

SEL-487E

Transformer Protection Relay

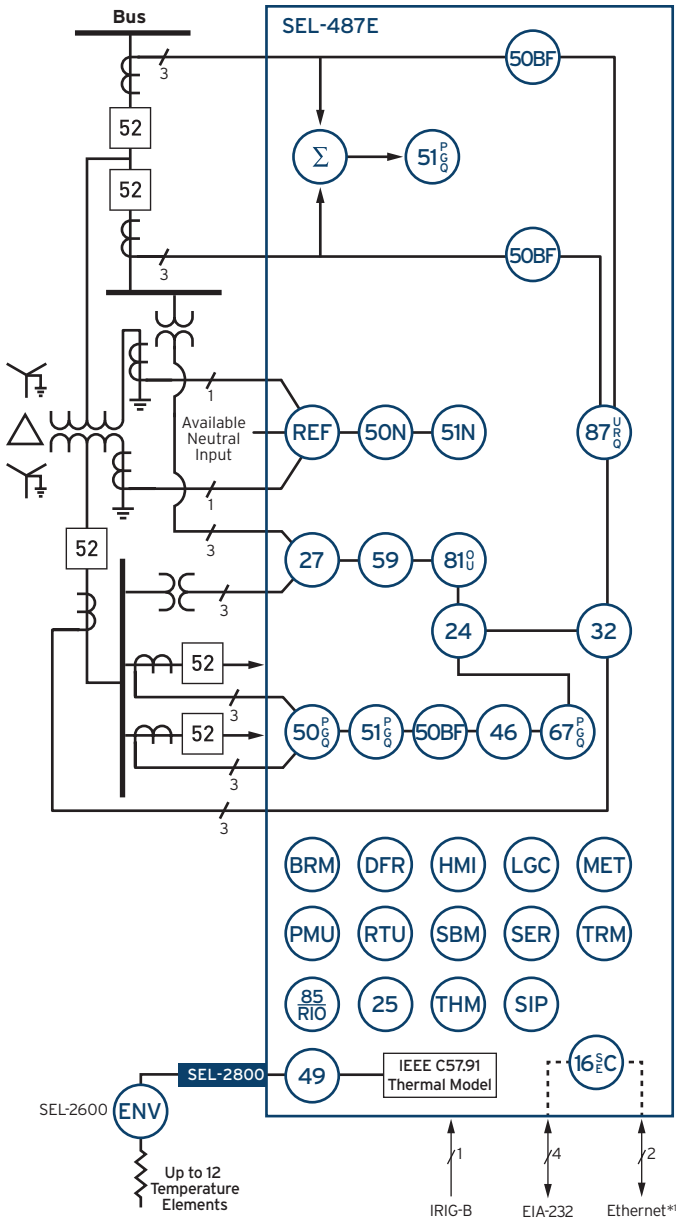


High-speed transformer differential protection for up to five terminals

- Advanced differential protection and three restricted earth fault (REF) elements minimize damage and expensive repairs to transformers.
- Through-fault, thermal, and circuit breaker monitoring provide comprehensive substation asset management.
- Industry-leading synchrophasors monitor the overall system status.
- Time-Domain Link (TiDL[®]) technology allows you to implement a digital secondary system in the simplest way possible.



Functional Overview



ANSI Number/Acronyms and Functions

16 SEC	Access Security (Serial, Ethernet)
24	Volts/Hertz
25	Synchronism Check
27	Undervoltage
32	Directional Power
46	Current Unbalance
49	Thermal
50BF	Breaker Failure Overcurrent
50N	Neutral Overcurrent
50 (P,G,Q)	Overcurrent (Phase, Ground, Neg. Seq.)
51N	Neutral Time-Overcurrent
51 (P,G,Q)	Time-Overcurrent (Phase, Ground, Neg. Seq.)
59	Overvoltage
67 (P,G,Q)	Directional Overcurrent (Phase, Ground, Neg. Seq.)
81 (O,U)	Over-/Underfrequency
85 RIO	SEL MIRRORED BITS® Communications
87 (U,R,Q)	Transformer Differential (Unrestrained, Restrained, Neg. Seq.)
DFR	Event Reports
ENV	SEL-2600
HMI	Operator Interface
LGC	Expanded SELogic® Control Equations
MET	High-Accuracy Metering
PMU	Synchrophasors
REF	Restricted Earth Fault
RTU	Remote Terminal Unit
SER	Sequential Events Recorder

