SEL-387 Current Differential and Overcurrent Protection Relay

Versatile Solution for Power Apparatus Protection

Major Features and Benefits

The SEL-387 Relay offers restrained and unrestrained differential protection for two to four terminals. Second-, fourth-, and fifth-harmonic elements, augmented by the dc element, provide security during transformer energization and overexcitation conditions in a user-defined choice of either harmonic restraint or harmonic blocking. Overcurrent elements provide backup protection that contributes to relay versatility. Oscillographic event reports, Sequential Events Recorder (SER), circuit breaker contact wear monitor, and substation battery voltage 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. A restricted earth-fault feature provides sensitive protection against earth faults for wye-connected transformers.

- **Protection.** Protect transformers, buses, generators, reactors, and other apparatus with a combination of differential and overcurrent protection. Set the differential element with either a single- or dual-slope percentage differential restraint characteristic for increased security during through-fault conditions. Select the optional thermal modeling element for key information about transformer overload capability.
- **Metering.** Interrogate the relay for instantaneous measurements of phase and demand current. 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 through-fault event monitor in the SEL-387-5 and SEL-387-6 for information on system through faults and the 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.

- ➤ **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. The SEL-387-5 and SEL-387-6 are supported by the ACSELERATOR QuickSet software.

Functional Overview

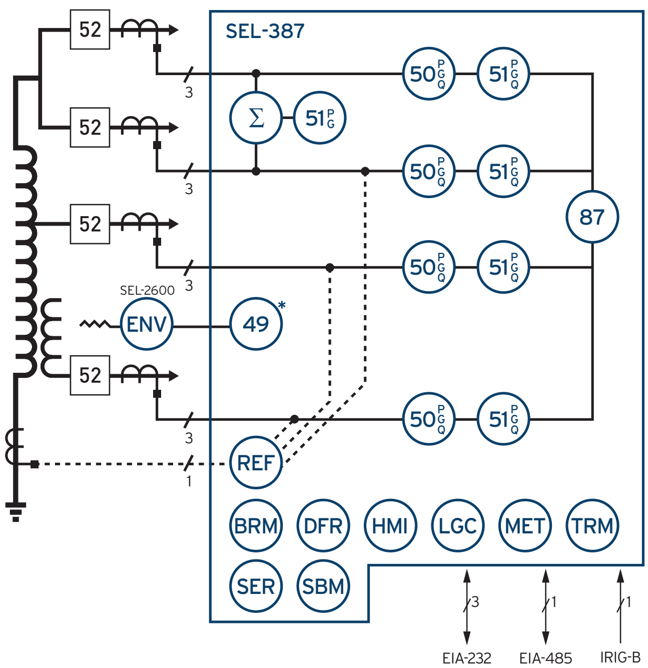


Figure 1 Functional Diagram

ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
49	Thermal Monitoring*
50 (P, G, Q)	Overcurrent (Phase, Ground, Neg. Seq.)
51 (P, G, Q)	Time-Overcurrent (Phase, Ground, Neg. Seq.)
87	Current Differential
DFR	Event Reports
ENV	SEL-2600
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

Protection Features

The SEL-387 contains a variety of protective elements and control logic to protect two-, three-, or four- 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 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.

Current Differential Elements

The SEL-387 has three differential elements. These elements use operate and restraint quantities calculated from the two-, three-, or four-winding input currents. The differential elements are set with either single- or dual-slope percentage differential characteristics. *Figure 2* illustrates a dual-slope setting. Slope 1 handles differential currents resulting from CT errors and tap-changing. Slope 2 prevents undesired relay operation resulting from CT saturation for heavy external faults.

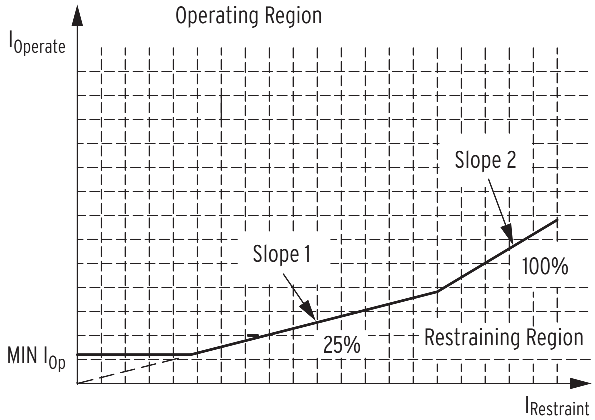


Figure 2 Dual-Slope Percentage Differential Restraint Characteristic

SEL-387-5 and SEL-387-6 relays guard 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 independently, and enable dc blocking and harmonic restraint features independently.

All SEL-387 relays provide an additional fifth-harmonic current alarm function that employs a separate threshold and an adjustable timer to warn of overexcitation. This may be useful for transformer applications in or near generating stations.

In addition, 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 4 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 4 inputs is used for the neutral CT, so a maximum of three winding inputs may be used for normal differential and overcurrent protection.

Overcurrent Protection

The SEL-387 has 11 overcurrent elements for each set of 3-phase current inputs, 44 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 sets of combined overcurrent elements operate on the vector sum of the Winding 1 and Winding 2 currents and the vector sum of the Winding 3 and Winding 4 currents, respectively. The individual currents are scaled by the appropriate ratio so that the combined current accurately reflects the primary system current. Inverse-time phase and residual elements are available for each of the combined currents. These combined elements offer added flexibility when the relay is applied with multiple breakers, such as in ring-bus or breaker-and-a-half applications. Different CT ratios are permitted on the two windings that are summed to create the combined current. For ideal CTs, these combined overcurrent functions do not respond to circulating current passing through both circuit 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

US	IEC
Moderately Inverse	Standard Inverse
Inverse	Very Inverse
Very Inverse	Extremely Inverse
Extremely Inverse	Long-Time Inverse
Short-Time Inverse	Short-Time Inverse

Metering and Monitoring

Table 2 Metering Capabilities

Quantities	Description
Current $I_{A,B,C}$, $3I_1$, $3I_2$, $I_{Residual}$	Phase and sequence currents for each winding.
Demand Current $I_{A,B,C}$, $3I_2$, $I_{Residual}$	Phase and sequence demand currents for each winding.
Peak Demand $I_{A,B,C}$, $3I_2$, $I_{Residual}$	Phase and sequence peak demand currents for each winding.
Phasors $I_{A,B,C}$, $3I_1$, $3I_2$, $I_{Residual}$	Phase and sequence current phasors for each winding (magnitudes and angles).
Differential Currents I_{OP}, I_{RT}, InF2, InF5	Operate, restraint, second harmonic, and fifth harmonic currents.
Harmonics $I_{A,B,C}$	Phase currents–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.

Metering Capabilities

The SEL-387 provides three types of fundamental frequency metering functions: instantaneous, demand (thermal), and peak demand. Metered quantities shown in *Table 2* include phase currents for all four winding inputs; positive-, negative-, and zero-sequence (residual) currents for all four winding inputs; and operate, restraint, second-harmonic, and fifth-harmonic currents for the three differential elements.

