SEL-387E Current Differential and Voltage Relay

Versatile Solution for Power Apparatus Protection

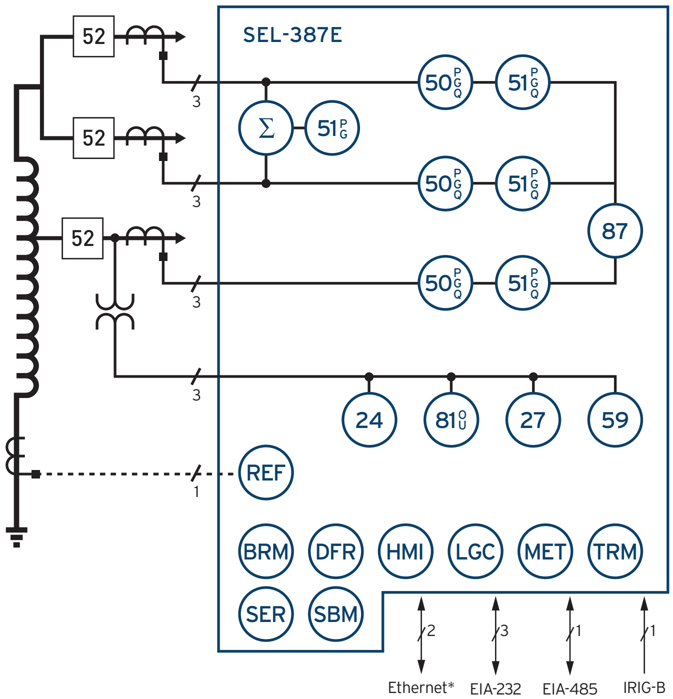
Key Features and Benefits

The SEL-387E Relay includes three-phase voltage inputs for metering, overexcitation, frequency, and over- and undervoltage functions. The three winding current differential elements use second-, fourth-, and fifth-harmonic elements, augmented by the dc element, to provide security during transformer energization and overexcitation conditions in a user-defined choice of either harmonic restraint or harmonic blocking. Overcurrent elements, over- and underfrequency elements, over- and undervoltage elements, power and energy metering, and overexcitation protection all contribute to relay versatility. Oscillographic event reports, Sequential Events Recorder (SER), circuit breaker contact wear monitor, and substation battery monitor are all standard features. Four communications ports, local display panel, and extensive automation features are also standard. Expanded I/O is available as an option.

- **Protection.** Protect transformers, buses, generators, reactors, and other apparatus with a combination of differential, overcurrent, and volts/hertz protection. The differential element is set with either a single- or dual-slope percentage differential characteristic for increased security during through-fault conditions.
- **Metering.** Interrogate the relay for instantaneous measurements of voltage, current, MW, MVAR, MVA, MWh, MVARh, demand current, and three-phase demand power. The recorded peak demand, including the date and time of occurrence, is provided.
- **Monitoring.** Schedule breaker maintenance when the breaker monitor indicates. Notify personnel of substation battery voltage problems. Use the SEL-387E through-fault event monitor for information on system through faults and resulting cumulative I^2t wear on transformer banks. Monitor critical operating temperatures through use of the SEL-2600A RTD module.

- ➤ **Automation.** Take advantage of automation features that include 16 elements for each of the following: local control and local indication with front-panel LCD and pushbuttons, remote control, and latch control. Use the serial communications ports for efficient transmission of such key information as metering data, protection elements and contact I/O status, SER reports, breaker contact wear monitor, relay summary event reports, and time synchronization. Select optional DNP3 Level 2 Slave protocol with virtual terminal support for SCADA system interface capability. Equip the SEL-387E with optional dual failover Ethernet communications for Telnet, FTP, read-only web server, and IEC 61850 communications support.
- ➤ **Relay and Logic Settings Software.** ACSELERATOR QuickSet® SEL-5030 Software reduces engineering costs for relay settings and logic programming. The built-in HMI provides phasor diagrams that help support commissioning and troubleshooting.

Functional Overview



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

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

* Optional Feature

Figure 1 Functional Diagram

Protection Features

The SEL-387E contains a variety of protective elements and control logic to protect two- or three-winding power transformers, reactors, generators, and other apparatus. It includes current differential elements with percentage restraint and harmonic blocking elements, sensitive restricted earth fault (REF) elements, and overcurrent elements. Use advanced SELOGIC® control equations to further tailor the relay to your particular application.

The relay has six independent setting groups. Use this flexibility to configure the relay automatically for virtually any operating condition including, for example, loading and source changes.

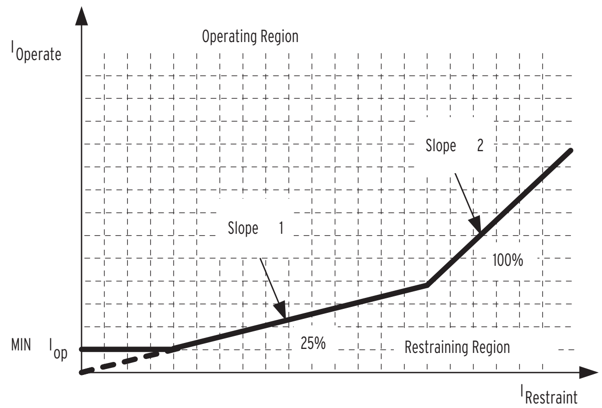


Figure 2 Dual-Slope Percentage Differential Restraint Characteristic

Current Differential Elements

The SEL-387E has three differential elements. These elements use operate and restraint quantities calculated from the two- or three-winding input currents. Set the differential elements with either single- or dual-slope percentage differential characteristics. *Figure 2* illustrates a dual-slope setting. The percent-slope characteristic helps prevent undesired relay operation because of 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.

The SEL-387E guards against harmonic conditions resulting from system and transformer events that can cause relay misoperation. Use the fifth-harmonic element to prevent relay misoperation during allowable overexcitation conditions. Even-harmonic elements (second- and fourth-harmonic) guard against inrush currents during transformer energization. The dc element, which measures dc offset, adds to this security. The even-harmonic element offers the choice between harmonic blocking and harmonic restraint. In the blocking mode, you select either blocking on an individual phase basis or on a common basis, as per application and philosophy. Set second-, fourth-, and fifth-harmonic thresholds and enable dc blocking and harmonic restraint features 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.

Restricted Earth Fault Protection

Apply the REF protection feature to provide sensitive detection of internal ground faults on grounded wye-connected transformer windings and autotransformers. Only one of the three ABC inputs of Winding 3 is used for introduction of neutral CT polarizing current. Operating current is derived from the residual current calculated for the protected winding. A directional element determines whether the fault is internal or external. Zero-sequence current thresholds and selectable CT saturation logic supervise tripping. One of the Winding 3 inputs is used for the neutral CT, so a maximum of two of the winding inputs may be used for normal differential and overcurrent protection.

Overcurrent Protection

The SEL-387E has 11 overcurrent elements for each set of three-phase current inputs, 33 elements total. Nine torque-controlled elements encompass one instantaneous, one definite-time, and one inverse-time element for each phase of the negative-sequence and residual currents. The phase elements operate on the maximum of the phase currents. The remaining two elements are phase segregated to assist in phase identification for targeting purposes or for level-sensing type functions. These are not torque-controlled.

Two additional combined overcurrent elements operate on the vectorial sum of phase currents from two relay terminals. Two inverse-time elements (one for phase current and one for residual) operate with summed currents from Windings 1 and 2. These elements operate on total transformer input or output current during use of CTs from two breakers in a ring bus or breaker-and-a-half configuration, eliminating the effect of circulating bus current flowing through both breakers.

The time-overcurrent curves listed in *Table 1* have two reset characteristic choices for each time-overcurrent element. One choice resets the elements if current drops below pickup for at least one cycle. The other choice emulates reset of an electromechanical induction disk relay.

Table 1 Time-Overcurrent Curves

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

Over- and Undervoltage Elements

Phase undervoltage, overvoltage, and sequence overvoltage elements help you create protection and control schemes, such as:

- ➤ Blown transformer high-side fuse detection logic
- ➤ Undervoltage load shedding

Phase undervoltage elements operate with the minimum of the measured phase voltage magnitudes; these elements operate if any single-phase measurement falls below the set threshold. The phase-to-phase undervoltage element operates with the minimum of the measured phase-to-phase voltages. The positive-sequence undervoltage element operates when the measured positive-sequence voltage falls below the set threshold.