Additional Functions

BRM	Breaker Wear Monitor
LDP	Load Data Profiling
SBM	Station Battery Monitor
SIP	Software-Invertible Polarities
THM	IEC 60255-Compliant Thermal Model
TiDL	Time-Domain Link Technology*
TRM	Transformer Monitor

*Copper or fiber-optic *Optional feature

Key Features

Multiwinding Protection

Configure the SEL-487E Transformer Protection Relay for differential protection in transformer applications using up to five restraint currents. This includes single transformers with tertiary windings. Three independent REF elements offer protection for grounded-wye windings. You can invert individual or grouped CT or PT polarities to account for field wiring or protection zone changes.

High-Speed, Adaptive Differential Protection

Implement a two-stage slope that automatically adapts to internal or external fault conditions, even with CT saturation and heavily distorted waveforms, for fast, sensitive, dependable, and secure differential protection. The adaptive differential element responds to internal fault conditions in less than 1.5 cycles.

Diverse Transformer Applications

Protect large transformers and autotransformers with breaker-and-a-half high- and low-side connections. You can configure the SEL-487E for a typical two-winding transformer application and use the remaining three-phase current inputs for feeder backup protection.

Sensitive Turn-to-Turn Fault Detection

The patented negative-sequence differential element detects turn-to-turn faults involving as little as 2 percent of the total winding, helping avoid catastrophic transformer failure.

Dependable Backup Protection

Provide backup protection with five phase, negative-sequence, and zero-sequence overcurrent elements and ten configurable time-overcurrent elements. By setting up breaker failure protection with subsidence detection, you can rapidly detect breaker failure and minimize system coordination times.

Generator Step-Up Protection

Protect generator step-up (GSU) transformers with built-in temperature measurement (requires the SEL-2600 RTD Module) that monitors generator and transformer winding temperatures simultaneously. In addition, the volts/hertz element provides overexcitation protection for loaded and unloaded generator operating conditions. By setting the directional power elements to detect forward and reverse power flow conditions, you can monitor and protect the GSU transformer in prime-power, standby, base-load, and peak-shaving applications. Built-in synchronism-check elements verify the generator breaker synchronization.

Advanced Asset Monitoring

Track transformer wear with through-fault and thermal monitoring. Advanced breaker monitoring reduces inefficient and costly breaker maintenance. You can also monitor substation dc power systems for out-of-tolerance voltage levels or excessive voltage ripple.

Station Phasor Measurement Unit (PMU)

Improve power quality with IEEE C37.118 synchrophasors from all 24 analog channels (6 voltage and 18 current sources) in your relay. Using synchrophasors over serial or Ethernet communications, you can easily detect reactive loop flows, turn state estimation into state measurement, and provide early warning of potential system instability. Real-time control is possible by receiving synchrophasor messages from two PMUs, and you can take action based on time-synchronized local and remote measurements.

TiDL Technology

Modernize your substation by applying the TiDL-enabled SEL-487E and SEL-2240 Axion® TiDL nodes. In a TiDL system, the Axion TiDL node provides remote I/O, digitizes analog signals, and sends these signals over fiber-optic cables to the relay. This simple and secure digital secondary system solution is easy to implement, with no external time source or network engineering required. Replacing copper wires with fiber-optic cables increases safety, reduces costs associated with using copper wires, improves reliability, and limits the impact of electromagnetic interference.

Product Overview

EIA-232 front serial port is quick and convenient for system setup and local access.

LCD allows you to control and view the status of disconnects and breakers.



Easy-to-use keypad aids simple navigation.

Front-panel LEDs indicate custom alarms and provide fast and simple information to assist dispatchers and line crews with rapid power restoration.



Programmable operator pushbuttons with user-configurable labels allow front-panel customization.

Choose from a vertical (5U only) or horizontal, panel-mount or rack-mount chassis and different size options.



The 18 current and 6 voltage channels support transformer differential protection for up to 5 three-phase terminals, 3 independent REF elements, and voltage elements.

