and angles, primary volts, for delta-connected potential transformers
VG	Residual-ground voltage and phase angle, primary volts, for wye-connected potential transformers
3V2	Negative-sequence voltage and phase angle, primary volts
kVA, kW, kVAR	Calculated apparent, real, and reactive power scaled to primary values
MWh, MVARh	Three-phase positive and negative megawatt-hours, megavar-hours
PF	Power factor (leading or lagging)
VS	Synchronism-check voltage channel, voltage magnitude and angle, primary volts
VDC	Station battery voltage
FREQ	Measured system frequency (Hz)
FREQS	Measured frequency (Hz) of synchronism-check channel
V/Hz	Calculated volts/hertz in percent, using highest measured voltage and frequency
RTD*n* (*n* = 1 to 12)	RTD temperature measurement (degrees C)

Synchronized Phasor Measurement

Combine the SEL-787 with an SEL IRIG-B time source to measure the system angle in real time with a timing accuracy of ±10 µs. Measure instantaneous voltage and current phase angles in real time to improve system operation with synchrophasor information. Replace state measurement, study validation, or track system stability. Use SEL-5077 SYNCHROWAVE® Server Software or SEL-5078-2 SYNCHROWAVE® Console Software to view system angles at multiple locations for precise system analysis and system-state measurement (see *Figure 11*).

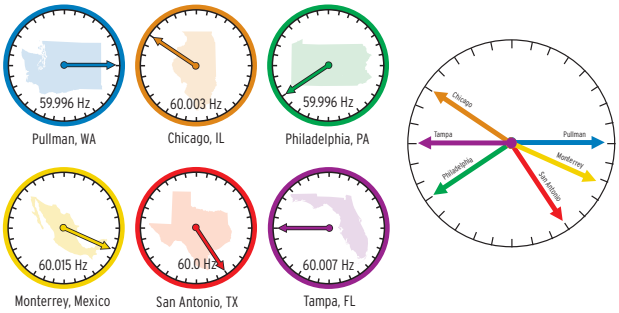


Figure 11 View of System Angle at Multiple Locations

Circuit Breaker Contact Wear Monitor

Circuit breakers experience mechanical and electrical wear every time they operate. Intelligent scheduling of breaker maintenance takes into account the manufacturer's published data of contact wear versus interruption levels and operation count. With the breaker manufacturer's maintenance curve as input data, the SEL-787 breaker monitor feature compares these input data to the measured (unfiltered) ac current at the time of trip and the number of close-to-open operations.

Every time the breaker trips, it integrates the measured current information. When the result of this integration exceeds the breaker wear curve threshold (see *Figure 12*), the relay alarms via output contact, communications port, or front-panel display. This kind of information allows timely and economical scheduling of breaker maintenance.

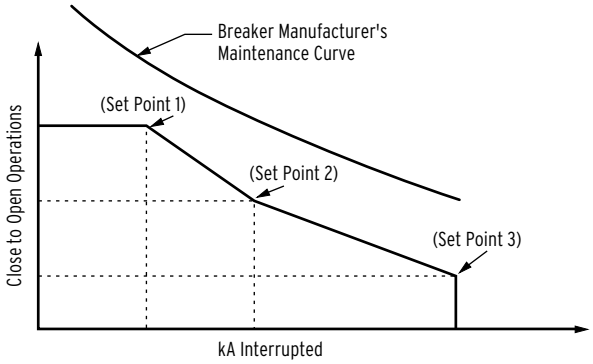


Figure 12 Breaker Contact Wear Curve and Settings

Through-Fault Monitoring

A through fault is an overcurrent event external to the differential protection zone. While a through fault is not an in-zone event, the currents required to feed this external fault can cause great stress on the apparatus inside the differential protection zone. Through-fault currents can cause transformer winding displacement, leading to mechanical damage and increased transformer thermal wear. An SEL-787 through-fault event monitor gathers current level, duration, and date/time for each through fault. The monitor also calculates a simple I^2t and cumulatively stores these data per phase. Use through-fault event data to schedule proactive transformer bank maintenance and help justify through-fault mitigation efforts. Apply the accumulated alarm capability of the relay to indicate excess through-fault current (I^2t) over time.

Event Reporting and Sequential Events Recorder (SER)

Event reports and the SER simplify post-fault analysis and improve understanding of simple and complex protective scheme operations. In response to a user-selected trigger, the voltage, current, frequency, and element status information contained in each event report confirms the relay scheme and system performance for every fault. Decide how much detail is necessary when you request an event report (e.g., 1/4-cycle or 1/32-cycle resolution, filtered or raw analog data, respectively).

The relay stores the most recent nineteen 64-cycle or seventy-seven 15-cycle event reports in nonvolatile memory. The relay always appends relay settings to the bottom of each event report.

The following analog data formats are available:

- 1/4-cycle or 1/32-cycle resolution
- Unfiltered or filtered analog
- ASCII or Compressed ASCII

The relay SER feature stores the latest 1024 entries. Use this feature to gain a broad perspective at a glance. An SER entry helps to monitor input/output change-of-state occurrences and element pickup/dropout.

The IRIG-B time-code input synchronizes the SEL-787 time to within ±5 ms of the time-source input. A convenient source for this time code is an SEL-2401 Satellite-Synchronized Clock or the SEL-3530 Real Time Automation Controller (RTAC), SEL-2032, SEL-2030, or SEL-2020 Communications Processor (via Serial Port 3 on the SEL-787).

Available reports, which also show the status of digital inputs and outputs, include the following:

- **Analog event reports** that use filtered data and show all analog channels at four samples per cycle.
- **Digital event reports** that show pickup of protection elements including overcurrent, demand, voltage overexcitation, frequency, and over- and undervoltage elements at four samples per cycle.
- **Differential event reports** that show differential quantities, element pickup, SELOGIC control equation set variables, and inputs and outputs at four samples per cycle.
- **Raw analog event reports** that use unfiltered data at 32 samples per cycle.

Automation

Flexible Control Logic and Integration Features

The SEL-787 is equipped with as many as four independently operated serial ports: one EIA-232 port on the front, one EIA-232 or EIA-485 port on the rear, one fiber-optic port, and one EIA-232 or EIA-485 port option card. The relay does not require special communications software. Use any system that emulates a standard terminal system for engineering access to the relay. Establish local or remote communication by connecting computers; modems; protocol converters; printers; an SEL-3530 RTAC, SEL-2032, SEL-2030, or SEL-2020 Communications Processor; SCADA serial port; or an RTU. Refer to *Table 6* for a list of communications protocols available in the SEL-787. Apply an SEL communications processor as the hub of a star network, with point-to-point fiber or copper connection between the hub and the SEL-787.

Table 6 Communications Protocols (Sheet 1 of 2)

Type	Description
Simple ASCII	Plain language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter and Fast Operate	Binary protocol for machine-to-machine communications. Quickly updates SEL-3530 RTAC, SEL-2032, SEL-2030, and SEL-2020 communications processors, RTUs, and other substation devices with metering information, relay elements, I/O status, time tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines, so control operator metering information is not lost while a technician is transferring an event report. Direct communications with the SEL-2600 RTD Module are possible using the unsolicited Fast Meter protocol to read incoming temperature data from the SEL-2600.
Fast SER Protocol	Provides SER events to an automated data collection system.
DNP3	Serial or Ethernet-based DNP3 protocols. Provides default and mappable DNP3 objects that include access to metering data, protection elements, Relay Word bits, contact I/O, targets, SER, relay summary event reports, and setting group selection.
Modbus	Serial- or Ethernet-based Modbus protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and setting groups.
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation. Operates remote bits and I/O. Monitors Relay Word bits and analog quantities.
Synchrophasors	IEEE C37.118-compliant synchrophasors for system state, response, and control capabilities.
Event Messenger	The use of the SEL-3010 allows you to receive alerts directly on your cell phone. Alerts can be triggered through relay events and can include measured quantities by the relay.
DeviceNet	Allows for connection to a DeviceNet network for access to metering data, protection elements, contact I/O, targets, and setting groups.