Harmonic metering provides a snapshot of harmonic current magnitudes in the phase currents, including the fundamental and harmonic components through the 15th.

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. They also aid in testing and troubleshooting relay settings and protection schemes.

Event Reports

In response to a user-selected trigger, the present 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, 30, or 60 cycles of data in nonvolatile memory. Specify pre-event information length through 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 12 currents at 4 or 8 samples per cycle, as well as the status of digital inputs and outputs.
- **Digital event reports**, showing pickup of overcurrent and demand 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 ACSELERATOR Analytic Assistant SEL-5601 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, if used.

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

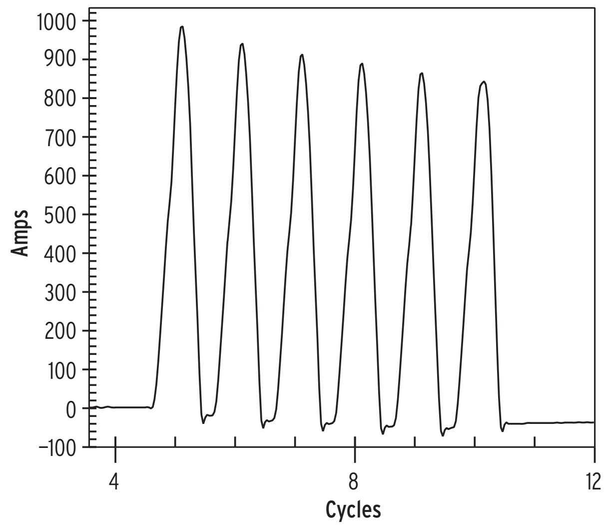


Figure 3 Transformer Energizing Inrush Current Plotted From Event Report

Substation Battery Monitor for DC Quality Assurance

The SEL-387 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 are notified before the substation battery voltage falls to unacceptable levels. Monitor these comparator outputs 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 LCD front-panel display, 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 compares published manufacturer breaker wear data, interruption levels, and operation count with actual field data. The SEL-387 breaker monitoring function captures the total interrupted current and number of operations for up to four breakers.

Each time a monitored breaker trips, the relay integrates the interrupted current with previously stored current values. When the results exceed the threshold set by the breaker wear curve (*Figure 4*), the relay can alarm via an output contact or the front-panel display. The typical settings shown in *Figure 4* are: Set Point 1 approximates the continuous load current rating of the breaker. Set Point 3 is the maximum rated interrupting current for the particular breaker. Set Point 2 is an intermediate current value providing the closest visual “fit” to the manufacturer’s curve.

The breaker wear monitor accumulates current by phase, and so calculates wear for each pole separately. When first applying the relay, preload any previous estimated breaker wear. The incremental wear for the next interruption, and all subsequent interruptions, adds to the prestored value for a total wear value. Reset the breaker monitor operation counters, cumulative interrupted currents by pole, and percent wear by pole after breaker maintenance or installing a new breaker.

The breaker wear monitor report lists all breakers, number of internal and external trips for each breaker, total accumulated rms current by phase, and the percent wear by pole.

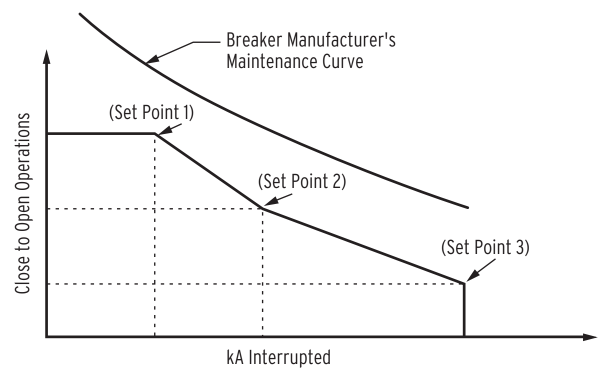


Figure 4 Breaker Contact Wear Curve and Settings

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. SEL-387-5 and SEL-387-6 through-fault event monitors gather current level, duration, and date/time for each through fault. The monitors also calculate a simple I^2t and cumulatively store 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.

Transformer Thermal Monitoring

Transformer thermal modeling per IEEE C57.91-1995 for mineral-oil immersed transformers is an optional feature in the SEL-387. Specify the SEL-387-6 to provide this capability for monitoring and protection of a single three-phase transformer as well as for monitoring and protection of three independent single-phase units. Use the thermal element to activate a control action or issue a warning or alarm when your transformer overheats or is in danger of excessive insulation aging or loss of life. Use the thermal event report to capture current hourly or daily data about your transformer.

Operating temperature calculations are based on load currents, type of cooling system, and/or actual temperature inputs (ambient and top oil). Use as many as four thermal sensor inputs: a single ambient temperature transducer and one transducer for top-oil temperature from each of three single-phase transformers.

Temperature data are obtained via a relay serial port. These data could come directly from an SEL-2600A RTD module (as shown in *Figure 5*) or from an SEL-2032 Communications Processor, which receives the temperature data from either an SEL-2600A RTD module or PLC. While the SEL-387-6 can receive temperature data at any rate, the thermal element uses these data only once a minute.

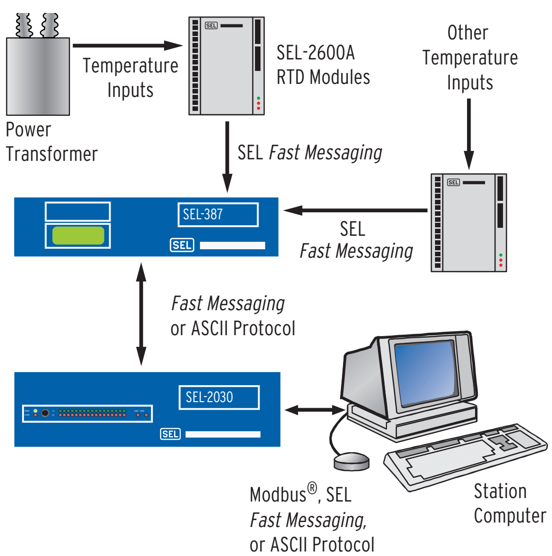


Figure 5 Typical Functional Diagram for Collecting Temperature Data

The thermal element operates in one of three modes, depending upon the presence or lack of measured temperature inputs: measured ambient and top-oil temperature inputs, measured ambient temperature only, and no measured temperature inputs. If the relay receives measured ambient and top-oil temperatures, the thermal element calculates hot-spot temperature. When the relay receives a measurement of ambient temperature without top-oil temperature, the thermal element calculates the top-oil temperature and hot-spot temperature. In the absence of any measured ambient or top-oil temperatures, the thermal element uses a default ambient temperature setting that you select and calculates the top-oil and hot-spot temperatures.