Communications protocols include FTP, Telnet, synchrophasors, DNP3 LAN/WAN, the Parallel Redundancy Protocol (PRP), the IEEE 1588 Precision Time Protocol Version 2 (PTPv2),** and IEC 61850 Edition 2.*

Use one front and three rear EIA-232 ports for MIRRORRED BITS communications, DNP3, SCADA, and engineering access.



Connectorized® hardware configuration or a Euro connector with low-energy analog (LEA) voltage inputs provide flexibility for different line voltage sensors or optical voltage transformers.

Choose from power supply options such as 24–48 Vdc; 48–125 Vdc or 110–120 Vac; or 125–250 Vdc or 110–240 Vac.

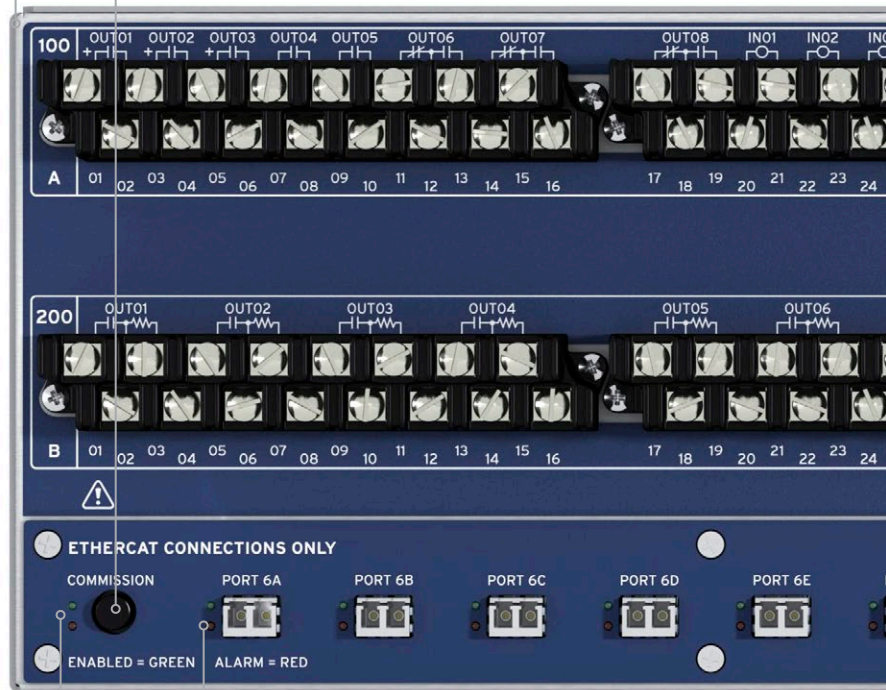
*Optional feature.

**For PTPv2 implementation, Ports 5A and 5B must be ordered as an option.

Product Overview—TiDL Option

4U chassis with horizontal mounting options (panel or rack) accommodates your application needs.

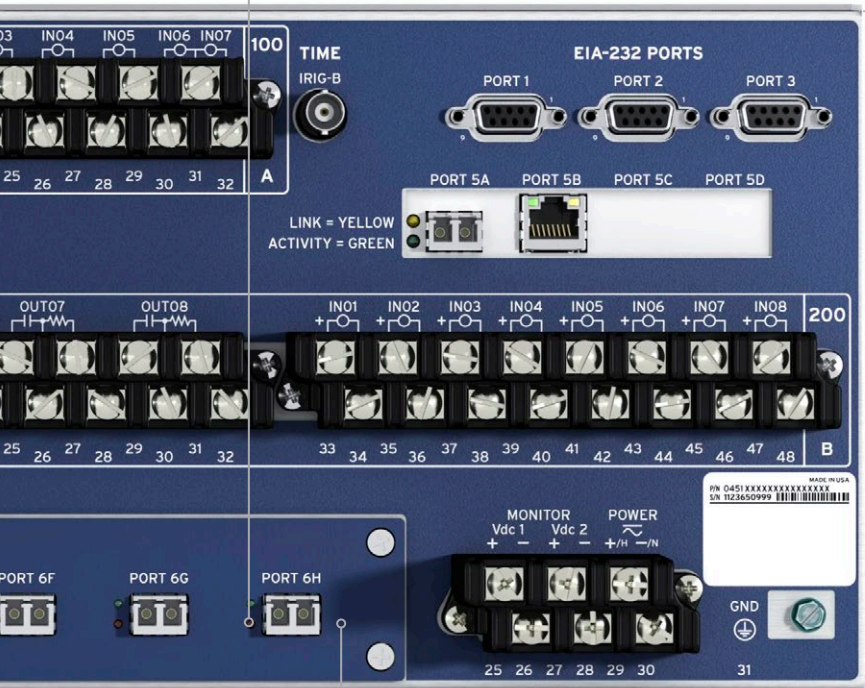
Commission button usage prompts the relay to communicate with the Axion TiDL nodes.