Table 6 Communications Protocols (Sheet 2 of 2)

Type	Description
SNTP	Ethernet-based protocol that provides time synchronization of the relay.
IEC 60870-5-103	Serial communications protocol–international standard for interoperability between intelligent devices in a substation.

SEL-787 control logic improves integration in the following ways:

- **Replaces traditional panel control switches.** Eliminate traditional panel control switches with 32 local bits. Set, clear, or pulse local bits with the front-panel pushbuttons and display. Program the local bits into the control scheme with SELOGIC control equations. Use the local bits to perform functions such as a trip test or a breaker trip/close.
- **Eliminates RTU-to-relay wiring.** Eliminate RTU-to-relay wiring with 32 remote bits. Set, clear, or pulse remote bits using serial port commands. Program the remote bits into the control scheme with SELOGIC control equations. Use remote bits for SCADA-type control operations such as trip, close, and settings group selection.
- **Replaces traditional latching relays.** Replace up to 32 traditional latching relays for such functions as "remote control enable" with latch bits. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the nonvolatile latch bits using optoisolated inputs, remote bits, local bits, or any programmable logic condition. The latch bits retain their state when the relay loses power.
- **Replaces traditional indicating panel lights.** Replace traditional indicating panel lights with 32 programmable displays. Define custom messages (e.g., `Breaker Open`, `Breaker Closed`) to report power system or relay conditions on the front-panel display. Use advanced SELOGIC control equations to control which messages the relay displays.
- **Eliminates external timers.** Eliminate external timers for custom protection or control schemes with 32 general purpose SELOGIC control equation timers. Each timer has independent time-delay pickup and dropout settings. Program each timer input with the element you want (e.g., time qualify a current element). Assign the timer output to trip logic, transfer trip communications, or other control scheme logic.
- **Eliminates settings changes.** Selectable setting groups make the SEL-787 ideal for applications requiring frequent setting changes and for adapting the protection to changing system conditions. The relay stores four setting groups. Select the active setting group by optoisolated input, command, or other programmable conditions. Use these setting groups to cover a wide range of protection and control contingencies. Switching setting groups switches logic and relay element settings. Program groups for different operating conditions, such as rental/spare transformer applications, station maintenance, seasonal operations, emergency contingencies, loading, source changes, and downstream relay setting changes.

Fast SER Protocol

SEL Fast Sequential Events Recorder (SER) protocol provides SER events to an automated data collection system. SEL Fast SER protocol is available on any rear serial port. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary SER messages from SEL-787 relays. SEL relays and communications processors have two separate data streams that share the same serial port. The normal serial interface consists of ASCII character commands and reports that are intelligible to people using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information, and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering or SER data.

Ethernet Network Architectures

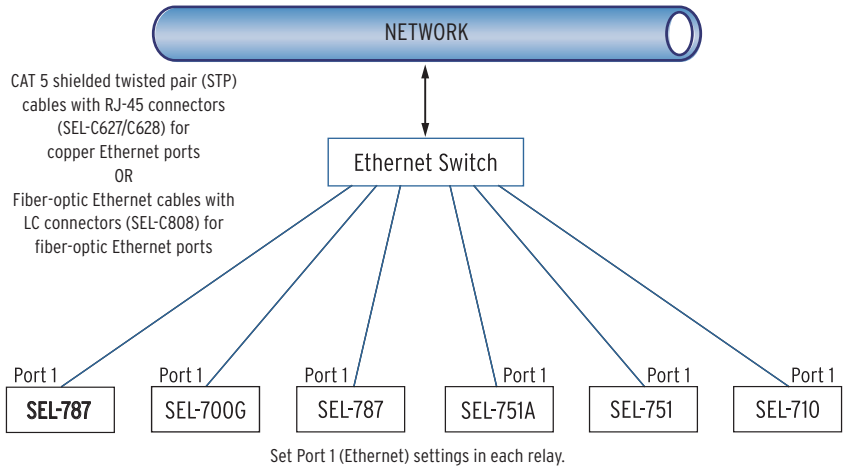


Figure 13 Simple Ethernet Network Configuration

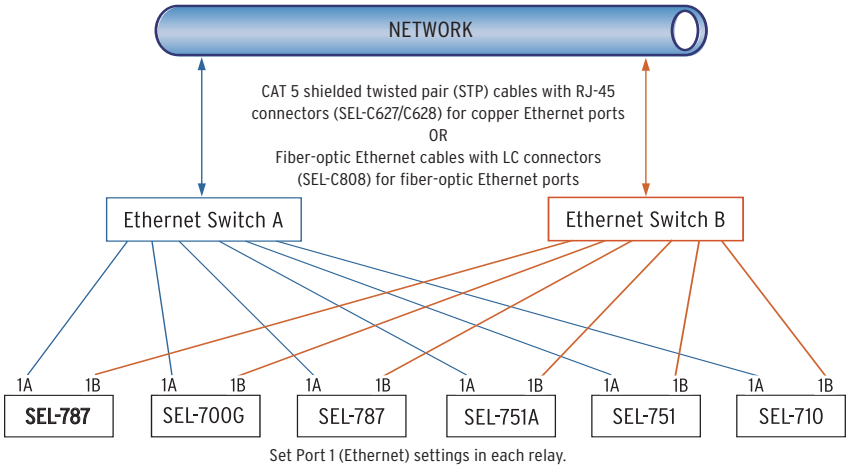


Figure 14 Simple Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)

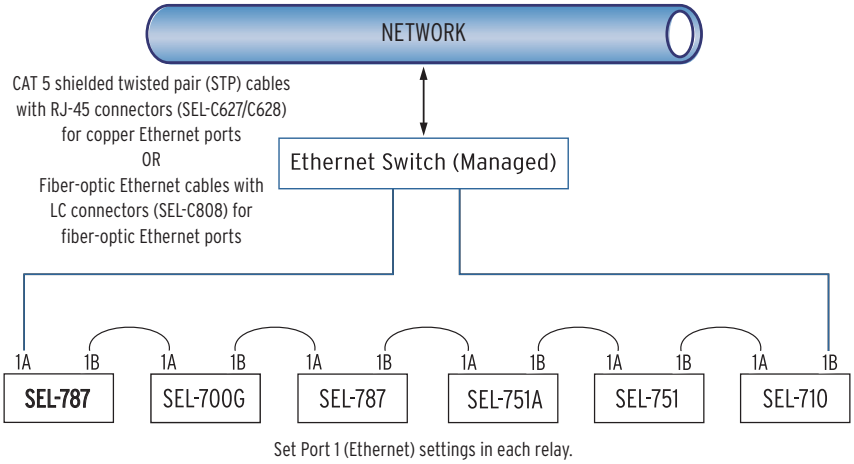


Figure 15 Simple Ethernet Network Configuration With Ring Structure (Switched Mode)

Additional Features

MIRRORED BITS Relay-to-Relay Communications

The SEL-patented MIRRORED BITS® communications technology provides bidirectional relay-to-relay digital communication. MIRRORED BITS communications can operate independently on as many as two EIA-232 rear serial ports and one fiber-optic rear serial port on a single SEL-787.

This bidirectional digital communication creates eight additional virtual outputs (transmitted MIRRORED BITS) and eight additional virtual inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS mode (see *Figure 16*). Use these MIRRORED BITS to transmit/receive information between upstream relays and a downstream relay to enhance coordination and achieve faster tripping for downstream faults. MIRRORED BITS technology also helps reduce total scheme operating time by eliminating the need to assert output contacts to transmit information.