The relay then uses operating temperature as a basis for calculating the insulation aging acceleration factor (F_{AA}) and loss-of-life quantities. Use the thermal element to indicate alarm conditions and/or activate control actions when one or more of the following exceed settable limits:

- Top-oil temperature
- Winding hot-spot temperature
- Insulation aging acceleration factor (F_{AA})
- Daily loss of life
- Total loss of life

When appropriate, request a thermal monitor report that indicates the present thermal status of the transformer. Historical thermal event reports and profile data are stored in the relay in hourly format for the previous 24 hours and in daily format for the previous 31 days.

Relay and Logic Setting Software

ACSELERATOR QuickSet software uses the Microsoft Windows® operating system to simplify settings and provide analysis support for the SEL-387-5 and SEL-387-6.

One can, for instance, open an ACSELERATOR QuickSet human machine interface (HMI) screen and obtain phasor information such as that shown in *Figure 6*.

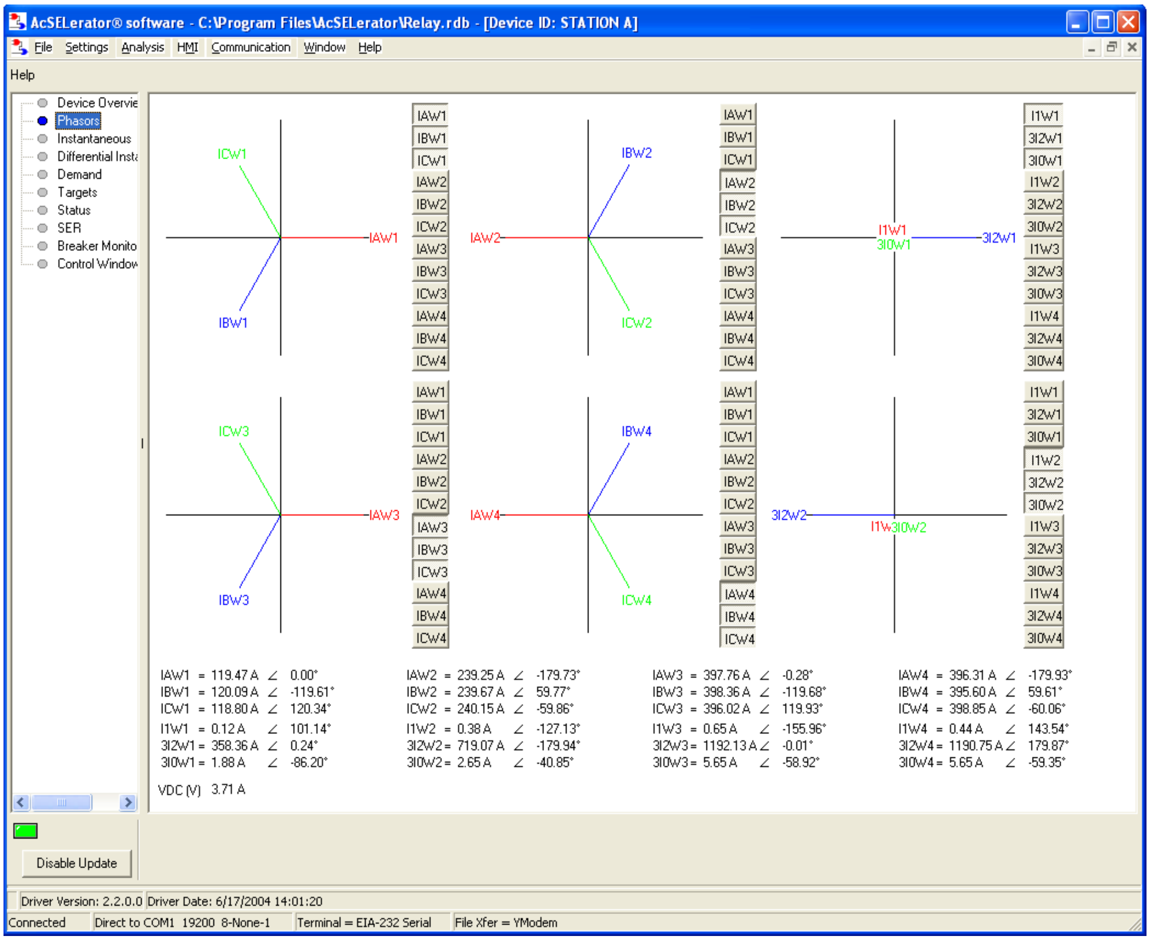


Figure 6 **ACSELERATOR QuickSet HMI Screen Showing SEL-387 Phasor Information**

Use ACSELERATOR QuickSet software to create and manage relay settings:

- ➤ Develop settings off-line with an intelligent settings editor that only allows valid settings.
- ➤ Use on-line 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 ACSELERATOR QuickSet software to verify settings and analyze events:

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

Use ACSELERATOR QuickSet software to aid with monitoring, commissioning, and testing the SEL-387-5 and SEL-387-6:

- ➤ Use the Human Machine Interface (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.

Note: To use ACSELERATOR QuickSet software in SEL-387-5 relays, one must have relay Firmware Version R602 or later. To use ACSELERATOR QuickSet software in SEL-387-6 relays, one must have relay Firmware Version R404 or later.

Automation

Serial Communications

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 and Fast Operate	Binary protocol for machine-to-machine communications. Quickly updates SEL communications processors, RTUs, 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 is transferring 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 dead-band thresholds for analog inputs, and virtual terminal support with full ASCII capability.

The SEL-387 is equipped with four independently operated serial ports: one EIA-232 port on the front and two EIA-232 ports and one EIA-485 port on the rear. The relay does not require special communications software. Use any system that emulates a standard terminal system. Establish communication by connecting computers, modems, protocol converters, printers, an SEL communications processor, SCADA serial port, and/or RTU for local or remote communication.

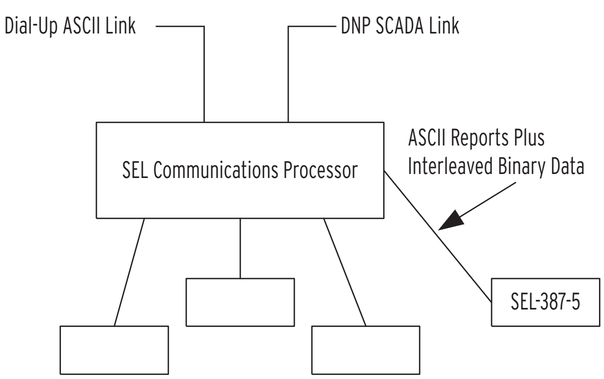


Figure 7 Example Communication System

SEL communications processors are often applied as the hub of a star network, with point-to-point fiber or copper connection between the hub and the SEL-387. The communications processor supports external communications links including the public switched telephone network for engineering access to dial-out alerts and private line connections to your SCADA system.