LEDs indicate a valid configuration and successful commissioning.

Eight 100 Mbps fiber-optic ports allow the TiDL-enabled relay to connect with eight remote Axion TiDL nodes and to receive remote analog and digital data.

LEDs indicate the connection status to a remote Axion TiDL node on a per-port basis.



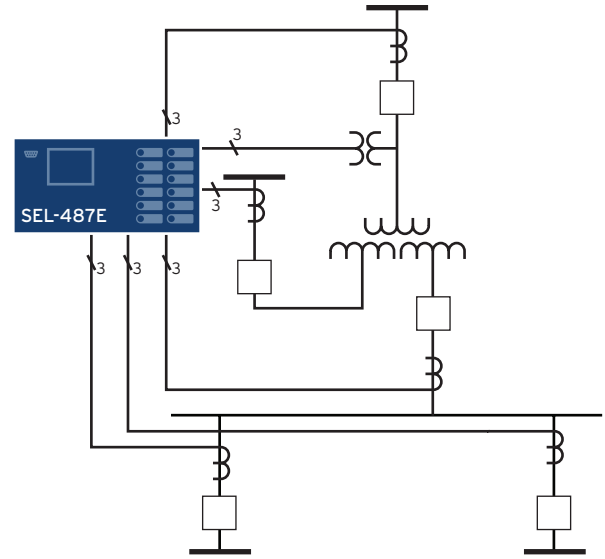
Applications

Multiwinding Differential Transformer Protection

Provide current differential protection for up to five 3-phase terminals with an adaptive-slope percentage restraint for transformers at power plants, transmission substations, distribution substations, and industrial plants. The adaptive differential element includes two slope settings. During normal operating conditions, Slope 1 provides a fast response to internal faults. For external faults, the relay switches from Slope 1 to Slope 2 to provide a high-security mode and avoid misoperation from CT saturation. When the operating quantities exceed the differential slope characteristic and fall in the operate region, the filtered differential element asserts. You can use the remaining 3-phase current inputs for feeder backup protection.

Combine harmonic-blocking and -restraint functions in parallel to provide secure operation and optimum operating speed during inrush conditions. Second- and fourth-harmonic blocking provide security during energization, while fifth-harmonic blocking provides security for overexcitation conditions. Fast subcycle external fault detection supervision adds security during external faults that have CT saturation.

Use the waveform-based inrush detection method to augment the harmonic-blocking and -restraint functions to prevent differential element operation during an inrush condition with low second-harmonic content. Low harmonic content is typical for newer transformers with cores that are made out of an improved iron core type, which has a different B-H characteristic (linear for high values of field intensity) than traditional transformers. In addition to the inrush detection algorithm, the waveform-based method also has a bidirectional differential overcurrent scheme that differentiates between an internal fault and an inrush condition.