Phase overvoltage elements operate with the maximum of the measured phase voltage magnitudes. Residual overvoltage elements operate with the vectorial sum of three-phase voltage measurements. The positive- and negative-sequence overvoltage elements operate when respective measurements exceed set thresholds. The phase-to-phase overvoltage element operates when maximum phase-to-phase voltage exceeds the set threshold.

When you choose single-phase voltage input, only phase voltage elements are active.

Frequency Protection

The SEL-387E provides six steps of over- and underfrequency elements. Each element operates as either an over- or underfrequency element with and 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-387E uses A-phase voltage to determine system frequency. All frequency elements are disabled if any phase voltage is less than a settable voltage threshold.

Volts/Hertz (Overexcitation) 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. In the SEL-387E, a volts/hertz element detects overexcitation. The SEL-387E 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 a SELOGIC torque control equation that you can use to enable/disable the element according to measured conditions or local or remote control.

Use SEL-5806 Curve Designer Software to set and define the user-defined curve. 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.

Metering and Monitoring

Metering Capabilities

The SEL-387E provides extensive metering capabilities. These capabilities are listed and described in *Table 2*.

Metering accuracies are listed in the *Specifications* on page 18.

Table 2 Metering Capabilities

Quantities	Description
Currents $I_{A,B,C}$	Individual phase currents for each set of three phase winding inputs.
Voltages $V_{A,B,C}$	Individual phase voltages are available for wye- or delta-connected PTs.
Power $MW_{A,B,C,3P}$, $MVAR_{A,B,C,3P}$, $MVA_{A,B,C,3P}$	Single- and three-phase megawatts, megavars, and megavolt-amperes are available with wye-connected PTs. Three-phase megawatts, megavars, and megavolt-amperes are available with delta-connected PTs.
Energy $MWh_{A,B,C,3P}$, $MVARh_{A,B,C,3P}$	Single- and three-phase megawatt hours and megavar hours are available with wye-connected PTs. Three-phase megawatt hours and megavar hours are available with delta-connected PTs.
Sequence $3I_1$, $3I_2$, $3I_0$, $3V_1$, $3V_2$, $3V_0$	Positive-, negative-, and zero-sequence currents and voltages for each winding.
Demand $I_{A,B,C}$, $3I_2$, $3I_0$, MW_{3P}, $MVAR_{3P}$	Individual phase, negative-, and zero-sequence currents for each winding. Three-phase real and reactive power for windings identified with the VIWDG setting.
Peak Demand $I_{A,B,C}$, $3I_2$, $3I_0$, MW_{3P}, $MVAR_{3P}$	Individual phase, negative-, and zero-sequence currents for each winding. Three-phase real and reactive power for windings identified with the VIWDG setting.
Phasors $I_{A,B,C}$, $V_{A,B,C}$	Individual phase and sequence current phasors including magnitudes and angles.
Differential Currents I_{OP}, I_{RT}, InF2, InF5	I-operate, I-restraint, I-second-harmonic, I-fifth-harmonic.
Harmonics $I_{A,B,C}$, $V_{A,B,C}$	Individual phase currents and voltages—fundamental to the 15th harmonic—for each winding.
RTD Temperatures	As many as 24 individual temperatures from two SEL-2600A RTD modules. Each SEL-2600A RTD module provides 12 RTD inputs.

Event Reporting and Sequential Events Recorder (SER)

Event report and SER features simplify post-fault analysis and improve understanding of simple and complex protective scheme operations. These features also aid in testing and troubleshooting relay settings and protection schemes.

Event Reports

In response to a user-selected trigger, the voltage, current, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. Decide how much detail you need when requesting an event report: 1/4- or 1/8-cycle resolution for filtered data; 1/4-, 1/8-, 1/16-, 1/32-, or 1/64-cycle resolution for raw analog data. For each report, the relay stores the most-recent 15, 29, or 60 cycles of data in nonvolatile memory. Specify the length of pre-event information with a setting. The relay stores 7 seconds of event report data. Relay settings are appended to the bottom of each event report.

Available reports include:

- **Winding event reports**, using filtered data and showing all analog channels at 4 or 8 samples per cycle, as well as the status of digital inputs and outputs.
- **Digital event reports**, showing pickup of overcurrent, demand current, voltage overexcitation, frequency, and over- and undervoltage elements at 4 or 8 samples per cycle, as well as the status of digital inputs and outputs.
- **Differential event reports**, showing differential quantities, element pickup, SELOGIC control equation set variables, and inputs and outputs at 4 or 8 samples per cycle, as well as the status of digital inputs and outputs.
- **Raw event reports**, using unfiltered data at 4, 8, 16, 32, or 64 samples per cycle, as well as the status of digital inputs and outputs.

Use event report information in conjunction with the SEL-5601-2 SYNCHROWAVE® Event Software to produce oscillographic type reports suitable for inclusion in analysis documents and reports. *Figure 3* presents an example of event report data showing transformer inrush current.

Sequential Events Recorder (SER)

The relay SER stores the latest 512 entries. Use this feature to gain a broad perspective of relay element operation. Events that trigger an SER entry include input/output change of state and element pickup/dropout. Each entry includes time data derived from an IRIG-B source.

The IRIG-B time-code input synchronizes the SEL-387E time to within ±5 ms of the time-source input. A convenient source for this time code is an SEL-2032, an SEL-2030, or an SEL-2020 Communications Processor.

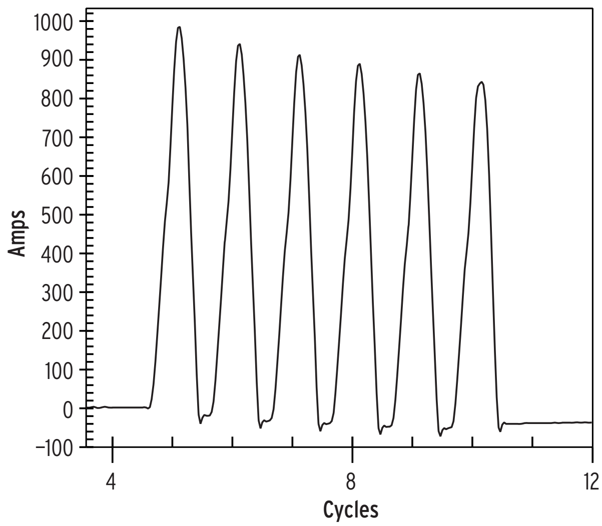


Figure 3 Transformer Energizing Inrush Current Plotted From Event Report

Substation Battery Monitor for DC Quality Assurance

The SEL-387E measures and reports the substation battery voltage at the relay power supply terminals. The relay includes four programmable threshold comparators and associated logic for alarm and control. For example, if the battery charger fails and the measured dc voltage falls below a programmable threshold, operations personnel receive notice before the substation battery voltage falls to unacceptable levels. Monitor these thresholds with an SEL communications processor and trigger messages, telephone calls, or other actions.

Obtain a report of the measured dc voltage in the METER display via serial port communications, on the front-panel LCD, and in the event report. Use event report data to see an oscillographic display of battery voltage. This report illustrates how substation battery voltage magnitude varies during trip, close, and other control operations.

Breaker Contact Wear Monitor

Circuit breakers experience mechanical and electrical wear every time they operate. Effective scheduling of breaker maintenance takes into account published manufacturer data of contact wear versus interruption levels and operation count. Each of the three current winding inputs for the relay has a separate breaker monitor function. Each breaker monitor calculates and accumulates current for each phase. The SEL-387E breaker monitor feature compares the published data from the breaker manufacturer to the interrupted current.

Every time the breaker trips, the interrupted current is integrated. When the result of this integration exceeds the threshold set by the breaker wear curve (*Figure 4*), the relay can alarm via the output contact or the front-panel display. The trips are segregated into internal trips (initiated by elements of a particular winding) or external trips (initiated by another source). With this kind of information, you can schedule breaker maintenance in a timely, economical fashion.

The breaker wear monitor report lists all breakers, number of internal and external trips for each breaker, total accumulated root-mean-square (rms) current by phase, and percent wear by pole.