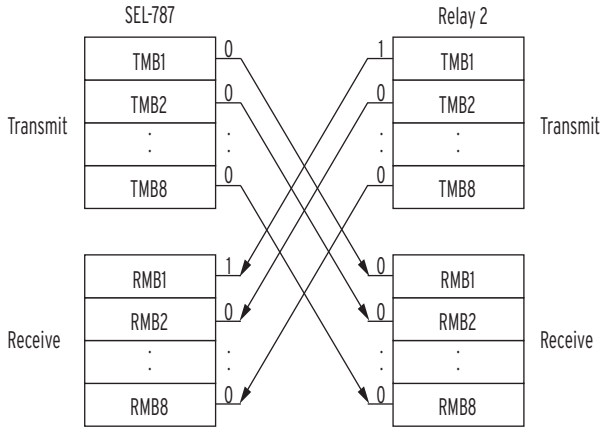


Figure 16 MIRRORED BITS Transmit and Receive Bits

Status and Trip Target LEDs

The SEL-787 includes 24 tricolor status and trip target LEDs on the front panel. When shipped from the factory, all LEDs are predefined and fixed in settings. You can reprogram these LEDs for specific applications. This combination of targets is explained and shown in *Figure 18*. Some front-panel relabeling of LEDs may be needed if you reprogram them for unique or specific applications—see *Configurable Labels*.

Event Messenger Points

The SEL-787, when used with the SEL-3010 Event Messenger, can allow for ASCII-to-voice translation of as many as 32 user-defined messages, along with analog data that has been measured or calculated by the relay. This combination allows you to receive voice message alerts (on any phone) regarding Relay Word bit transitions in the relay.

Verbal notification of breaker openings, fuse failures, RTD alarms, etc. can now be sent directly to your cell phone through the use of your SEL-787 and SEL-3010 (must be connected to an analog telephone line). In addition, messages can include an analog value such as current, voltage, or power measurements made by the SEL-787.

Configurable Labels

Use the configurable labels to relabel the operator controls and LEDs (shown in *Figure 18*) to suit the installation requirements. This feature includes preprinted labels (with factory-default text), blank label media, and a Microsoft® Word template on CD-ROM. This allows quick, professional-looking labels for the SEL-787. Labels may also be customized without the use of a PC by writing the new label on the blank stock provided. The ability to customize the control and indication features allows specific utility or industry procedures to be implemented without the need for adhesive labels.

Additional Ordering Options

The following options can be ordered for the SEL-787 model (see the SEL-787-3,-4 Model Option Table for details).

- Single or dual port Ethernet 10/100BASE-T or 100BASE-FX, Modbus TCP, SNTP, DNP3 Serial, DNP3 LAN/WAN, FTP, Telnet, IEC 61850, IEC 60870-5-103
- EIA-232 or EIA-485 communications
- Additional EIA-232 or EIA-485 port
- Analog I/O (4 AI/4 AO)
- Digital I/O (4 DI/4 DO, 8 DI, 8 DO, 3 DI/4 DO/1 AO, 4 DI/3 DO)
- Voltage input for synchronism check/station DC battery monitor
- 10 RTDs
- Conformal coating for chemically harsh and high-moisture environments
- The relay supports the Spanish language as an ordering option.