SEL manufactures a variety of standard cables for connecting this and other relays to a variety of external devices. Consult your SEL representative for more information on cable availability.

Control Logic and Integration

Control logic for the SEL-387-5 and SEL-387-6 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 up to 16 traditional latching relays for such functions as "remote control enable" with latch control switches. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the nonvolatile latch control switches via optoisolated inputs, remote control switches, local control switches, or any programmable logic condition. The latch control switches retain their state when the relay loses power.
- **Replaces traditional indicating panel lights.** Replace traditional indicating panel lights with 16 programmable displays. Define custom 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.

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 current (50/51) and directional level detecting elements, timer elements, SELogic control 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 within 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 for 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 current 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-387 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

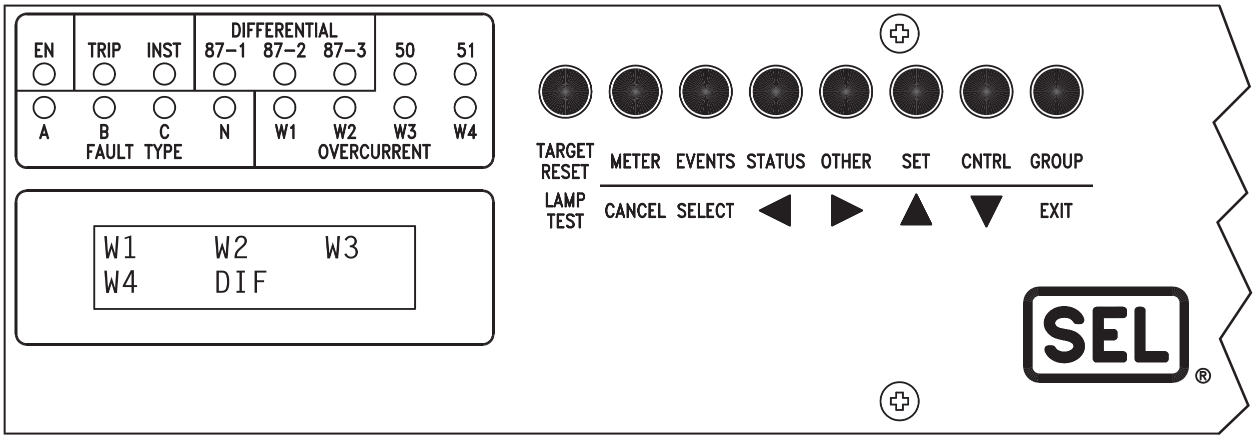


Figure 8 Status and Trip Target LEDs, Front-Panel Display, and Pushbuttons

A close-up view of the user interface portion of the SEL-387 front panel is shown in *Figure 8*. It includes a 2-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. The display is controlled 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 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} pushbutton returns the display to the default display, if the relay is performing some other front-panel function.

Error messages such as self-test failures are displayed on the LCD in place of the default display when they occur.

During power up, the LCD displays “Initializing.” It will then scroll through the winding current and voltage displays until the relay is again enabled. When the EN LED indicates the relay is enabled, the active Display Points will be scrolled.

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 due to an instantaneous overcurrent, definite-time overcurrent, or current differential element operation.
DIFFERENTIAL 87-1, 87-2, 87-3	A current differential element operated.
50	Trip resulting from an instantaneous or definite-time overcurrent element.
51	Trip resulting from an inverse-time-overcurrent element.
FAULT TYPE	
A, B, C	Phases involved in the fault.
N	Ground involved in the fault.
OVERCURRENT W1, W2, W3, W4	Windings involved in the fault.

The SEL-387 includes 16 status and trip target LEDs on the front panel. These targets are shown in *Figure 8* 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 states of the 12 dedicated LEDs (all but EN, A, B, C) are stored in nonvolatile memory. If power to the relay is lost, these 12 targets will be restored to their last state when power is restored.

Model Options

The SEL-387-0 has provided sophisticated and reliable service for many years. It continues to satisfy the needs of many of our customers. However, we recommend using either the SEL-387-5 or the SEL-387-6 for new designs because of the enhanced features they provide. The SEL-387-6 differs from the SEL-387-5 in that it includes a transformer thermal model with protection elements and reporting functions.

Table 5 Model Option Differences

Features	SEL-387-5, SEL-387-6	SEL-387-0
Local Control Switches	16	None
Latch Control Switches	16	8
Binary SER	Standard	Not available
CT Ratios	Allow mismatched in combined current elements	Require equal in combined current elements
DNP3 Level 2 Slave	An option	Not offered
Through-Fault Monitor	Yes	Not available
Temperature Monitoring	Yes	Not available
ACSELERATOR QuickSet Support	Yes	Not available

The base model SEL-387 has 8 output contacts and 6 optoisolated inputs. All SEL-387 models include the option of an additional 12 outputs and 8 inputs, or, for the SEL-387-6, an additional 16 inputs and 4 outputs. Assign the inputs for control functions, monitoring logic, and general indication. Except for a dedicated alarm output, each output contact is programmable through use of SELOGIC control equations.

Application Examples

Two Circuit Breakers on Both High- and Low-Voltage Sides

Figure 9 illustrates a typical application of a four-restraint winding relay on a two-winding transformer. When the SEL-387-5 is applied in this manner, each of the four current transformers can have a different ratio. The SEL-387-5 combined overcurrent backup functions operate on the sum of two of the individual winding current inputs—the sum of the currents in the Winding 1 and Winding 2 inputs and/or the sum of the currents in the Winding 3 and Winding 4 inputs. This arrangement allows you to set overcurrent functions, one phase and one residual, for each transformer winding.

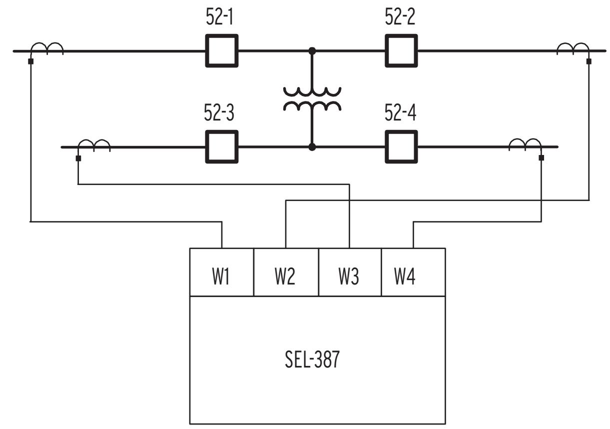


Figure 9 Two Circuit Breakers on High and Low Sides

Combined Transformer and Low-Voltage Bus Differential Protection

Figure 10 shows how one SEL-387-5 provides both transformer differential and low-side bus differential protection. The transformer differential protection comes from CT1 and CT2A, which connect to the SEL-387-5 Winding 1 and Winding 2 current inputs. The combined differential application shown in *Figure 10* generally does not use the combined currents for Winding 1 and Winding 2.