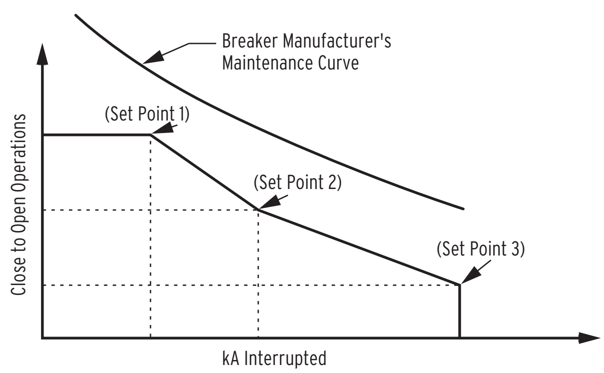


Figure 4 Breaker Contact Wear Curve and Settings

Through-Fault Event Monitor

A “through fault” is an overcurrent event external to the differential protection zone. Though 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-387E 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 I^2t alarm capability of the relay to indicate excess through-fault current over time.

Relay and Logic Setting Software

QuickSet uses the Microsoft Windows operating system to simplify settings and provide analysis support.

One can, for instance, open a QuickSet HMI screen and obtain phasor information such as that shown in *Figure 5*.

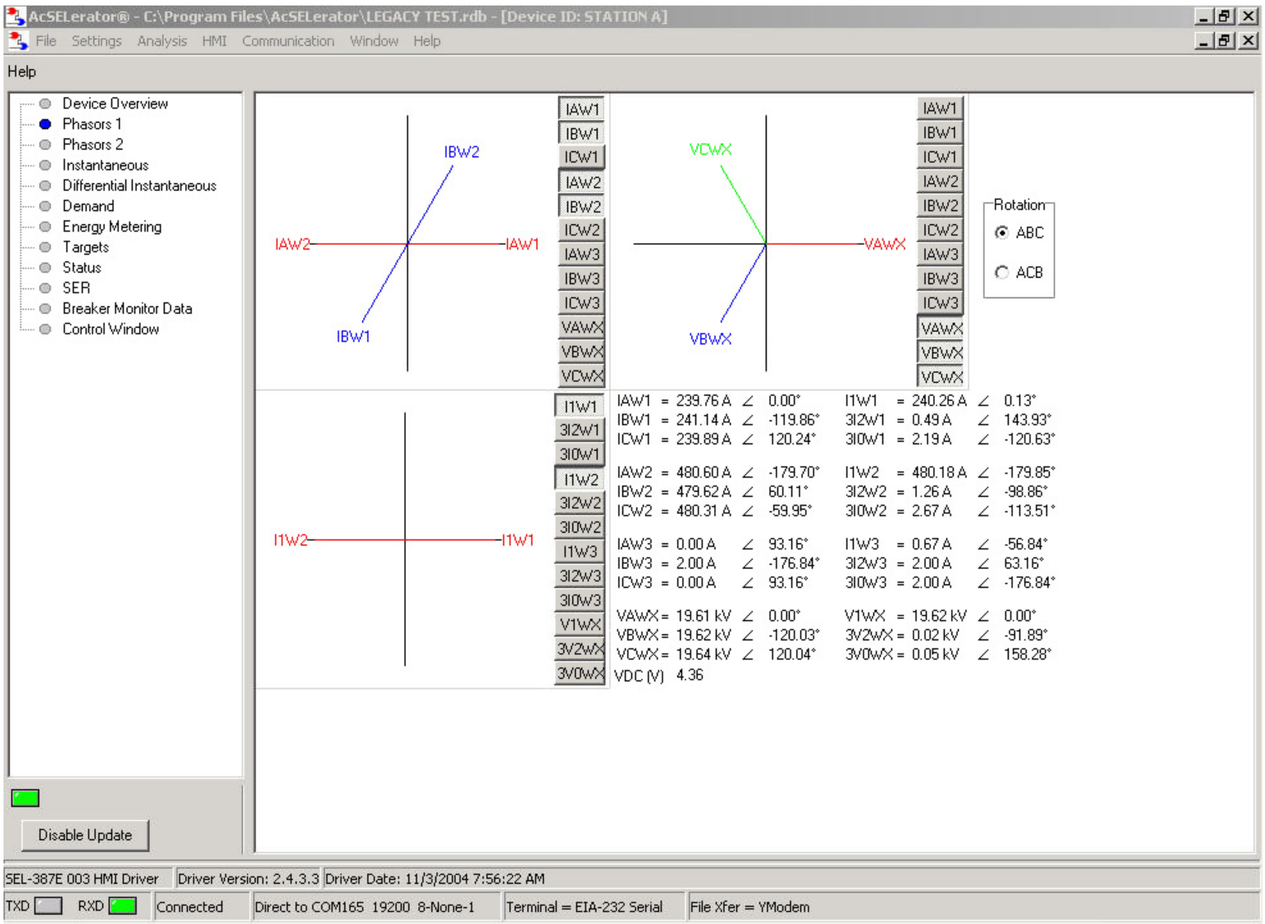


Figure 5 QuickSet HMI Screen Showing SEL-387E Phasor Information

Use QuickSet to create and manage relay settings:

- ➤ Develop settings offline with an intelligent settings editor that only allows valid settings.
- ➤ Use online help to assist with configuration of proper settings.
- ➤ Organize settings with the relay database manager.
- ➤ Load and retrieve settings through use of a simple PC communications link.

Use QuickSet to verify settings and analyze events:

- ➤ Analyze power system events with integrated waveform and harmonic analysis tools.

Use QuickSet to aid with monitoring, commissioning, and testing:

- ➤ Use the HMI to monitor current phasor information during testing.
- ➤ Use the PC interface to remotely retrieve breaker wear, monitor accumulated through-fault levels, and obtain other power system data.

Automation

Flexible Control Logic and Integration Features

The SEL-387E control logic offers many benefits:

- **Replaces traditional panel control switches.** Eliminate traditional panel control switches with 16 local control switches. Set, clear, or pulse local control switches with the front-panel pushbuttons and display. Program the local control switches into your control scheme via SELOGIC control equations. Use the local control switches to perform functions such as a trip test or a breaker trip/close.
- **Eliminates RTU-to-relay wiring.** Eliminate RTU-to-relay wiring with 16 remote control switches. Set, clear, or pulse remote control switches via serial port commands. Program the remote control switches into your control scheme via SELOGIC control equations. Use remote control switches for SCADA-type control operations such as trip, close, and settings group selection.
- **Replaces traditional latching relays.** Replace traditional latching relays for such functions as "remote control enable" with 16 latch control switches. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the latch control switches via optoisolated inputs, remote control switches, local control switches, or any programmable logic condition. The latch control switches retain state when the relay loses power.
- **Replaces traditional indicating panel lights.** Replace traditional indicating panel lights with 16 programmable displays. Define customer messages (e.g., Breaker Open, Breaker Closed) to report power system or relay conditions on the front-panel display. Control which messages are displayed via SELOGIC control equations; drive the LCD via any logic point in the relay.

Serial Communications

The SEL-387E 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. Software protocols consist of standard SEL ASCII, SEL Distributed Port Switch, SEL Fast Meter, SEL Compressed ASCII, and Distributed Network Protocol (DNP3), Level 2 Slave.

- Three EIA-232 serial ports and one isolated EIA-485 serial port. Each serial port operates independently.
- Full access to event history, relay status, and meter information from the serial ports.
- Settings and group switching have password control.
- Open communications protocols (see *Table 3*).
- To interface with fiber optics, connect the appropriate SEL-2800 series transceiver directly to any EIA-232 port. The SEL-2800 family includes single- and multimode devices that are capable of full-duplex communication over distances as great as 80 kilometers.

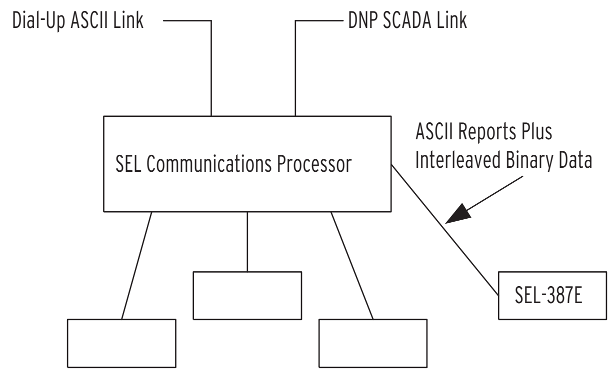


Figure 6 Example Communications System

The relay does not need special communications software. You need only have printing terminals, dumb terminals, or a computer supplied with terminal emulation and a serial communications port. SEL manufactures a variety of standard cables for connecting this and other relays to a variety of external devices. Contact your SEL representative for more information on cable availability.