Protection Using Any Combination of Nominal CT Inputs

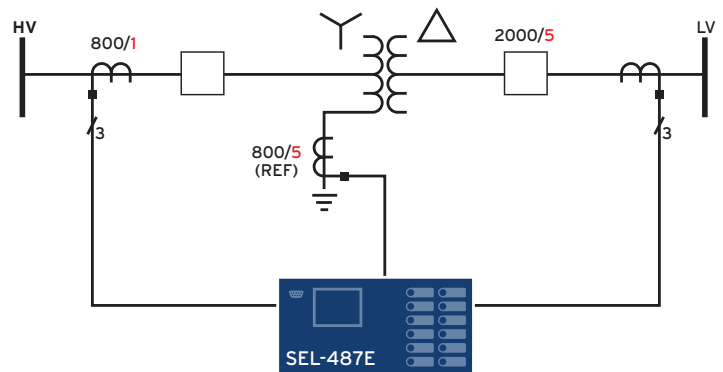
You can order any combination of nominal CT inputs at 5 A and 1 A for each transformer winding, including the following examples:

- 1 A on high-voltage side, 5 A on low-voltage side.
- 1 A on high-voltage side, 5 A on low-voltage side, 1 A on tertiary side.

Support up to 35:1 CT ratio mismatch without a loss of performance.

Possible applications include:

- Breaker-and-a-half installation.
- Busbar protection for up to five terminals with mismatched CT ratios.

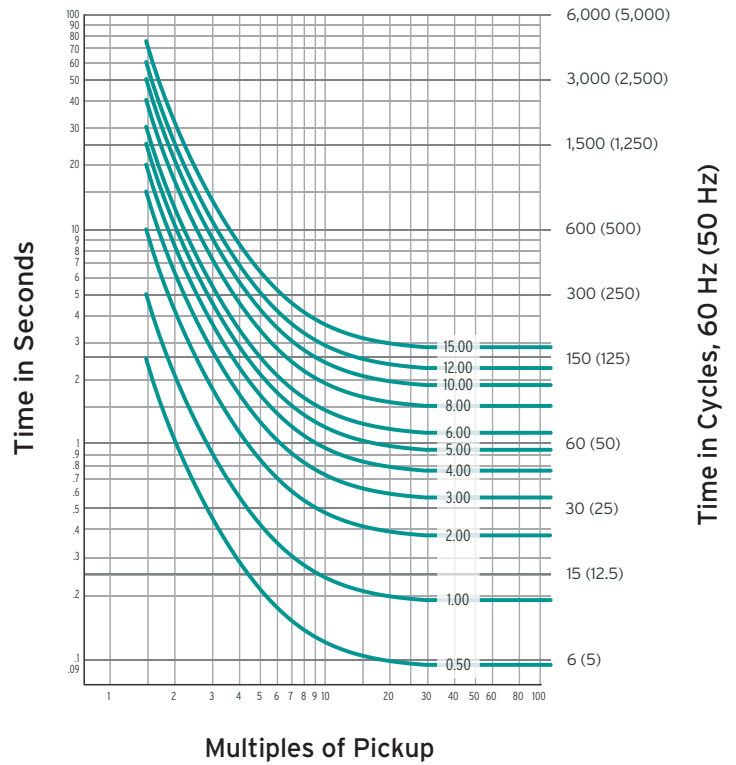


Comprehensive Time-Overcurrent Protection

Eliminate the need to change settings groups to accommodate different time-overcurrent pickup and time dial settings. The programmable time-delay and pickup levels in the selectable time-overcurrent elements allow the pickup and time-delay settings to change instantly, without needing to switch settings groups. You can choose from ten time-overcurrent curves.

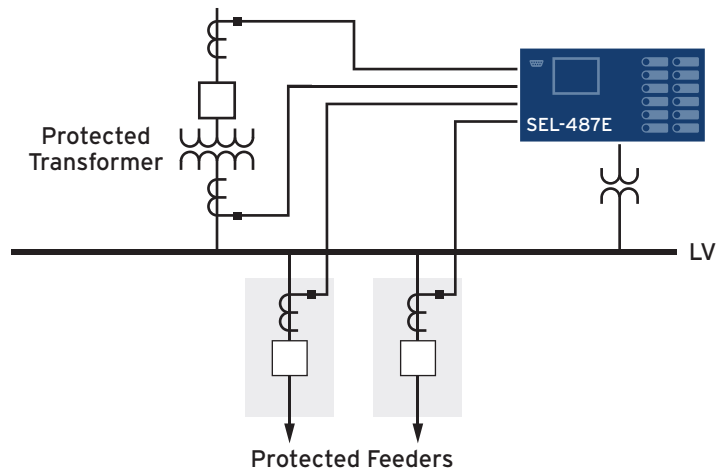
Programming the time-delay and pickup levels as math variables allows the numeric value of the pickup and time-delay settings to change based on any number of conditions, without the short delay of having to change relay settings groups. For example, you can change pickup and time-delay settings dynamically in a parallel-transformer application based on single- or parallel-transformer configurations. Another example would be to change feeder time-overcurrent element pickup and coordination delays based on distributed generation being connected downstream of a transformer.