CT2B and the feeder breaker CTs supply low-voltage bus differential protection. *Figure 10* shows three feeders, but the bus differential protection can be used with additional feeder breakers. The current from CT2B is applied to the Winding 3 input of the SEL-387-5, while the currents from the feeders (CT3, CT4, and CT5) are connected in parallel and applied to the Winding 4 input. The bus differential connections are based on the assumption that all of the feeder current transformers have the same ratio. If the feeder current transformers do not have the same ratio, then this scheme cannot be applied. If all of the current transformers used in the bus differential protection (including CT2B) have the same ratio, you can parallel all of low-side CTs into one of the SEL-387-5 winding current inputs. The overcurrent elements associated with that winding current input would then be used for the bus differential protection. For the bus differential protection shown in *Figure 10*, the feeders can contribute fault current for a bus fault.

However, when the ratio of CT2B varies from that of the feeder CTs, the connections of *Figure 10* must be used. In this case the combined time-overcurrent elements for Winding 3 and Winding 4 are used for the bus differential protection.

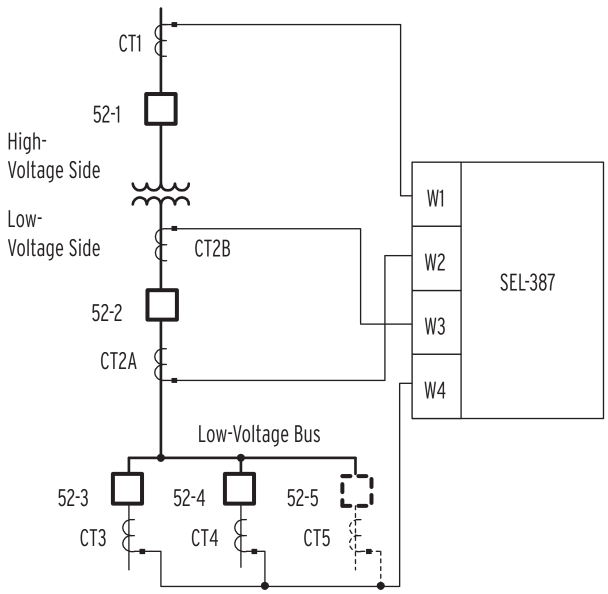


Figure 10 Combined Transformer and Low-Voltage Bus Differential Protection

Transformer Fed From a Tapped Transmission Line

In *Figure 11*, avoiding the need for a high-side breaker at the transformer saves significant costs. When a fault occurs in the transformer, the SEL-387 detects the fault and asserts an output contact. The SEL-2100 Logic Processor detects the output contact change-of-state and sends a direct transferred trip MIRRORED BITS® message to the remote line relays via optical fiber. The line relays then immediately trip Breakers 52-1 and 52-2, isolating the fault.

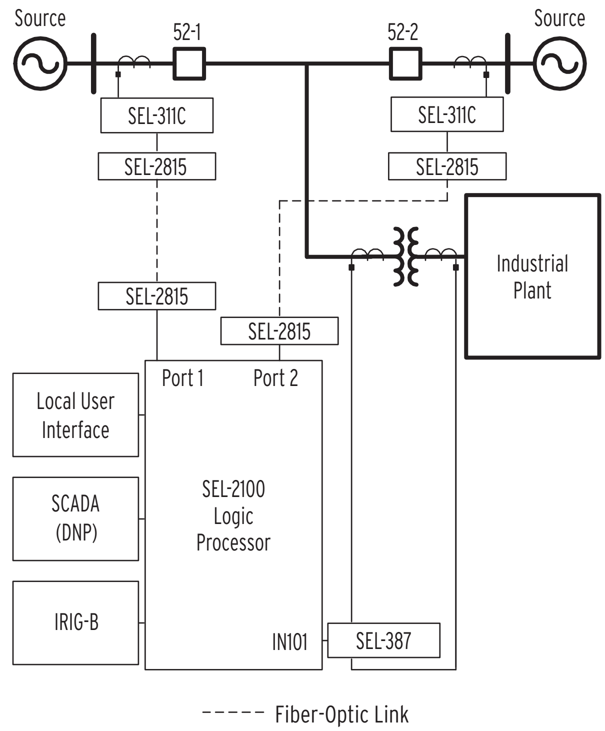


Figure 11 Transformer Fed From Tapped Transmission Line

Wiring Diagrams

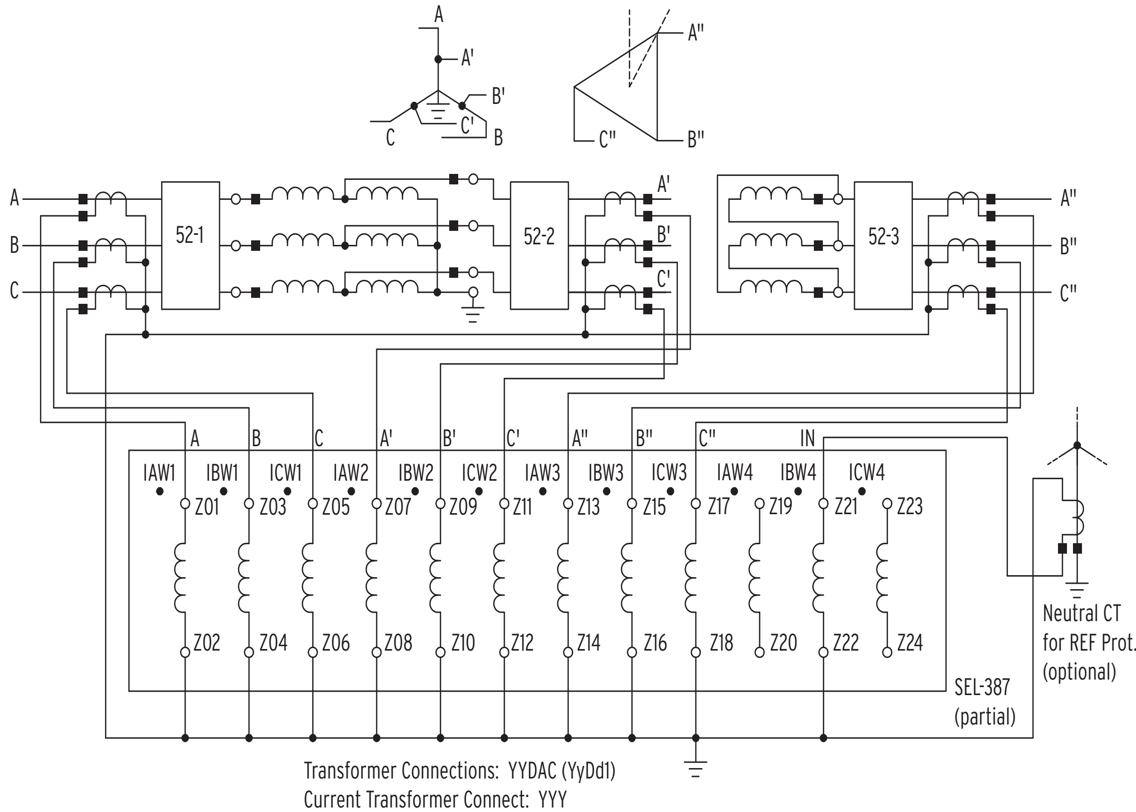


Figure 12 Typical AC Connection Diagram, Three-Winding Autotransformer Application