IEC 61850 Ethernet Communications

IEC 61850 Ethernet-based communications provides interoperability between intelligent devices within the substation. Logical Nodes using the IEC 61850 communications allow standardized interconnection of intelligent devices from different manufacturers for monitoring and control of the substation. Reduce wiring between various manufacturers' devices and simplify operating logic with SEL-387E relays equipped with IEC 61850. Eliminate system RTUs by streaming monitoring and control information from the intelligent devices directly to remote SCADA client devices.

The SEL-387E can be ordered with embedded IEC 61850 communications operating on dual failover 100 Mbps Ethernet interfaces. Use the IEC 61850 Ethernet communications for relay monitoring and control functions, including:

- As many as 16 incoming GOOSE messages. The incoming GOOSE messages can be used to control as many as 32 control bits in the relay with <10 ms latency from device to device. These messages provide binary control inputs to the relay for high-speed control functions and monitoring.
- As many as 8 outgoing GOOSE messages. Outgoing GOOSE messages can be configured for Boolean or analog data. Boolean data are provided with <10 ms latency from device to device. Use outgoing GOOSE messages for high-speed control and monitoring of external breakers, switches, and other devices.
- IEC 61850 Data Server. The SEL-300 Series Relays equipped with embedded IEC 61850 Ethernet communications provide data according to predefined logical node objects. As many as six simultaneous client associations are supported by each relay. Relevant Relay Word bits are available within the logical node data, so the status of relay elements, inputs, outputs, or SELOGIC control equations can be monitored using the IEC 61850 data server provided in the relay.

Use the SEL-5032 ACSELERATOR Architect® Software to manage the logical node data for all IEC 61850 devices on the network. This Microsoft Windows-based software provides easy-to-use displays for identifying and binding IEC 61850 network data between logical nodes using IEC 61850-compliant CID (Configured IED Description) files. CID files are used by Architect to describe the data that will be provided by the IEC 61850 logical node within each relay.

Telnet, FTP, and Read-Only Web Server

Order the SEL-387E with Ethernet communications and use the built-in Telnet and FTP (File Transfer Protocol) that come standard with Ethernet to enhance relay communication sessions. Use Telnet to access relay settings, metering, and event reports remotely using the ASCII interface. Upload IEC 61850 CID files to the relay via the high-speed Ethernet port using FTP.

Enable the integrated read-only web server and browse the relay with any standard web browser to safely read settings, verify relay self-test status, inspect meter reports, read relay configuration, and more. The web server allows no control or modification actions, so users can be confident that an inadvertent button press will have no adverse effects.

Table 3 Open Communications Protocols

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	Binary protocol for machine-to-machine communications. Quickly updates SEL communications processors and other substation devices with metering information, relay element, 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 transfers an event report.
Distributed Port Switch Protocol	Enables multiple SEL devices to share a common communications bus (two-character address setting range is 01–99). Use this protocol for low-cost, port-switching applications.
DNP3 Level 2 Slave	Certified Distributed Network Protocol. Includes automatic dial-out capability for settings-based DNP events, full-point remapping, individual scaling and deadband thresholds for analog inputs, and virtual terminal support with full ASCII capability.
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation.

Unique Capabilities

Advanced SELOGIC Control Equations

Advanced SELOGIC control equations allow the engineer to assign relay outputs to any logical combination of relay elements or inputs.

Program SELOGIC control equations by combining relay elements, inputs, and outputs with SELOGIC control equation operators. The state of all logical elements in the relay is reflected by bits of a table called the "Relay Word." These logical elements include all voltage (27/59), current (50/51), power and directional level detecting elements, timer elements, SELOGIC equation variables, inputs, outputs, and remote, local, and latched bits. Use any element in the Relay Word in these equations.

SELOGIC control equation operators include: OR, AND, invert, parentheses, and rising and falling edges of element state changes.

The basic building blocks of SELOGIC control equations are the Relay Word bits. The Relay Word bits are simple digital quantities with a logical value of either 0 or 1. The terms "assert" or "asserted" refer to a Relay Word bit that has a value of 1 or is changing from 0 to 1. The terms "deassert" or "deasserted" refer to a Relay Word bit that has a value of 0 or is changing from 1 to 0. Various relay elements assert or deassert Relay Word bits and use these in the fixed internal logic of the relay to make decisions, to interpret inputs, or to drive outputs. These same bits are available to you so that you can exercise flexibility in defining inputs or outputs, specifying control variables for internal logic, or creating special customized logic through the use of SELOGIC control equations.

In addition to Boolean logic, 16 general purpose SELOGIC control equation timers eliminate external timers for custom protection or control schemes. Each timer has independent time-delay pickup and dropout settings. Program each timer input with any element you want (e.g., time qualify a voltage element). Assign the timer output to trip logic, transfer trip communications, or other control scheme logic.

Six Independent Setting Groups Increase Operation Flexibility

The relay stores six setting groups. Selectable setting groups make the SEL-387E ideal for applications needing frequent setting changes and for adapting the protection to changing system conditions. Select the active setting group by contact input, command, or other programmable conditions. Use these setting groups to cover a wide range of protection and control contingencies.

Selecting a group also selects logic settings. Program group selection logic to adjust settings for different operating conditions such as station maintenance, seasonal operations, emergency contingencies, loading, source changes, and adjacent relay setting changes.

Additional Features

Front-Panel User Interface

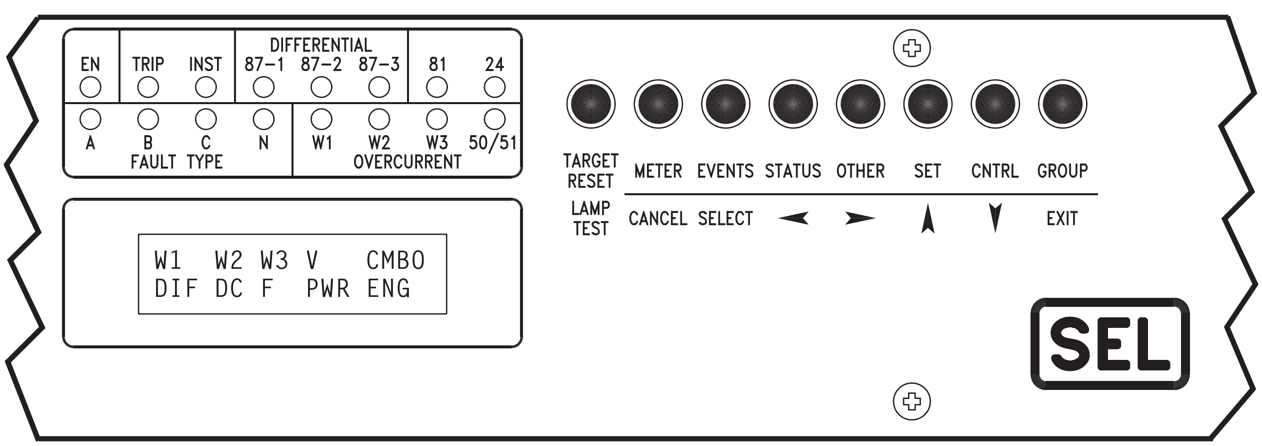


Figure 7 Status and Trip Target LEDs, Front-Panel Display, and Pushbuttons

A close-up view of the user interface portion of the SEL-387E front panel is shown in *Figure 7*. It includes a two-line, 16-character LCD; 16 LED target indicators; and 8 pushbuttons for local communication.

Front-Panel Display

The LCD shows event, metering, setting, and relay self-test status information. Control the display with the eight multifunction pushbuttons. The target LEDs display relay target information as described in *Table 4*.

The LCD is controlled by the pushbuttons, automatic messages the relay generates, and user-programmed Display Points. The default display scrolls through any active, nonblank Display Points. If none are active, the relay scrolls through four two-line displays of the A-, B-, and C-phase currents and voltages in primary quantities. Each display remains for two seconds before scrolling continues. Any message the relay generates for an alarm condition takes precedence over the normal default display. The EXIT button returns the display to the default display if the relay is performing some other front-panel function.