Wiring Diagram for SEL-787-3E Model Option

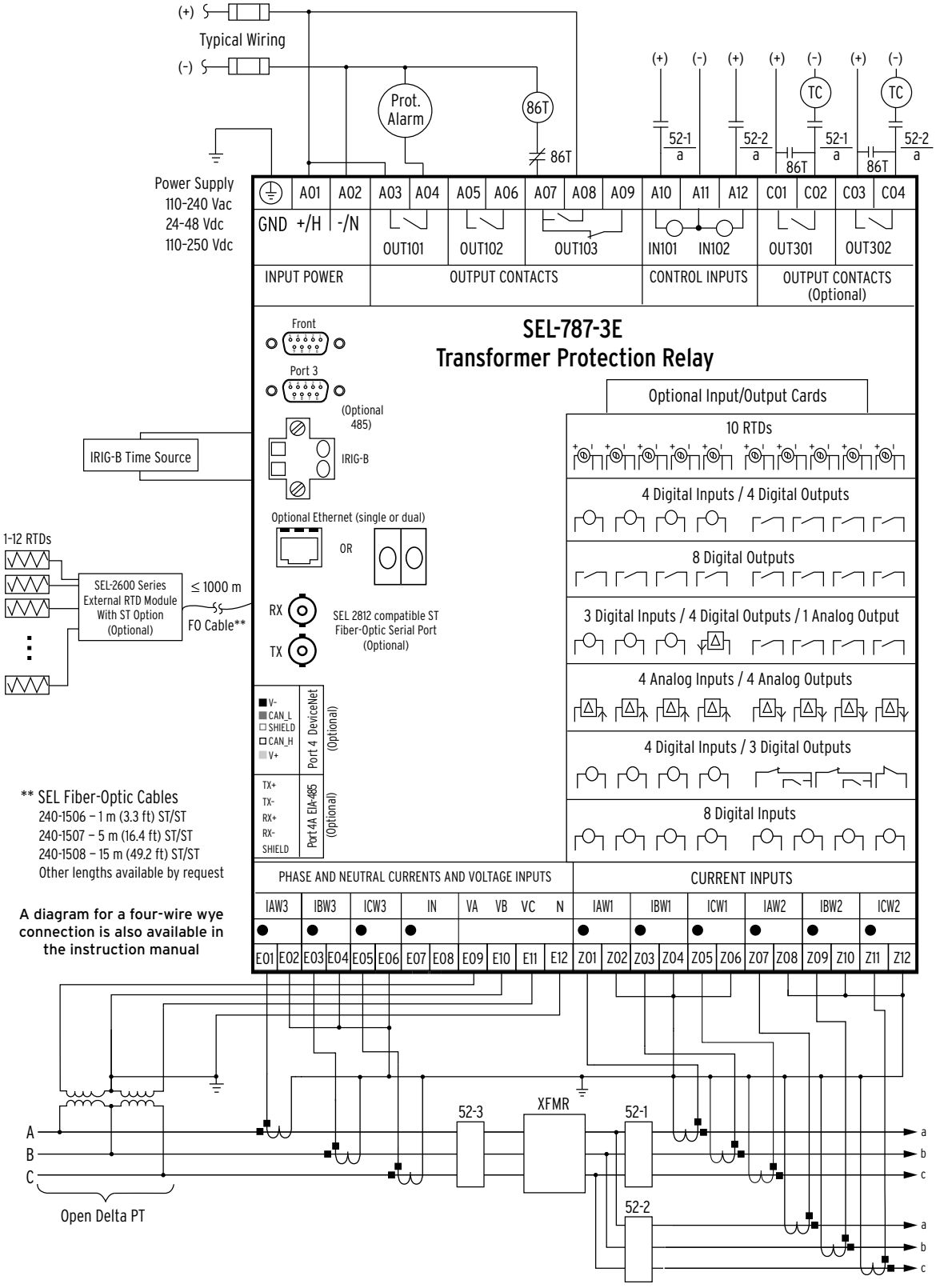


Figure 17 Wiring Diagram SEL-787-3E Transformer Protection Relay

SEL-787-4X Panel Diagrams

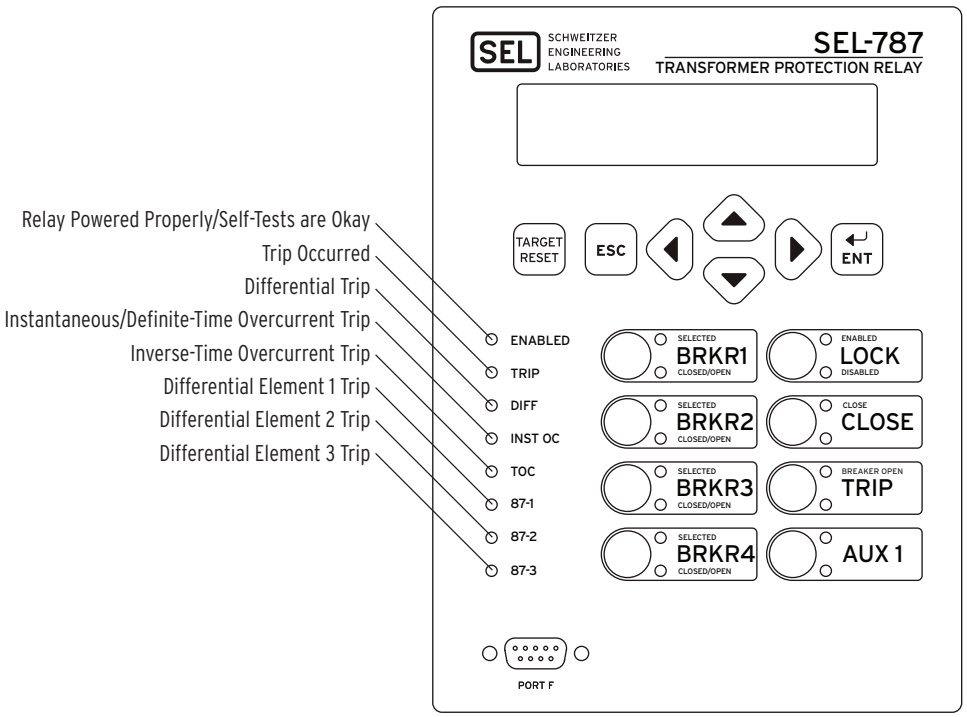
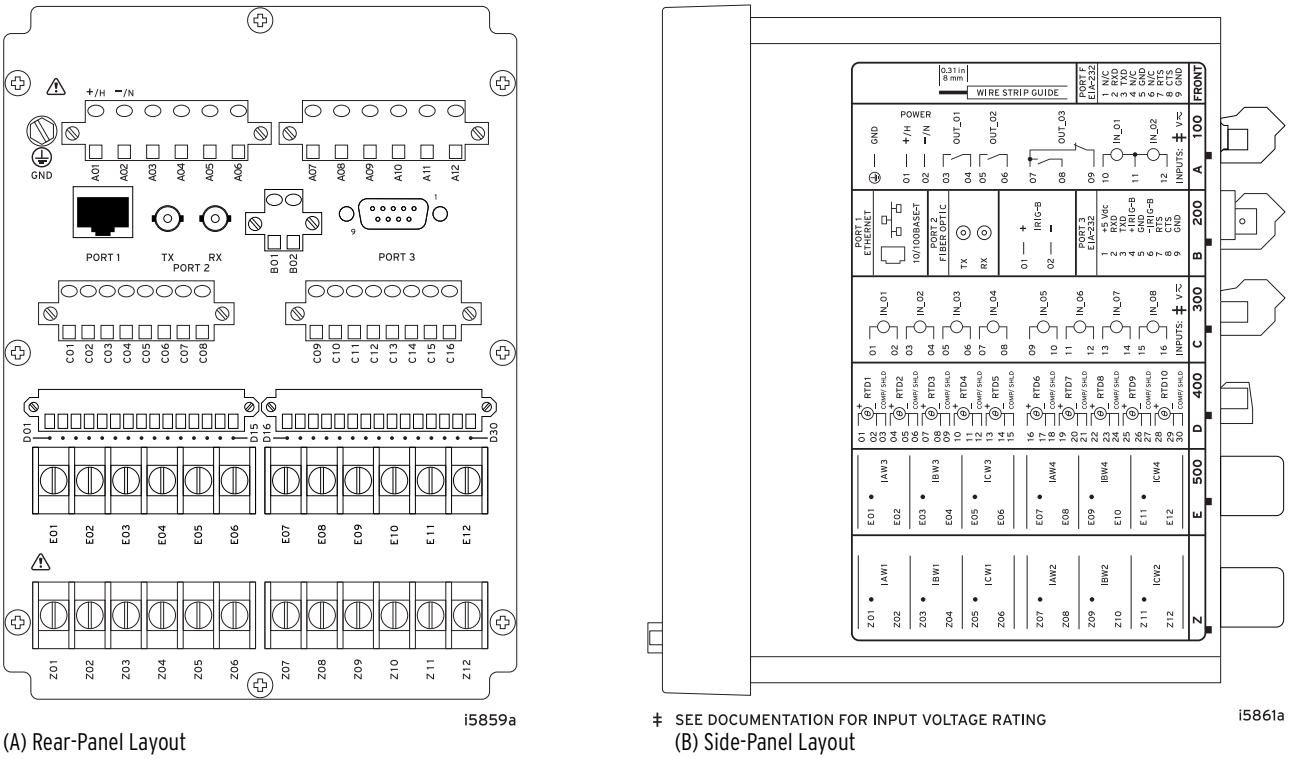


Figure 18 Front Panel With Default Configurable Labels



(A) Rear-Panel Layout

(B) Side-Panel Layout

Figure 19 SEL-787-4X With Single Copper Ethernet, 8 DI, and RTD Option

SEL-787-3E/S Front-Panel Diagram

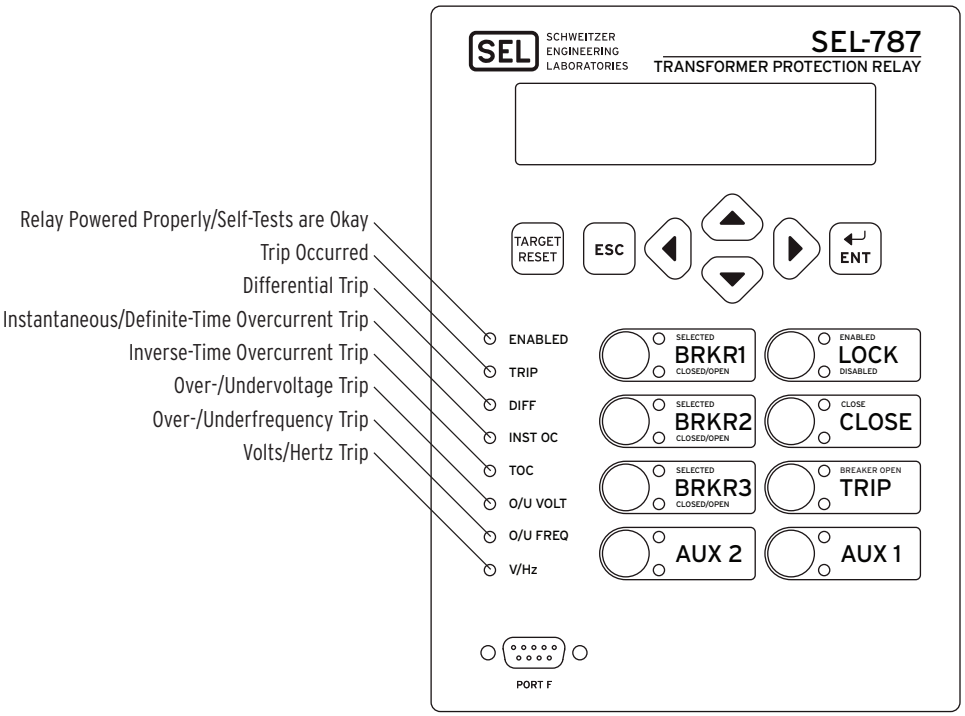
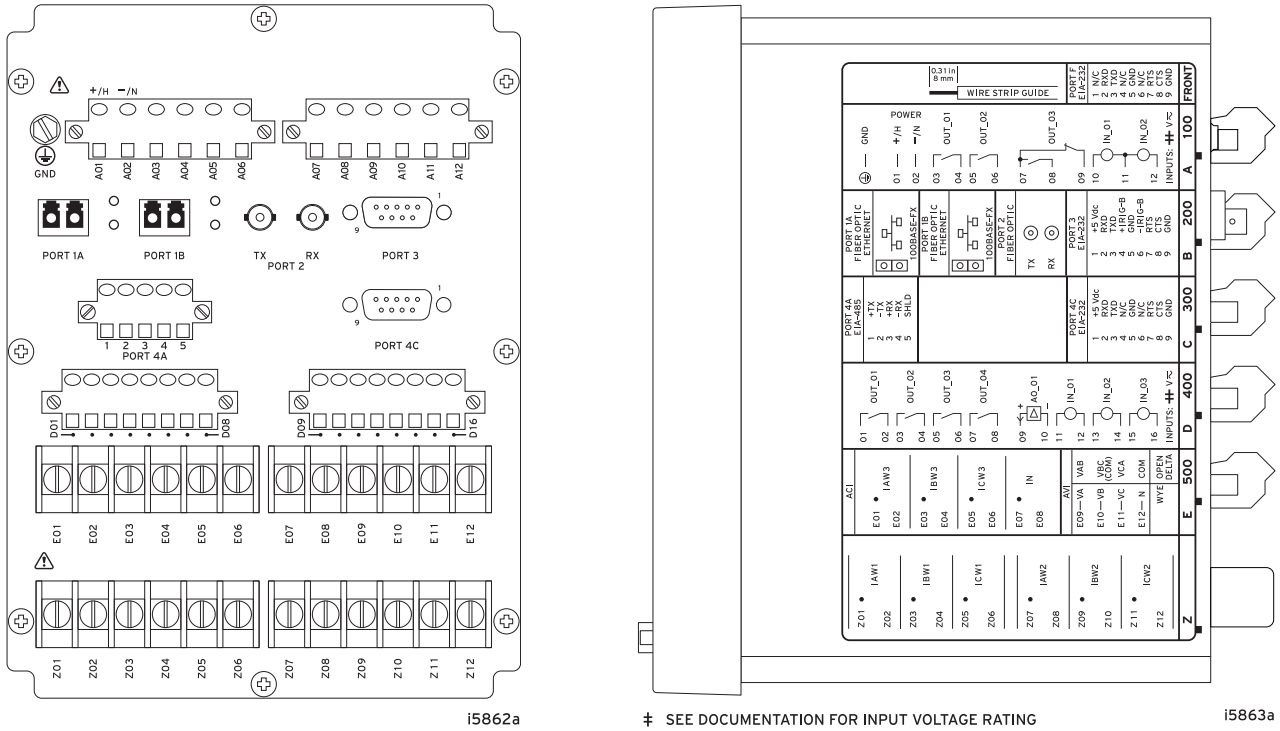