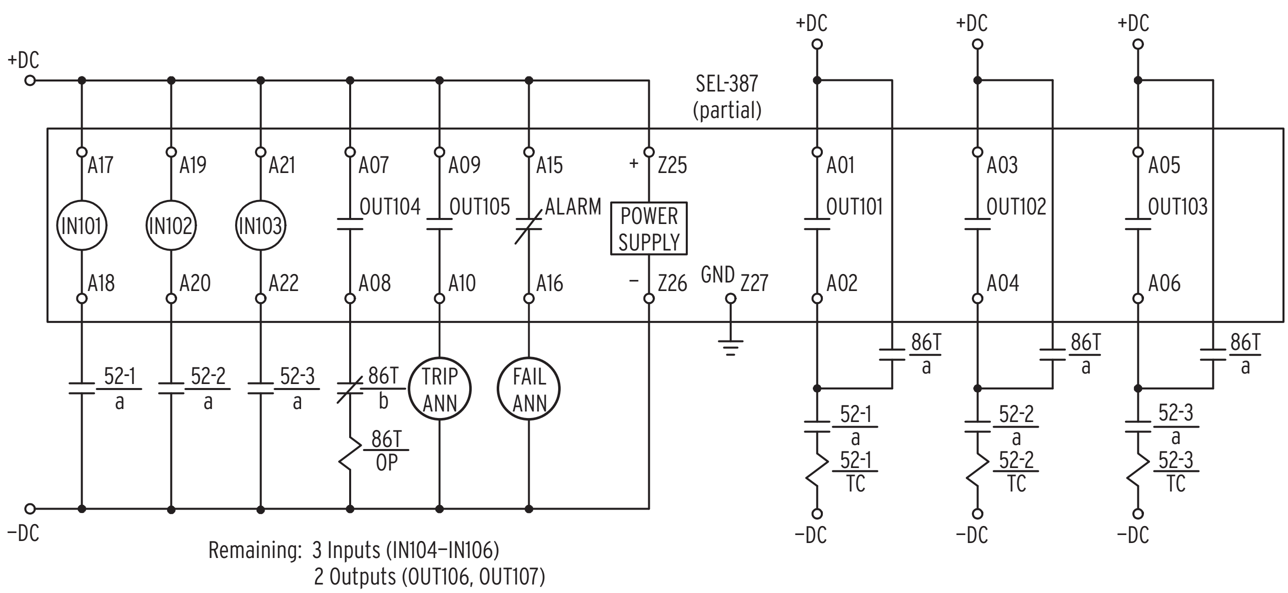
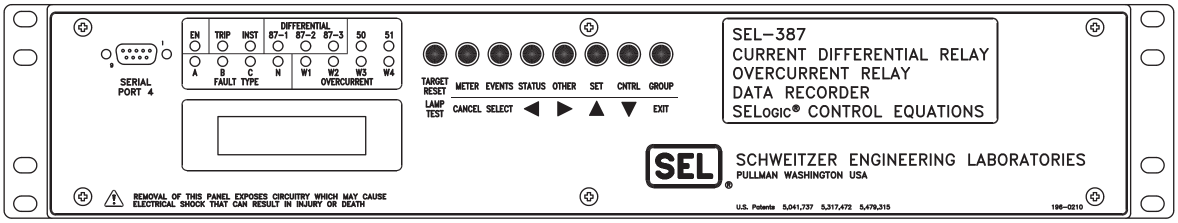


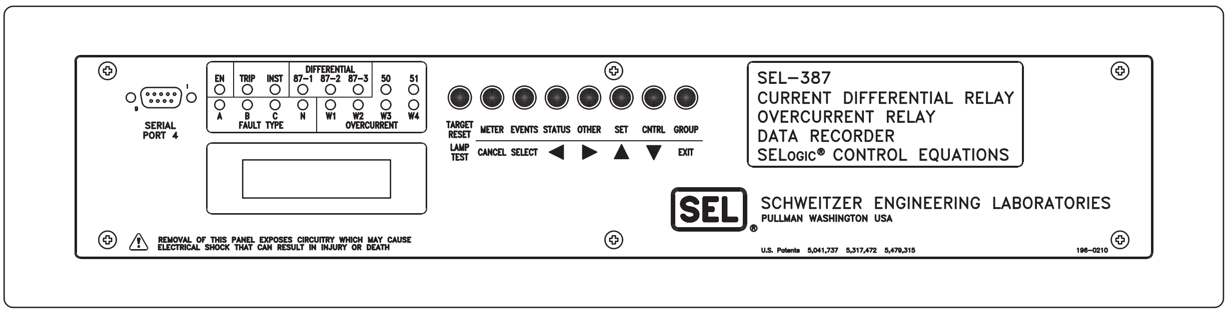
Figure 13 Typical DC Connection Diagram, Three-Winding Transformer Application