When errors (such as self-test failures) occur, error messages display on the LCD in place of the default display.

Status and Trip Target LEDs

Table 4 Description of Target LEDs

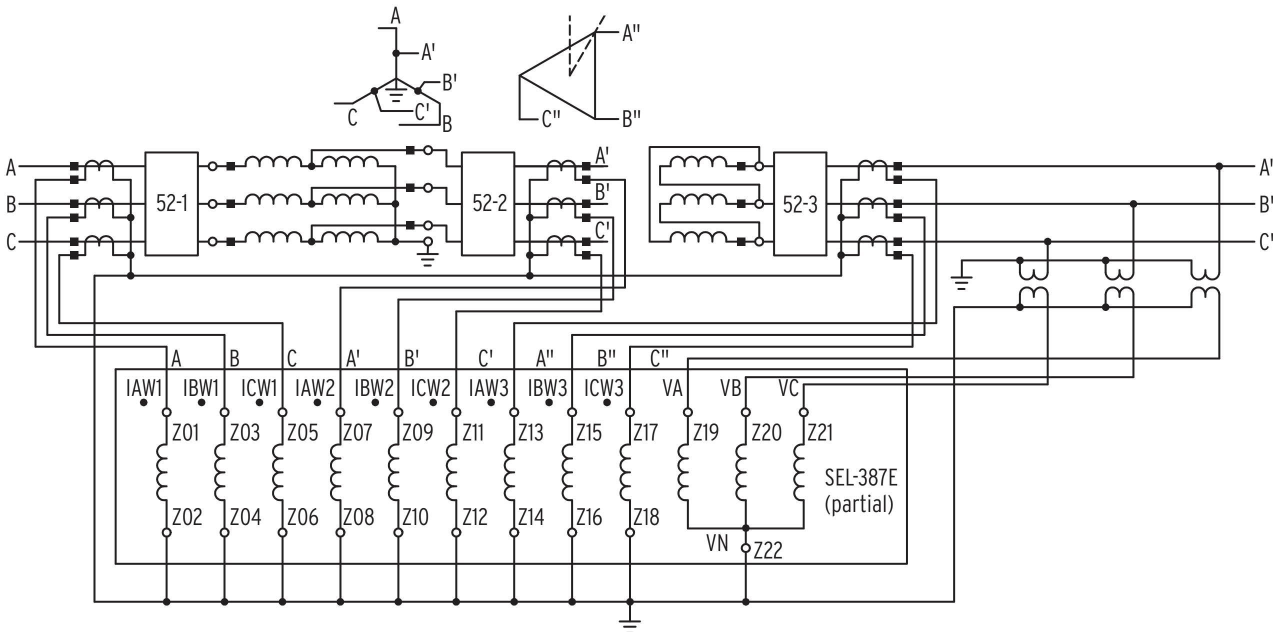
Target LED	Function
EN	Relay powered properly, self-tests okay.
TRIP	A trip occurred.
INST	Trip resulting from an instantaneous overcurrent, definite-time overcurrent, or current differential element operation.
DIFFERENTIAL 87-1, 87-2, 87-3	A current differential element operated.
81	An under-/overfrequency element operated.
24	The volts/hertz element operated.
FAULT TYPE A, B, C, N	Phases involved in the fault. Ground involved in the fault.
OVERCURRENT W1, W2, W3	Windings involved in the fault.
50/51	Any instantaneous, definite-time, or inverse-time overcurrent element operated for fault.

The SEL-387E includes 16 status and trip target LEDs on the front panel. These targets are shown in *Figure 7* and explained in *Table 4*. The target LEDs are an indication of what the relay has detected on the power system and how the relay has reacted. The relay stores the states of the 12 dedicated LEDs (all but **EN**, **A**, **B**, **C**) in nonvolatile memory. If power to the relay is lost, these 12 targets will be restored to their last state when power is restored.

Digital Inputs and Outputs

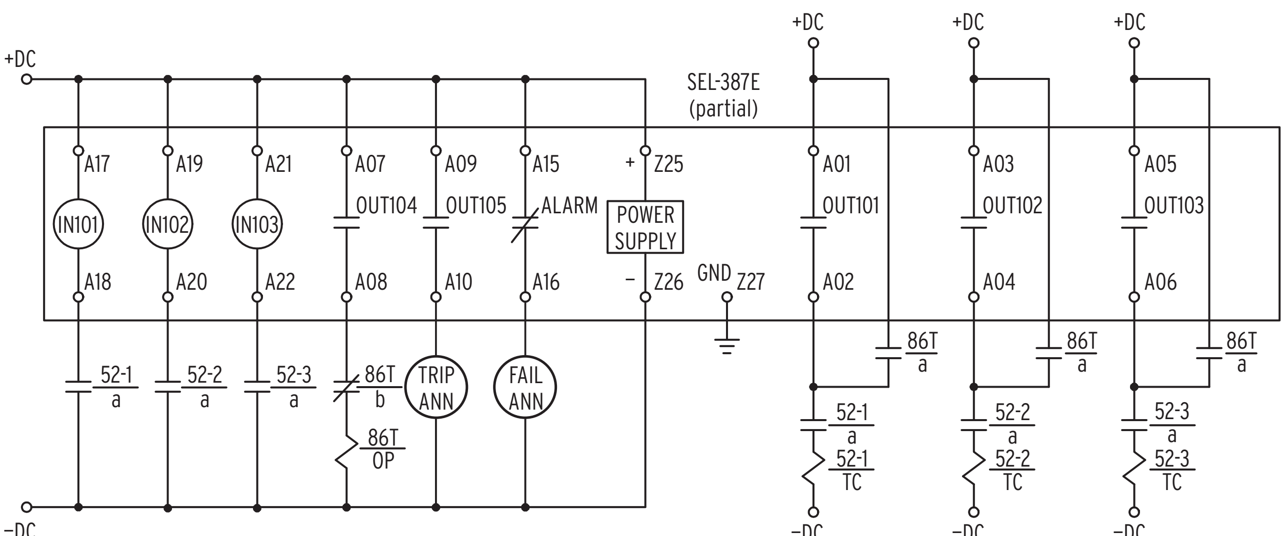
The base model SEL-387E includes 8 output contacts and 6 optoisolated inputs. Available options include the addition of 12 outputs and 8 inputs or 16 inputs and 4 outputs. Assign the inputs for control functions, monitoring logic, and general indication. Except for a dedicated alarm output, you can use SELOGIC control equations to program each output contact.

Wiring Diagrams



Transformer Connections: YYDAC (Yy0d1)
Current Transformer Connection: YYY

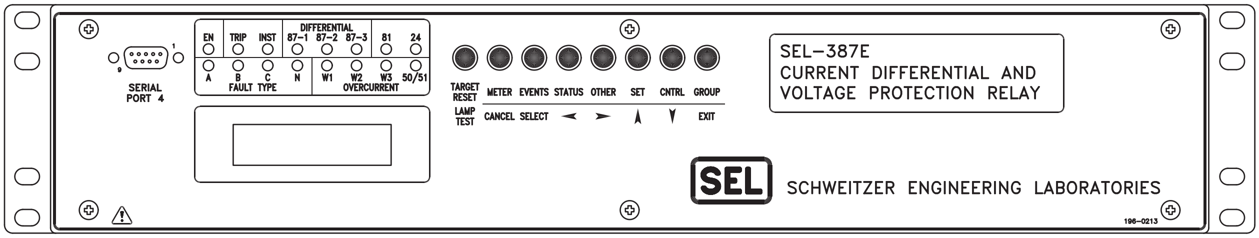
Figure 8 Typical AC Connection Diagram, Three-Winding Autotransformer Application



Remaining: 3 Inputs (IN104–IN106)
2 Outputs (OUT106, OUT107)