Figure 20 Front Panel With Default Configurable Labels

SEL-787-3E Rear- and Side-Panel Diagrams

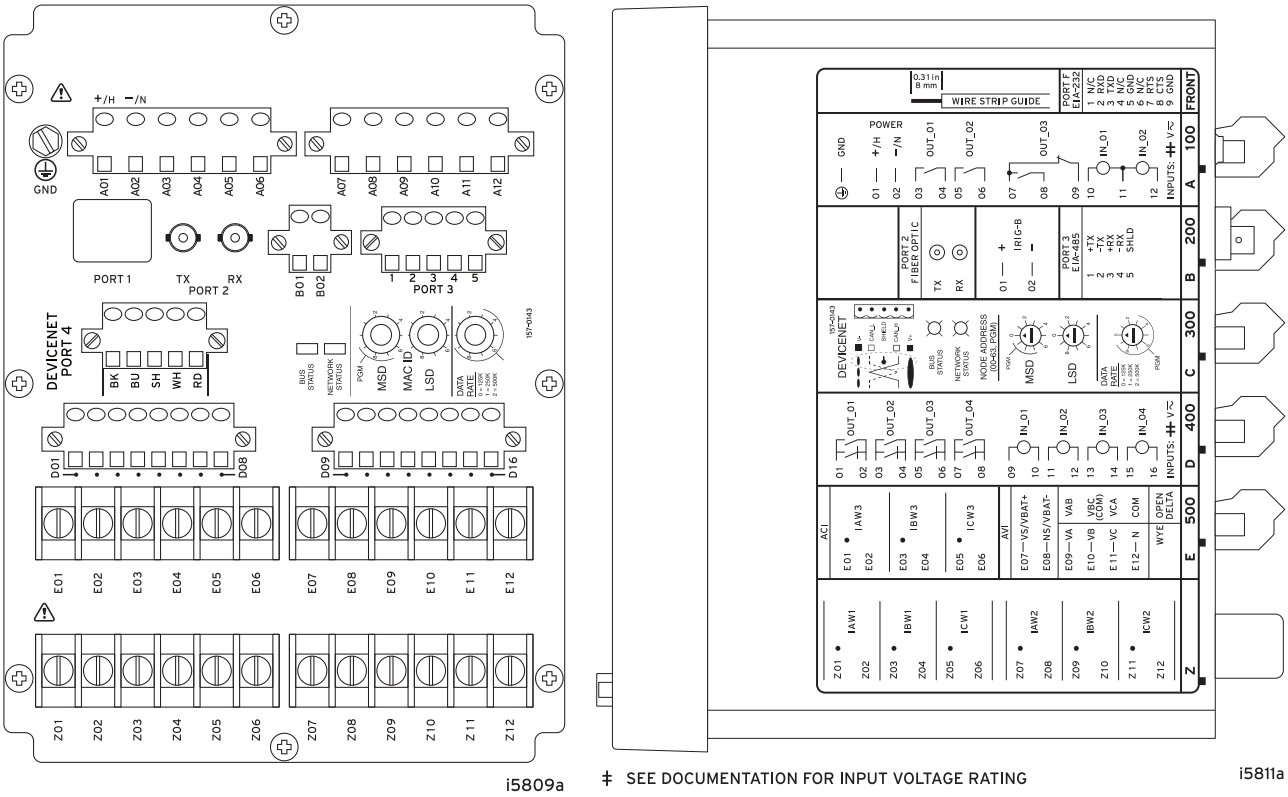


‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(A) Rear-Panel Layout (B) Side-Panel Layout

Figure 21 SEL-787-3E With Dual-Fiber Ethernet, EIA-232 Communication, 3 DI/4 DO/1 AO Option

SEL-787-3S Rear- and Side-Panel Diagrams



‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(A) Rear-Panel Diagram (B) Side-Panel Diagram

Figure 22 SEL-787-3S With DeviceNet and Hybrid 4 DI/4 DO Option

Relay Dimensions

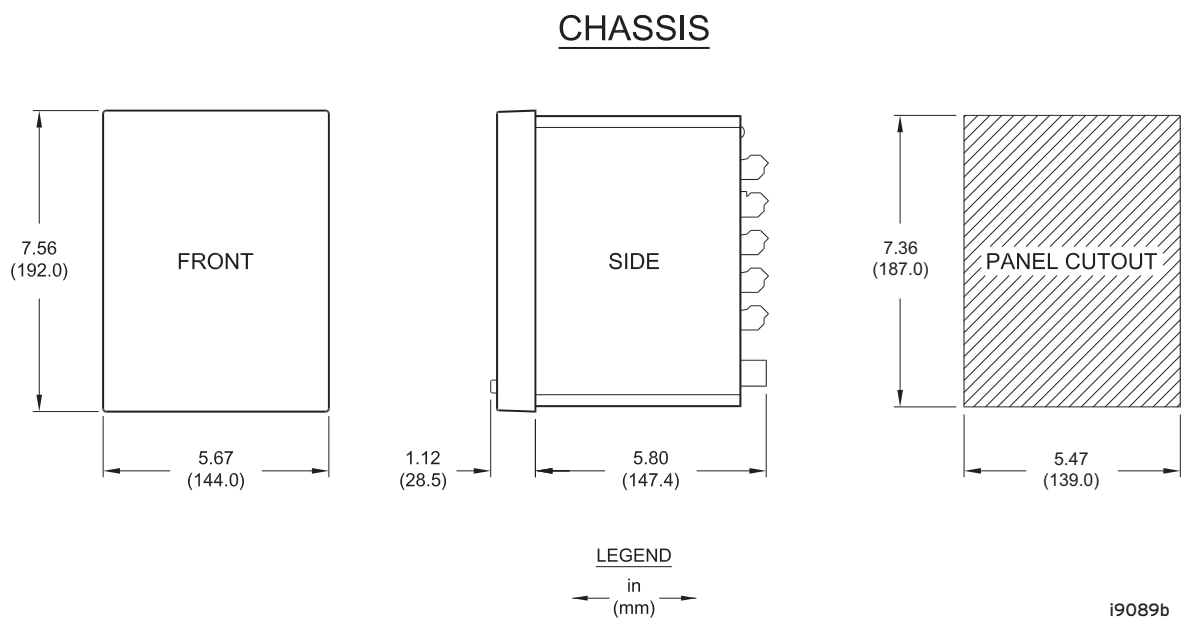


Figure 23 SEL-787 Dimensions for Rack- and Panel-Mount Models

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

49 CFR 15B, Class A

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commerical environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio comunications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