Front- and Rear-Panel Diagrams



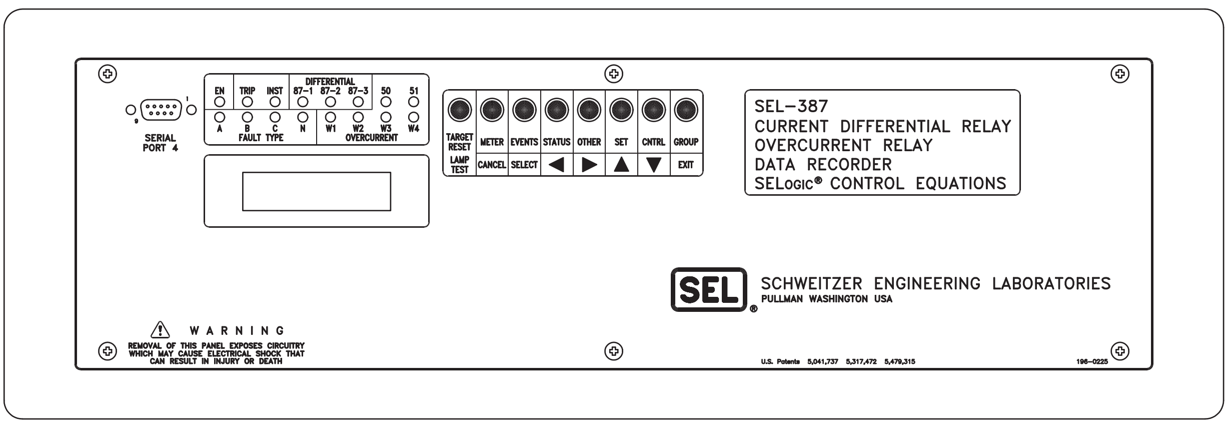
i3008b

2U Rack-Mount Front Panel



i3011a

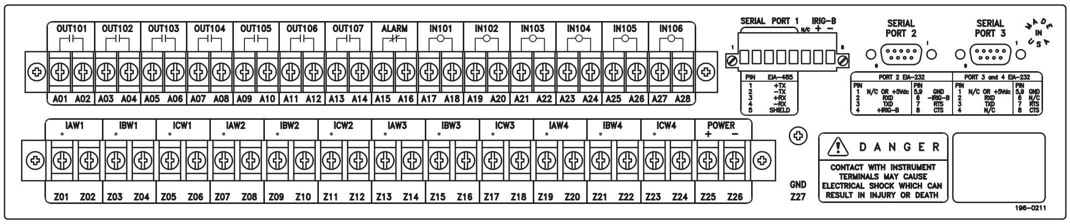
2U Panel-Mount Front Panel



i3014a

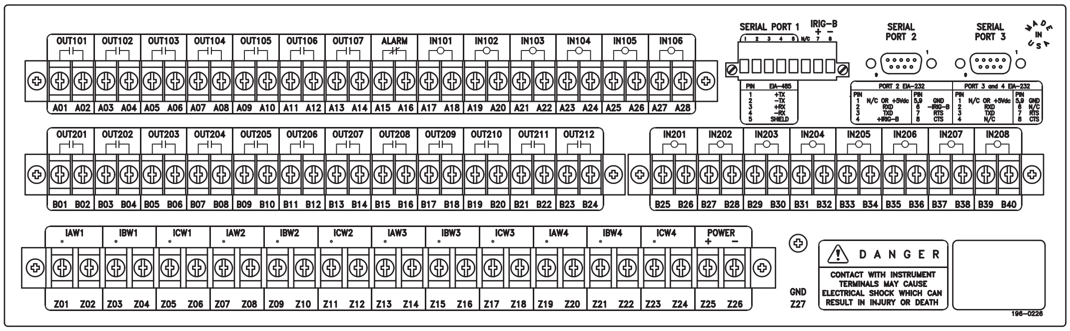
3U Panel-Mount Front Panel

Figure 14 SEL-387 Front Panels



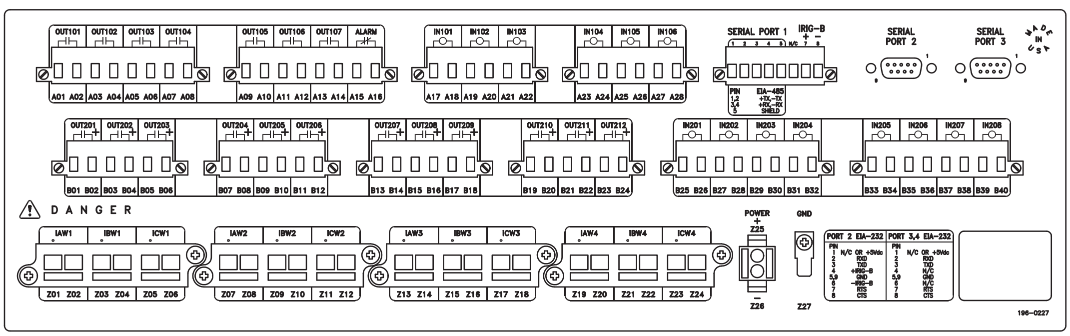
i3009c

2U Screw-Terminal Rear Panel, No Additional I/O Board



i3013c

3U Screw-Terminal Rear Panel, Additional I/O Board

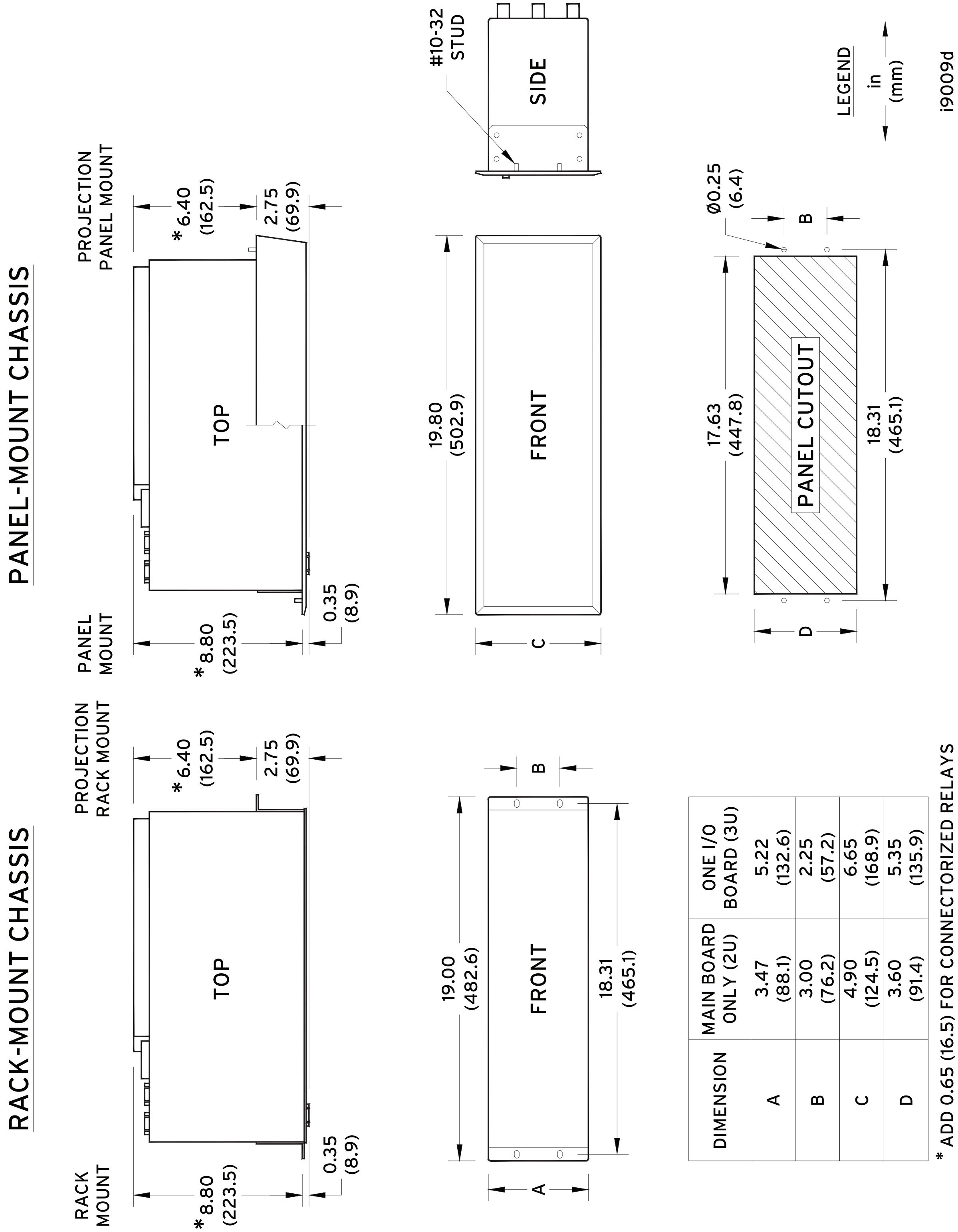


i3015b

3U Connectorized® Rear Panel, Additional I/O Board

Figure 15 SEL-387 Rear-Panel Diagrams

Relay Dimensions



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

* ADD 0.65 (16.5) FOR CONNECTORIZED RELAYS

Figure 16 SEL-387 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
RCM Mark

General

AC Current Inputs

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

Power Supply

125/250 Vdc or Vac

Range:	85–350 Vdc or 85–264 Vac
Burden:	<25 W
Interruption:	45 ms at 125 Vdc
Ripple:	100%

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%

24/48 Vdc

Range:	18–60 Vdc polarity dependent
Burden:	<25 W
Interruption:	110 ms at 48 Vdc
Ripple:	100%

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

Output Contacts

Standard:

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection:	270 Vac/360 Vdc; 130 J
Pickup Time:	<5 ms
Dropout Time:	<5 ms, typical

Breaking Capacity (10,000 Operations):

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

Cyclic Capacity (2.5 Cycles/Second):

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

High-Current Interrupting Option

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection:	330 Vdc; 130 J
Pickup Time:	<5 ms
Dropout Time:	<8 ms, typical

Breaking Capacity (10,000 Operations):

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

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

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

Note: Do not use high current interrupting output contacts to switch ac control signals. These outputs are polarity dependent.
Note: Make per IEEE C37.90-1989; Breaking and Cyclic Capacity per IEC 60255-23:1994.

Optoisolated Inputs

Contact inputs have a fixed, 1/4-cycle debounce time

250 Vdc:	Pickup 200–300 Vdc; Dropout 150 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout 132 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout 75 Vdc
110 Vdc:	Pickup 88–132 Vdc; Dropout 66 Vdc
48 Vdc:	Pickup 38.4–60 Vdc; Dropout 28.8 Vdc
24 Vdc:	Pickup 15.0–30 Vdc

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

Frequency and Rotation

System Frequency:	50 or 60 Hz
Phase Rotation:	ABC or ACB

Communications Ports

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

Operating Temperature

–40° to +85°C (–40° to +185°F)

Time-Code Input

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

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 2001-03, *Installing and Servicing Connectors for Connectorized® Relays*)

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

Terminal Connections

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

Routine Dielectric Strength

AC current inputs:	2500 Vac for 10 s
Power supply, optoisolated inputs, and output contacts:	3100 Vdc for 10 s

Weight

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

Type Tests

Emissions