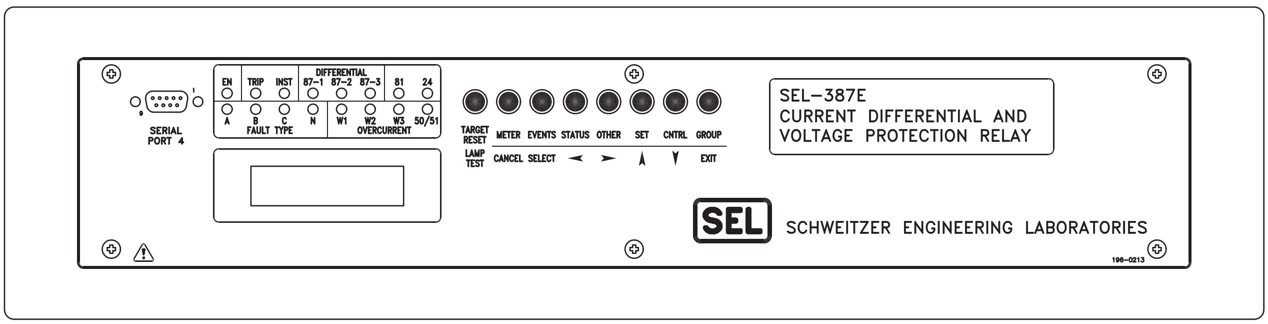
Figure 9 Typical DC Connection Diagram, Three-Winding Transformer Application