UL Listed to U.S. and Canadian safety standards (File: E212775; NRGU; NRGU7)

CE Mark

RCM Mark

General

AC Current Input

Phase and Neutral Currents

I_{NOM} = 1 A or 5 A secondary depending on model

I_{NOM} = 5 A

Continuous Rating:	3 • I_{NOM} @ 85°C, linear to 96 A symmetrical 4 • I_{NOM} @ 55°C, linear to 96 A symmetrical
1 Second Thermal:	500 A
Burden (per phase):	<0.1 VA @ 5 A

I_{NOM} = 1 A

Continuous Rating:	3 • I_{NOM} @ 85°C, linear to 19.2 A symmetrical 4 • I_{NOM} @ 55°C, linear to 19.2 A symmetrical
1 Second Thermal:	100 A
Burden (per phase):	<0.01 VA @ 1 A
Measurement Category:	II

AC Voltage Inputs

VNOM (kV L-L)/PT Ratio Range:	100–250 V (if DELTA_Y := DELTA) 100–440 V (if DELTA_Y := WYE)
Rated Continuous Voltage:	300 Vac
10 Second Thermal:	600 Vac
Burden:	<0.1 VA
Input Impedance:	4 MΩ differential (phase-to-phase) 7 MΩ common mode (phase-to-chassis)

Power Supply

125/250 Vdc or 120/240 Vac

Rated Supply Voltage:	110–240 Vac, 50/60 Hz 110–250 Vdc
Input Voltage Range:	85–264 Vac 85–300 Vdc
Power Consumption:	<40 VA (ac) <20 W (dc)
Interruptions:	50 ms @ 125 Vac/Vdc 100 ms @ 250 Vac/Vdc

24/48 Vdc

Rated Supply Voltage:	24–48 Vdc
Input Voltage Range:	19.2–60.0 Vdc
Power Consumption:	<20 W (dc)
Interruptions:	10 ms @ 24 Vdc 50 ms @ 48 Vdc
Relay Start-Up Time:	Approximately 5–10 seconds (after power is applied until the **ENABLED** LED comes on)

Fuse Ratings

LV Power Supply Fuse

Rating:	3.15 A
Maximum Rated Voltage:	300 Vdc, 250 Vac
Breaking Capacity:	1500 A at 250 Vac
Type:	Time-lag T

HV Power Supply Fuse

Rating:	3.15 A
Maximum Rated Voltage:	300 Vdc, 250 Vac
Breaking Capacity:	1500 A at 250 Vac
Type:	Time-lag T
Heater Fuses F2, F3:	5 A, 125 V slow blow 125 Vdc/50 A break rating

Fuses are not serviceable.

Output Contacts

The relay supports Form A, B, and C outputs.

Dielectric Test Voltages:	2500 Vac
Impulse Withstand Voltage (U_{IMP}):	4700 V
Mechanical Durability:	100,000 no-load operations

Standard Contacts

Pickup/Dropout Time:	≤8 ms (coil energization to contact closure)

DC Output Ratings

Rated Operational Voltage:	250 Vdc
Rated Voltage Range:	19.2–275 Vdc
Rated Insulation Voltage:	300 Vdc
Make:	30 A @ 250 Vdc per IEEE C37.90
Continuous Carry:	6 A @ 70°C 4 A @ 85°C
Thermal:	50 A for 1 s
Contact Protection:	360 Vdc, 40 J MOV protection across open contacts

Breaking Capacity (10,000 Operations) per IEC 60255-0-20:1974:

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

Cyclic (2.5 Cycles/Second) per IEC 60255-0-20:1974:

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

AC Output Ratings

Maximum Operational Voltage (U_e) Rating:	240 Vac
Insulation Voltage (U_i) Rating (excluding EN 61010-1):	300 Vac
Contact Rating Designation:	B300

B300 (5 A Thermal Current, 300 Vac Max)			
	Maximum Current		Max VA
Voltage	120 Vac	240 Vac	—
Make	30 A	15 A	3600
Break	3 A	1.5 A	360
PF < 0.35, 50–60 Hz			

Utilization Category: AC-15

AC-15		
Operational Voltage (Ue)	120 Vac	240 Vac
Operational Current (Ie)	3 A	1.5 A
Make Current	30 A	15 A
Break Current	3 A	1.5 A
Electromagnetic loads > 72 VA, PF < 0.3, 50–60 Hz		

Voltage Protection Across Open Contacts: 270 Vac, 40 J

Fast Hybrid (High-Speed, High-Current Interrupting)

DC Output Ratings

Rated Operational Voltage: 250 Vdc

Rated Voltage Range: 19.2–275 Vdc

Rated Insulation Voltage: 300 Vdc

Make: 30 A @ 250 Vdc per IEEE C37.90

Continuous Carry: 6 A @ 70°C
4 A @ 85°C

1-Second Rating: 50 A

Open State Leakage Current: <500 µA

MOV Protection (Maximum Voltage): 250 Vac/330 Vdc

Pickup Time: <50 µs, resistive load

Dropout Time: ≤8 ms, resistive load

Breaking Capacity (10,000 Operations) per IEC 60255-0-20:1974:

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

Cyclic Capacity (4 Cycles in 1 Second, Followed by 2 Minutes Idle for Thermal Dissipation) per IEC 60255-0-20:1974:

48 Vdc	10.0 A	L/R = 40 ms
125 Vdc	10.0 A	L/R = 40 ms
250 Vdc	10.0 A	L/R = 20 ms

AC Output Ratings

See *AC Output Ratings* for *Standard Contacts*.

Optoisolated Control Inputs

When Used With DC Control Signals

250 V: ON for 200–312.5 Vdc
OFF below 150 Vdc

220 V: ON for 176–275 Vdc
OFF below 132 Vdc

125 V: ON for 100–156.2 Vdc
OFF below 75 Vdc

110 V: ON for 88–137.5 Vdc
OFF below 66 Vdc

48 V: ON for 38.4–60 Vdc
OFF below 28.8 Vdc

24 V: ON for 15–30 Vdc
OFF for below 5 Vdc

When Used With AC Control Signals

250 V: ON for 170.6–312.5 Vac
OFF below 106 Vac

220 V: ON for 150.2–275 Vac
OFF below 93.3 Vac

125 V: ON for 85–156.2 Vac
OFF below 53 Vac

110 V: ON for 75.1–137.5 Vac
OFF below 46.6 Vac

48 V: ON for 32.8–60 Vac
OFF below 20.3 Vac

24 V: ON for 14–30 Vac
OFF below 5 Vac

Current draw at nominal dc voltage: 2 mA (at 220–250 V)
4 mA (at 48–125 V)
10 mA (at 24 V)

Rated Impulse Withstand Voltage (U_{imp}): 4000 V

Analog Output (Optional)

	1A0	4A0
Current:	4–20 mA	±20 mA
Voltage:	—	±10 V
Load at 1 mA:	—	0–15 kΩ
Load at 20 mA:	0–300 Ω	0–750 Ω
Load at 10 V:	—	> 2000 Ω
Refresh Rate:	100 ms	100 ms
% Error, Full Scale, at 25°C:	<±1%	<±0.55%
Select From:	Analog quantities available in the relay	

Analog Inputs (Optional)

Maximum Input Range: ±20 mA
±10 V
Operational range set by user

Input Impedance: 200 Ω (current mode)
>10 kΩ (voltage mode)

Accuracy at 25°C:

With user calibration: 0.05% of full scale (current mode)
0.025% of full scale (voltage mode)