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

Note: * = Terminal Block version only.

Environmental Tests

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

Dielectric Strength and Impulse Tests

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

Electrostatic Discharge Test

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

RFI and Interference Tests

1 MHz Burst Disturbance:	IEC 60255-22-1:1988 Class 3
Fast Transient Disturbance:	IEC 60255-22-4:1992 IEC 61000-4-4:1995 Level 4
Radiated EMI:	IEC 60255-22-3:1989 ENV 50140:1993 IEEE C37.90.2-1995 35 V/m
Surge Withstand:	IEEE C37.90.1-1989 3.0 kV oscillatory; 5.0 kV fast transient

Vibration and Shock Tests

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

Object Penetration

Object Penetration:	IEC 60529:1989 IP30, IP54 from the front panel using the optional SEL-9103 front- cover dust and splash protection

Processing Specifications

64 samples per power system cycle

Metering Accuracy

5 A Model

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

1 A Model

Phase Currents:	±1.5% ±0.02 A and ±1.5°
Sequence Currents:	±3.0% ±0.02 A and ±2.0°
Differential Quantities:	±5.0% ±0.02 A
2nd and 5th Harmonic:	±5.0% ±0.02 A
Current Harmonics:	±5.0% ±0.02 A

Substation Battery Voltage Monitor

Pickup Range:	20–300 Vdc
Pickup Accuracy:	±2% of setting

Relay Elements

Differential Element

Unrestrained Pickup Range:	1–20 in per unit of tap
Restrained Pickup Range:	0.1–1.0 in per unit of tap

Pickup Accuracy (A secondary)

5 A Model:	±5% ±0.10 A
1 A Model:	±5% ±0.02 A
Unrestrained Element Pickup Time:	0.8/1.0/1.9 cycles (Min/Typ/Max)

Restrained Element (with harmonic blocking) Pickup Time:	1.5/1.6/2.2 cycles (Min/Typ/Max)
Restrained Element (with harmonic restraint) Pickup Time:	2.62/2.72/2.86 cycles (Min/Typ/Max)

Harmonic Element

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

Winding Instantaneous/Definite-Time Overcurrent Elements

Pickup Ranges (A secondary)	
5 A Model:	0.25–100.00 A
1 A Model:	0.05–20.00 A
Pickup Accuracies (A secondary)	
5 A Model:	
Steady State:	±3% ±0.10 A
Transient:	±5% ±0.10 A
1 A Model:	
Steady State:	±3% ±0.02 A
Transient:	±5% ±0.02 A

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

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

Winding and Combined Current Time Overcurrent Elements

Pickup Ranges (A secondary)	
5 A Model:	0.5–16.0 A
1 A Model:	0.1–3.2 A
Pickup Accuracies (A secondary)	
5 A Model:	
Steady State:	±3% ±0.10 A
Transient:	±5% ±0.10 A
1 A Model:	
Steady State:	±3% ±0.02 A
Transient:	±5% ±0.02 A

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

Curve	
U1 =	U.S. Moderately Inverse
U2 =	U.S. Inverse
U3 =	U.S. Very Inverse
U4 =	U.S. Extremely Inverse
U5 =	U.S. Short-Time Inverse
C1 =	IEC Class A (Standard Inverse)
C2 =	IEC Class B (Very Inverse)
C3 =	IEC Class C (Extremely Inverse)
C4 =	IEC Long-Time Inverse
C5 =	IEC Short-Time Inverse
Time-Dial Range	
US Curves:	0.50–15.00
IEC Curves:	0.05–1.00
Timing Accuracy:	±4% ±1.5 cycles for current between 2 and 30 multiples of pickup
Reset Characteristic:	Induction-disk reset emulation or 1 cycle linear reset

This product is covered by the standard SEL 10-year warranty. For warranty details, visit selinc.com or contact your customer service representative.

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