Diagrams and Dimensions



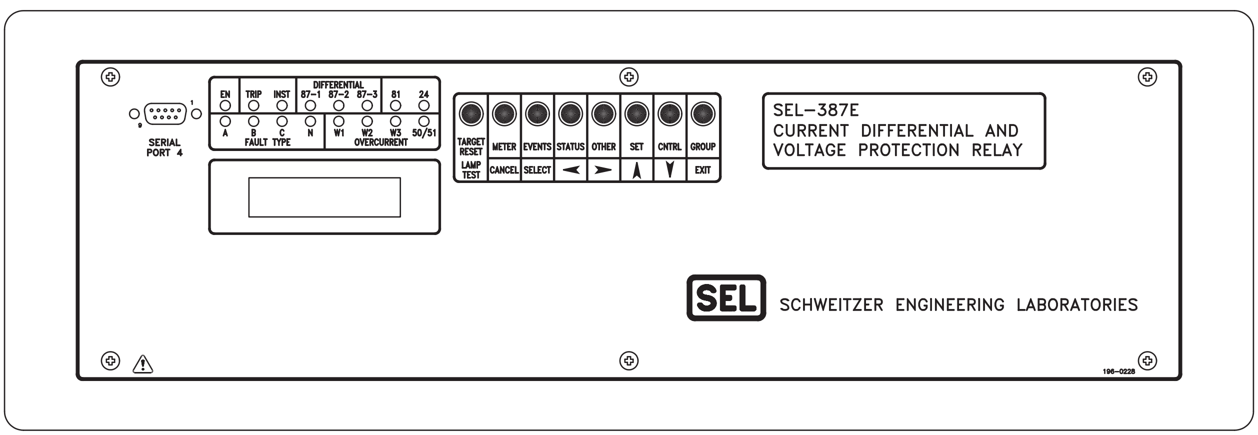
i3012b

Figure 10 SEL-387E 2U Rack-Mount Front Panel



i3019b

Figure 11 SEL-387E 2U Panel-Mount Front Panel



i3020a

Figure 12 SEL-387E 3U Panel-Mount Front Panel

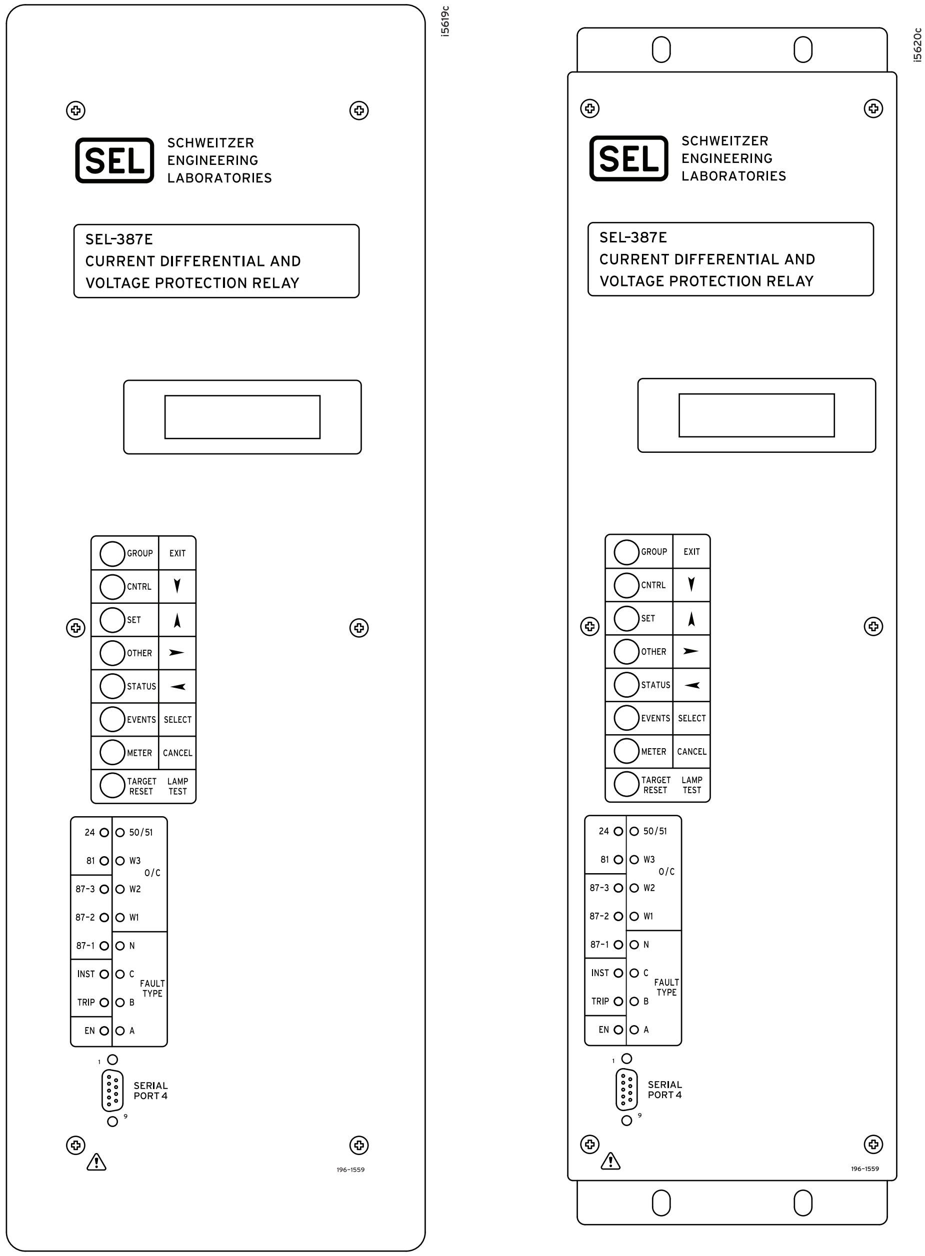


Figure 13 SEL-387E 3U Panel-Mount and Rack-Mount Vertical Front Panels

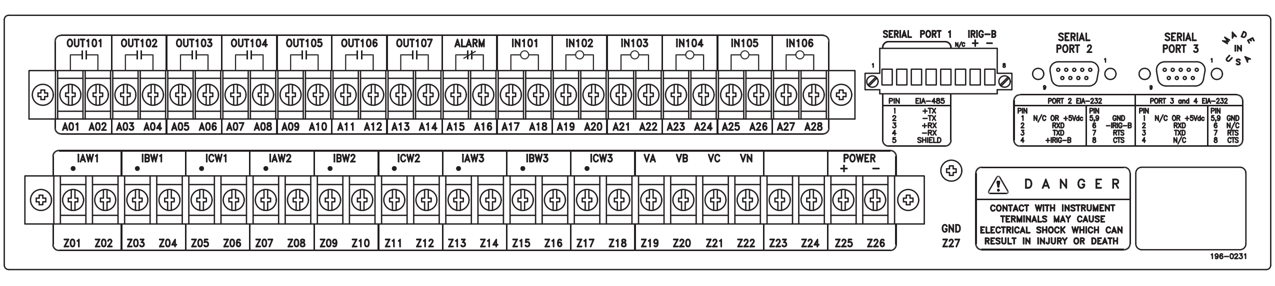
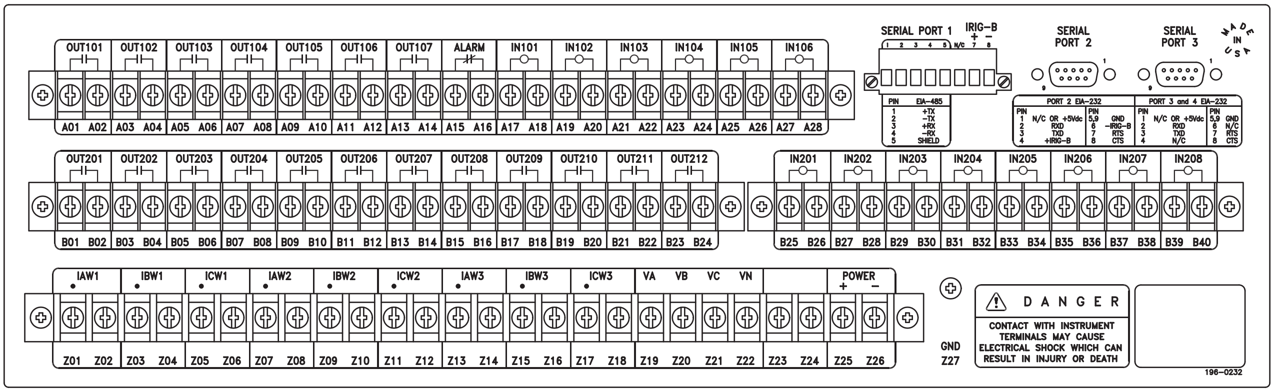
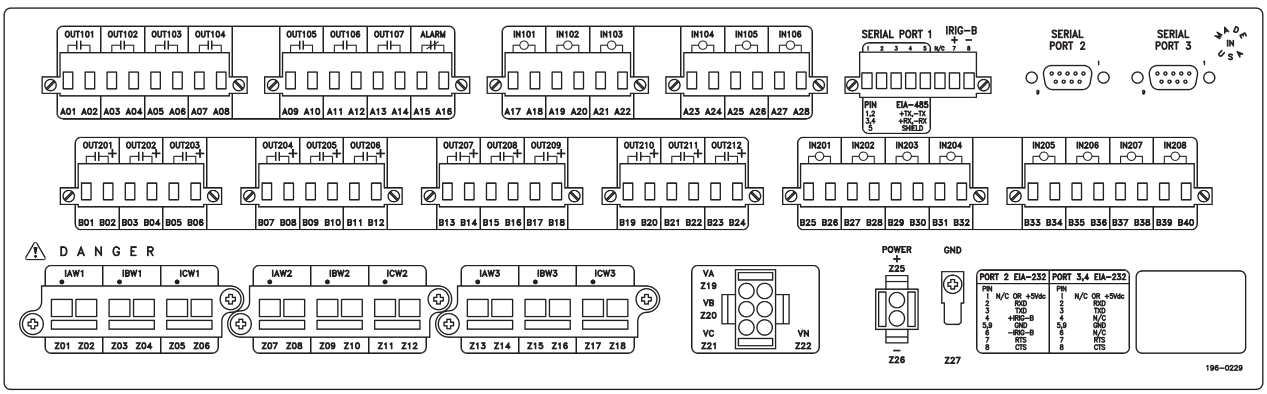