Without user calibration: Better than 0.5% of full scale at 25°C

Accuracy Variation With Temperature: ±0.015% per °C of full-scale (±20 mA or ±10 V)

Frequency and Phase Rotation

System Frequency: 50, 60 Hz

Phase Rotation: ABC, ACB

Frequency Tracking: 15–70 Hz (requires ac voltage inputs)

Time-Code Input

Format: Demodulated IRIG-B

On (1) State: $V_{ih} \geq 2.2$ V

Off (0) State: $V_{il} \leq 0.8$ V

Input Impedance: 2 kΩ

Synchronization Accuracy:

Internal Clock: ±1 µs

Synchrophasor Reports (e.g., **MET PM**): ±10 µs

All Other Reports: ±5 ms

Simple Network Time Protocol (SNTP) Accuracy

Internal Clock: ±5 ms

Unsynchronized Clock Drift Relay Powered: 2 minutes per year, typically

Communications Ports

Standard EIA-232 (2 ports)

Location:	Front Panel Rear Panel
Data Speed:	300–38400 bps

EIA-485 Port (optional)

Location:	Rear Panel
Data Speed:	300–19200 bps

Ethernet Port (optional)

Single/Dual 10/100BASE-T copper (RJ45 connector)

Single/Dual 100BASE-FX (LC connector)

Standard Multimode Fiber-Optic Port

Location:	Front Panel
Data Speed:	300–38400 bps

Fiber-Optic Ports Characteristics

PORT 1 (or 1A, 1B) Ethernet

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

PORT 2 Serial (SEL-2812 compatible)

Wavelength:	820 nm
Optical Connector Type:	ST
Fiber Type:	Multimode
Link Budget:	8 dB
Typical TX Power:	–16 dBm
RX Min. Sensitivity:	–24 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~1 km
Data Rate:	5 Mb
Typical Fiber Attenuation:	–4 dB/km

Optional Communications Cards

Option 1:	EIA-232 or EIA-485 communications card
Option 2:	DeviceNet communications card

Communications Protocols

SEL, Modbus, DNP, FTP, TCP/IP, Telnet, SNTP, IEC 61850, IEC 60870-5-103, MIRRORED BITS, EVMSG, C37.118 (synchrophasors), and DeviceNet.

Operating Temperature

IEC Performance Rating: –40° to +85°C (–40° to +185°F)
(per IEC/EN 60068-2-1 & 60068-2-2)

NOTE: Not applicable to UL applications.

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

DeviceNet Communications Card Rating: +60°C (140°F) maximum

Operating Environment

Pollution Degree:	2
Overvoltage Category:	II
Atmospheric Pressure:	80–110 kPa
Relative Humidity:	5–95%, noncondensing
Maximum Altitude:	2000 m

Dimensions

144.0 mm (5.67 in.) x 192.0 mm (7.56 in.) x 147.4 mm (5.80 in.)

Weight

2.0 kg (4.4 lbs)

Relay Mounting Screws (#8–32) Tightening Torque

Minimum:	1.4 Nm (12 in-lb)
Maximum:	1.7 Nm (15 in-lb)

Terminal Connections

Terminal Block

Screw Size:	#6
Ring Terminal Width:	0.310 in maximum

Terminal Block Tightening Torque

Minimum:	0.9 Nm (8 in-lb)
Maximum:	1.4 Nm (12 in-lb)

Compression Plug Tightening Torque

Minimum:	0.5 Nm (4.4 in-lb)
Maximum:	1.0 Nm (8.8 in-lb)

Compression Plug Mounting Ear Screw Tightening Torque

Minimum:	0.18 Nm (1.6 in-lb)
Maximum:	0.25 Nm (2.2 in-lb)

Type Tests

Environmental Tests

Enclosure Protection:	IEC 60529:2001 + CRDG:2003 IP65 enclosed in panel IP20 for terminals IP50 for terminals enclosed in the dust-protection assembly (protection against solid foreign objects only, SEL Part #915900170). The 10°C temperature derating applies to the temperature specifications of the relay.
Vibration Resistance:	IEC 60255-27:2013 IEC 60255-21-1:1988 Class 2 Endurance, Class 2 Response
Shock Resistance:	IEC 60255-21-2:1988 Class 1 Withstand, Class 2 Response
Seismic Resistance:	IEC 60255-21-3:1993 Class 2 Response
Cold:	IEC 60068-2-1:2007 EN 60068-2-1:2007 –40°C, 16 hours
Damp Heat, Cyclic:	IEC 60068-2-30:2005 EN 60068-2-30:2005 Test Db; Variant 2; 25–55°C, 6 cycles, 95% relative humidity minimum
Damp Heat, Steady State:	IEC 60068-2-78:2001 Severity Level: 93% relative humidity minimum 40°C, 10 days
Dry Heat:	IEC 60068-2-2:2007 EN 60068-2-2:2007 85°C, 16 hours

Dielectric Strength and Impulse Tests

Dielectric (HiPot):	IEC 60255-5:2000 IEEE C37.90-2005 2.5 kVac on contact inputs/outputs and analog inputs 3.1 kVdc on power supply 1.0 kVac on analog outputs
Impulse:	IEC 60255-5:2000 IEEE C37.90-2005 0.5 J, 5 kV on power supply, contact I/O, ac current and voltage inputs 0.5 J, 1 kV on analog outputs

RFI and Interference Tests

EMC Immunity

Electrostatic Discharge Immunity:	IEC 60255-26:2013; Section 7.2.3 EN 60255-26:2012; Section 7.2.3 IEC 61000-4-2:2008 EN 61000-4-2:2009 IEEE C37.90.3:2001 Severity Level 4 8 kV contact discharge 15 kV air discharge
Radiated RF Immunity:	IEC 60255-26:2013; Section 7.2.4 EN 60255-26:2013; Section 7.2.4 IEC 61000-4-3:2008 EN 61000-4-3:2006/A1:2008 10 V/m IEEE C37.90.2-2004 20 V/m
Fast Transient, Burst Immunity:	IEC 61000-4-4:2011 EN 61000-4-4:2012 IEC 60255-22-4:2008 EN 60255-22-4:2008 4 kV @ 5.0 kHz 2 kV @ 5.0 kHz for comm. ports
Surge Immunity:	IEC 61000-4-5:2005 EN 61000-4-5:2006 IEC 60255-22-5:2008 1 kV line-to-line 2 kV line-to-earth
Surge Withstand Capability Immunity:	IEC 60255-26:2013; Section 7.2.6 EN 60255-26:2013; Section 7.2.6 IEC 61000-4-18:2006 EN 61000-4-18:2007 2.5 kV common mode 1.0 kV differential mode 1.0 kV common mode on comm. ports IEEE C37.90.1-2002 2.5 kV oscillatory 4.0 kV fast transient
Conducted RF Immunity:	IEC 60255-26:2013; Section 7.2.8 EN 60255-26:2013; Section 7.2.8 IEC 61000-4-6:2008 EN 61000-4-6:2009 10 Vrms
Magnetic Field Immunity:	IEC 60255-26:2013; Section 7.2.10 EN 60255-26:2013; Section 7.2.10 IEC 61000-4-8:2009 EN 61000-4-8:2010 1000 A/m for 3 seconds 100 A/m for 1 minute; 50/60 Hz IEC 61000-4-9:2001 EN 61000-4-9:1993/A1:2001 1000 A/m IEC 61000-4-10:2001 EN 61000-4-10:1993/A1:2001 100 A/m (100 kHz and 1 MHz)

EMC Emissions

Radiated and Conducted Emissions:	IEC 60255-26:2013; Section 7.1 EN 60255-26:2013; Section 7.1 CISPR 22:2008 EN 55022:2001 CISPR 11:2009/A1:2010 EN 55011:2009/A1:2010 FCC CFR47 - 2008; Part 15.107, 15.109

Processing Specifications and Oscillography

AC Voltage and Current Inputs:	32 samples per power system cycle
Frequency Tracking Range:	15–70 Hz (requires ac voltage inputs option)
Digital Filtering:	One-cycle cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.
Protection and Control Processing:	Processing interval is 4 times per power system cycle (except for math variables and analog quantities, which are processed every 25 ms). The 51 elements are processed 2 times per power system cycle. Analog quantities for rms data are determined through use of data averaged over the previous 8 cycles.

Oscillography

Length:	15, 64, or 180 cycles
Sampling Rate:	32 samples per cycle unfiltered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII
Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy:	±5 ms

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (with respect to time source):	±5 ms

Relay Elements

Instantaneous/Definite-Time Overcurrent (50P, 50G, 50N, 50Q)

Pickup Setting Range, A secondary:

5 A models:	0.50–96.00 A, 0.01 A steps
1 A models:	0.10–19.20 A, 0.01 A steps
Time Delay:	0.00–5.00 seconds, 0.01 second steps 0.00–120.00 seconds, 0.01 second steps (50Q) ±0.5% plus ±0.25 cycle
Accuracy:	±3% plus ±0.02 • INOM A secondary (steady state) ±5% plus ±0.02 • INOM A secondary (transient) ±6% plus ±0.02 • INOM A secondary (transient for 50Q)
Pickup/Dropout Time:	<1.5 cycle

Inverse Time Overcurrent (51P, 51G, 51N, 51Q)

Pickup Setting Range, A secondary:

5 A models:	0.50–16.00 A, 0.01 A steps
1 A models:	0.10–3.20 A, 0.01 A steps
Accuracy:	±5% of setting plus ±0.02 • I_{NOM} A secondary (steady-state pickup)

Time Dial:

US:	0.50–15.00, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Accuracy:	±1.5 cycles plus ±4% between 2 and 30 multiples of pickup (within rated range of current)

Differential (87)

Unrestrained Pickup Range:	1.0–20.0 in per unit of TAP
Restrained Pickup Range:	0.10–1.00 in per unit of TAP
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±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)

Harmonics

Pickup Range (% of fundamental):	5–100%
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Time Delay Accuracy:	±0.5% plus ±0.25 cycle

Restricted Earth Fault (REF)

Pickup Range (per unit of INOM of neutral current inputs, IN, and/or Winding 3):	0.05–3.00 per unit, 0.01 per-unit steps
Pickup Accuracy (A secondary):	
5 A Model:	±5% plus ±0.10 A
1 A Model:	±5% plus ±0.02 A
Timing Accuracy:	
Directional Output:	1.25–1.75 cycles
ANSI Extremely Inverse TOC Curve (U4 With 0.5 Time Dial):	±5 cycles plus ±5% between 2 and 30 multiples of pickup (within rated range of current)

Undervoltage (27P, 27PP, 27S)

Setting Range:	OFF, 12.50–300.00 V (Phase elements, phase-to-phase elements with delta inputs or synchronism voltage input) OFF, 12.50–520.00 V (Phase-to-phase elements with wye inputs)
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.5 cycle
Time Delay:	0.00–120.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

Overvoltage (59P, 59PP, 59G, 59Q, 59S)

Setting Range:	OFF, 12.50–300.00 V (Phase elements, phase-to-phase elements with delta inputs or synchronism voltage input) OFF, 12.50–520.00 V (Phase-to-phase elements with wye inputs)
Accuracy:	±1% of setting plus ±0.5 V
Pickup/Dropout Time:	<1.5 cycle
Time Delay:	0.00–120.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

Volts/Hertz (24)

Definite-Time Element

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

Inverse-Time Element

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

Composite-Time Element

Combination of definite-time and inverse-time specifications

User-Definable Curve Element

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

Directional Power (32)

Instantaneous/Definite-Time, 3 Phase Elements

Type:	+W, –W, +VAR, –VAR
Pickup Settings Range, VA secondary:	
5 A Model:	1.0–6500.0 VA, 0.1 VA steps
1 A Model:	0.2–1300.0 VA, 0.1 VA steps
Accuracy:	±0.10 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (5 A nominal) ±0.02 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element (1 A nominal)
Pickup/Dropout Time:	<10 cycles
Time Delay:	0.00–240.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

Frequency (81)

Setting Range:	OFF, 20.0–70.0 Hz
Accuracy:	±0.01 Hz (V1 > 60 V) with voltage tracking
Pickup/Dropout Time:	<4 cycles
Time Delay:	0.00–240.00 seconds, 0.01 second steps
Accuracy:	±0.5% plus ±0.25 cycle

RTD Protection

Setting Range:	OFF, 1–250°C
Accuracy:	±2°C
RTD Open-Circuit Detection:	>250°C

RTD Short-Circuit Detection:	<–50°C
RTD Types:	Pt100, Ni100, Ni120, Cu10
RTD Lead Resistance:	25 ohm max. per lead
Update Rate:	<3 s
Noise Immunity on RTD Inputs:	To 1.4 Vac (peak) at 50 Hz or greater frequency
RTD Trip/Alarm Time Delay:	Approx. 6 s

Synchronism Check (25)

Pickup Range, Secondary Voltage:	0.00–300.00 V
Pickup Accuracy, Secondary Voltage:	±1% plus ±0.5 volts (over the range of 2.00–300.00 V)
Slip Frequency Pickup Range:	0.05 Hz–0.50 Hz
Slip Frequency Pickup Accuracy:	±0.02 Hz
Phase Angle Range:	0–80°
Phase Angle Accuracy:	±4°

Station Battery Voltage Monitor

Operating Range:	0–350 Vdc (300 Vdc for UL purposes)
Pickup Range:	20.00–300.00 Vdc
Pickup Accuracy:	±2% of setting plus ±2 Vdc

Timers

Setting Range:	Various
Accuracy:	±0.5% of setting plus ±1/4 cycle

Metering Accuracy

Accuracies are specified at 20°C, nominal frequency, ac currents within (0.2–20.0) • I_{NOM} A secondary, and ac voltages within 50–250 V secondary unless otherwise noted.

Phase Currents

Magnitude Accuracy:	±1.0% (I_{NOM} = 1 A or 5 A)
Phase Accuracy:	±1.0° (I_{NOM} = 5 A), ±1.0° at 0.5–20.0 times I_{NOM} (I_{NOM} = 1 A), ±2.5° at 0.2–0.5 times I_{NOM} (I_{NOM} = 1 A)
Differential Quantities:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
Current Harmonics:	±5% of reading plus ±0.1 A (5 A nominal), ±0.02 A (1 A nominal)
I1 Positive-Sequence Current:	±2% of reading
IG (Residual Current):	±2% of reading, ±2° (±5.0° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
IN (Neutral Current):	±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
3I2 Negative-Sequence Current:	±2% of reading
System Frequency:	±0.01 Hz of reading for frequencies within 15–70 Hz (requires ac voltage inputs, V1 > 60 V)
Line-to-Line Voltages:	±1% of reading, ±1° for voltages within 24–264 V
Line-to-Ground Voltages:	±1% of reading, ±1° for voltages within 24–264 V
Voltage Harmonics:	±5% of reading plus ±0.5 V
V1 Positive-Sequence Voltage:	±2% of reading for voltages within 24–264 V
3V2 Negative-Sequence Voltage:	±2% of reading for voltages within 24–264 V
Real 3-Phase Power (kW):	±3% of reading for 0.10 < pf < 1.00
Reactive 3-Phase Power (kVAR):	±3% of reading for 0.00 < pf < 0.90
Apparent 3-Phase Power (kVA):	±3% of reading
Power Factor:	±2% of reading for 0.86 ≤ pf ≤ 1
RTD Temperatures:	±2°C

Synchrophasor Accuracy

Maximum Message Rate

Nominal 60 Hz System:	60 messages per second
Nominal 50 Hz System:	50 messages per second

The following are the accuracy specifications for voltages and currents for the SEL-787-3E and SEL-787-3S models. Note that the SEL-787-4X model does not track frequency, so the accuracy specifications are only applicable when the applied signal frequency equals FNOM.

Accuracy for Voltages

Level 1 compliant as specified in IEEE C37.118 under the following conditions for the specified range.

Notes

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com

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