Figure 14 SEL-387E 2U Screw-Terminal Rear Panel, No Additional I/O Board



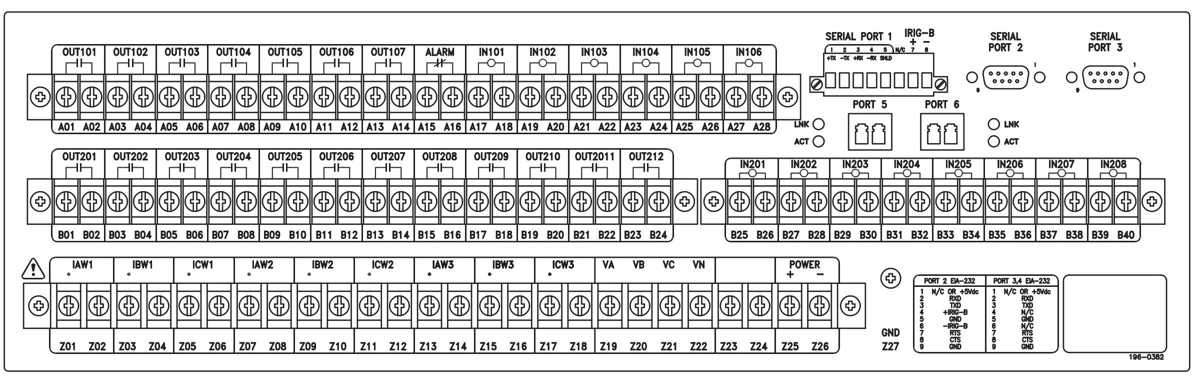
i3021c

Figure 15 SEL-387E 3U Screw-Terminal Rear Panel, Additional I/O Board



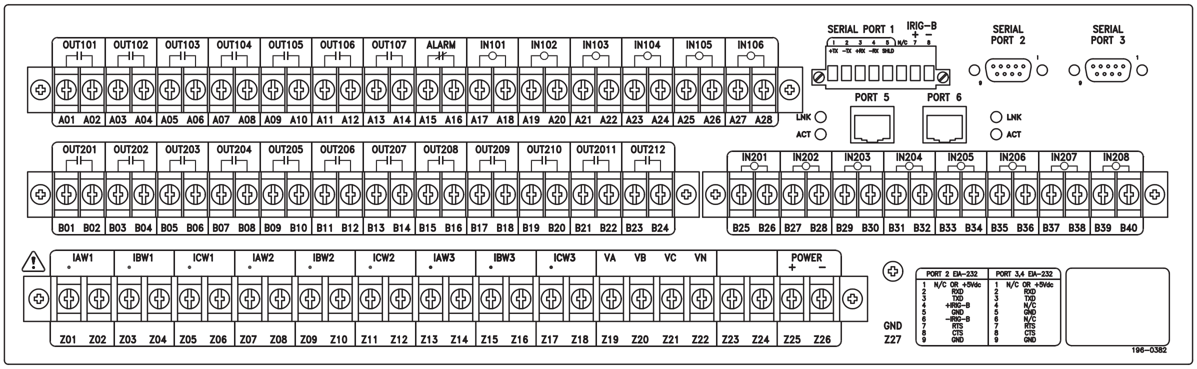
i3027b

Figure 16 SEL-387E 3U Connectorized® Rear Panel, Additional I/O Board



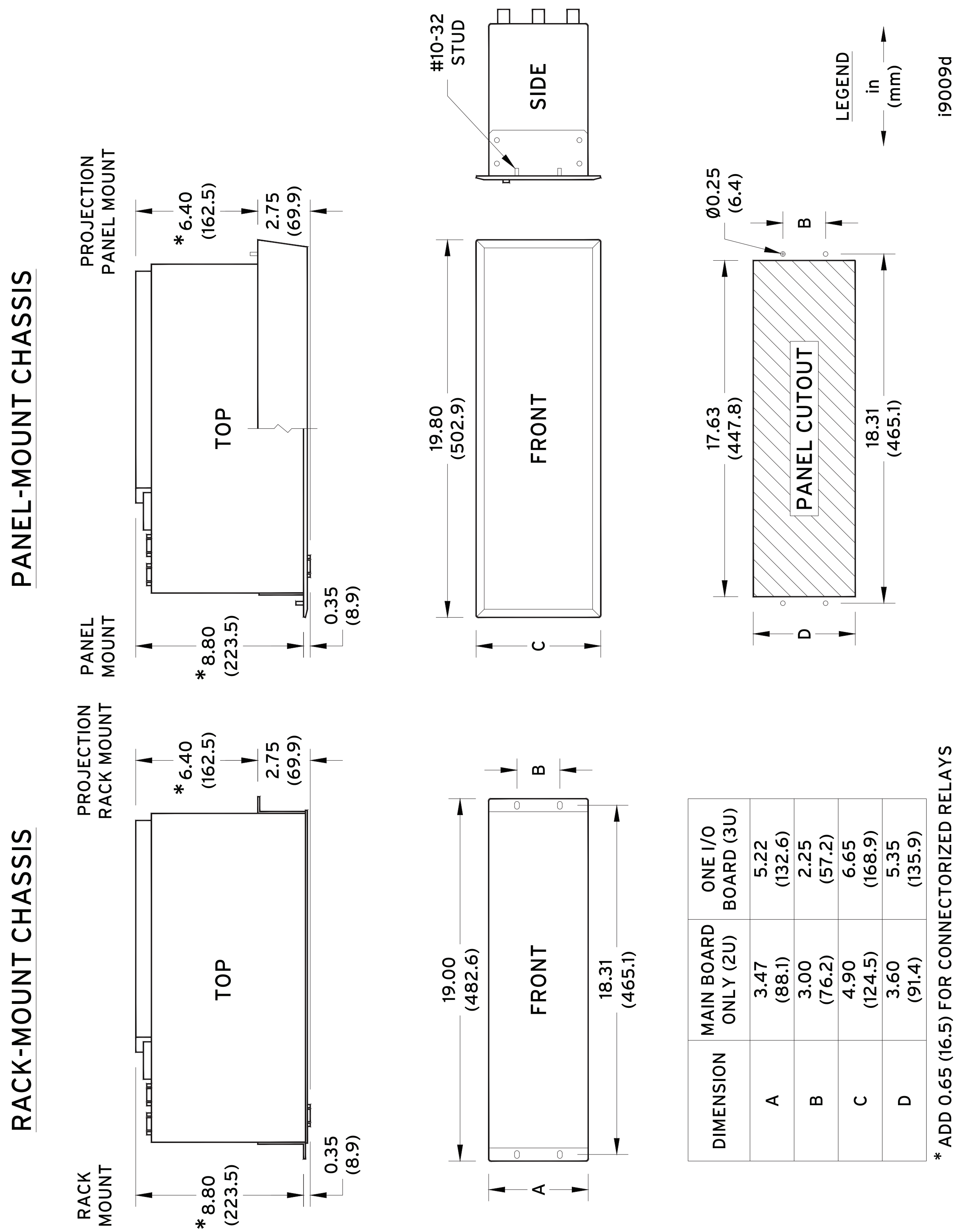
i3981a

Figure 17 SEL-387E 3U Screw-Terminal Rear Panel, Additional I/O Board With Dual 100BASE-FX Ethernet



i3980a

Figure 18 SEL-387E 3U Screw-Terminal Rear Panel, Additional I/O Board With Dual 10/100BASE-T Ethernet



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

* ADD 0.65 (16.5) FOR CONNECTORIZED RELAYS

(Horizontal Mounting Shown; Dimensions Also Apply to Vertical Mounting)

Figure 19 SEL-387E Dimensions for Rack- and Panel-Mount Models

Specifications

Compliance

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

General

Terminal Connections

Rear Screw-Terminal Tightening Torque Terminal Block

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

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

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

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

AC Current Input

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

AC Voltage Inputs

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

Power Supply

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

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

Output Contacts

Standard

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

Breaking Capacity (10,000 Operations):

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

Cyclic Capacity (2.5 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
1s Rating:	50 A
MOV Protection:	330 Vdc, 130 J
Pickup Time:	Less than 5 ms
Dropout Time:	Less than 8 ms, typical
Update Rate:	1/8 cycle

Breaking Capacity (10,000 Operations):

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

Cyclic Capacity (2.5 Cycle/Second):

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

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

Optoisolated Inputs

250 Vdc	
Pickup:	200–300 Vdc
Dropout:	150 Vdc
125 Vdc	
Pickup:	105–150 Vdc
Dropout:	75 Vdc
110 Vdc	
Pickup:	88–132 Vdc
Dropout:	66 Vdc
48 Vdc	
Pickup:	38.4–60 Vdc
Dropout:	28.8 Vdc
24 Vdc	
Pickup:	15.0–30 Vdc

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

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

Routine Dielectric Strength

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

Frequency and Rotation

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

Note: V_A required for frequency tracking

Serial Communications Ports

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

Ethernet Communications Port

Application Protocols

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

Physical Layer Options (PORT 5 and PORT 6)

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

Indicators (PORT 5 and PORT 6)

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

Fiber-Optic Ports Characteristics

Port 1 (or 1A, 1B) Ethernet

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

Time-Code Input

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

Operating Temperature

–40° to +85°C (–40° to +185°F)

Weight

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

Type Tests

Electromagnetic Compatibility Emissions

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

Electromagnetic Compatibility Immunity

Conducted RF Immunity:	ENV 50141:1993, 10 Vrms IEC 61000-4-6: 1996 10 Vrms
Digital Radio Telephone RF Immunity:	ENV 50204: 1995 10 V/m at 900 MHz and 1.89 GHz
Electrostatic Discharge Immunity:	IEC 60255-22-2:2008 IEC 61000-4-2:2008 Level 2, 4, 6, 8 kV contact; Level 2, 4, 8, 15 kV air
Fast Transient/Burst Immunity:	IEC 60255-22-4:1992 4 kV at 2.5 kHz and 5 kHz IEC 61000-4-4:1995 4 kV at 2.5 kHz on power supply; 2 kV, 5 kHz on I/O, signal, data, and control lines
Generic Immunity:	EN 50082-2:1995
Magnetic Field Immunity:	IEC 61000-4-8:1993 800 A/m for 3 s, 100 A/m for 1 min
Power Supply Immunity:	IEC 60255-11:1979 IEC 61000-4-11:2004
Radiated Radio Frequency Immunity:	IEC 60255-22-3:1989 IEC 61000-4-3:2002 ENV 50140:1993 10 V/m IEEE C37.90.2-1995 35 V/m, no keying test, frequency element accurate to 0.1 Hz
Surge Immunity:	IEC 60255-22-5:2002 IEC 61000-4-5:2005 1 kV Line-to-Line; 2 kV Line-to-Earth
Surge Withstand Capability:	IEC 60255-22-1:1988 2.5 kV peak common mode; 2.5 kV peak differential mode IEEE C37.90.1-1989 3000 V oscillatory; 5000 V fast transient

Environmental

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

Shock and Bump:	IEC 60255-21-2:1988 Class 1–Shock Withstand, Bump Class 2–Shock Response
Seismic:	IEC 60255-21-3:1993 Class 2

Safety

Dielectric Strength:	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 comm. port
Impulse:	IEC 60255-5:1977 0.5 J, 5000 V

Sampling Specifications

64 samples per power system cycle

Processing Specifications

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

Metering Accuracy

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

Station DC Battery Monitor

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

Differential Element

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

Harmonic Element

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

Instantaneous/Definite-Time Overcurrent Elements (Winding)

Pickup Accuracy (A secondary)	
5 A Model:	0.25–100.00 A
1A Model:	0.05–20.00 A
5 A Model Pickup Accuracy (A secondary)	
Steady State:	±3% ±0.10 A
Transient:	±5% ±0.10 A
Transient for 50Q:	±6% ±0.10 A
1 A Model Pickup Accuracy (A secondary)	
Steady State:	±3% ±0.02 A
Transient:	±5% ±0.02 A
Transient for 50Q:	±6% ±0.02 A
Pickup Time (Typ/Max):	0.75/1.20 cycles
Time Delay Range:	0–16000 cycles
Time Delay Accuracy:	±0.1% ±0.25 cycle

Time-Overcurrent Elements (Winding and Combined Current)

Pickup Accuracy (A secondary)	
5 A Model:	0.50–16.00 A
1A Model:	0.10–3.20 A
5 A Model Pickup Accuracy (A secondary)	
Steady State:	±3% ±0.10 A
Transient:	±5% ±0.10 A
Transient for 50Q:	±6% ±0.10 A
1 A Model Pickup Accuracy (A secondary)	
Steady State:	±3% ±0.02 A
Transient:	±5% ±0.02 A
Transient for 50Q:	±6% ±0.02 A
Curve	U1 = U.S. Moderately Inverse 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	
U.S. Curves:	0.50–15.00
IEC Curves:	0.05–1.00
Timing Accuracy:	±4% ±1.5 cycles for current between 2 and 30 multiples of pickup. Curves operate on definite time for current greater than 30 multiples of pickup.

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

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

Over-/Undervoltage Elements

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

Frequency Element

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

Volts/Hertz Element

Definite-Time Element

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

Inverse-Time Element

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

User-Definable Curve Element

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

Notes

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