U.S. Inverse Curve: U2



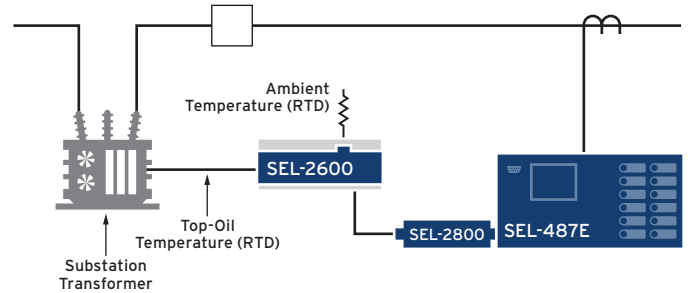
Flexible Backup Protection Using Directional Overcurrent Control Elements

When voltage inputs are connected to the SEL-487E, directional elements can supervise phase and ground overcurrent elements on a per-winding basis. The phase and ground directionally controlled overcurrent elements provide backup protection for transformer differential or feeder overcurrent relays. Voltage-polarized directional elements supervise currents that are on the same side of the transformer as the selected polarizing voltages.



Thermal Protection and Monitoring

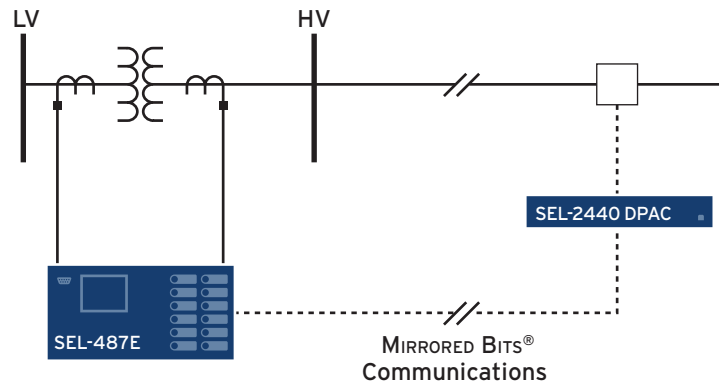
The SEL-487E provides the IEEE C57.91 and IEC 60255-149 thermal models for protection and monitoring the thermal response of top-oil and hotspot temperatures. Use the IEC thermal element to trip a breaker, or use either the IEC or the IEEE thermal elements to activate a control action or issue an alarm when the transformer is in danger of excessive insulation aging or loss of life. The relay includes three loss-of-insulation-life alarms: loss of life per day, total loss of life, and insulation aging factor.



Flexible Communications

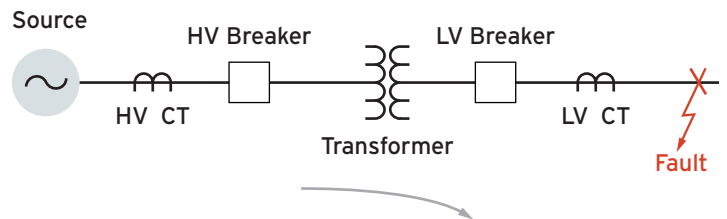
An Ethernet card option provides two copper or fiber ports for redundancy. Available Ethernet communications protocols include FTP, Telnet, the Simple Network Time Protocol (SNTP), DNP3 LAN/WAN, IEC 61850 Edition 2, IEEE C37.118 synchrophasors, the IEEE 1588 PTPv2, and PRP.

All four independent EIA-232 serial ports support SEL Fast Messages, SEL ASCII, Compressed ASCII, SEL Fast Operate, SEL Fast Meter, SEL Fast SER, enhanced SEL MIRRORING BITS communications, DNP3 Level 2 Outstation plus dial out, Virtual Terminal, and communications with the SEL-2600 (SEL-2800 Fiber-Optic Transceiver required).



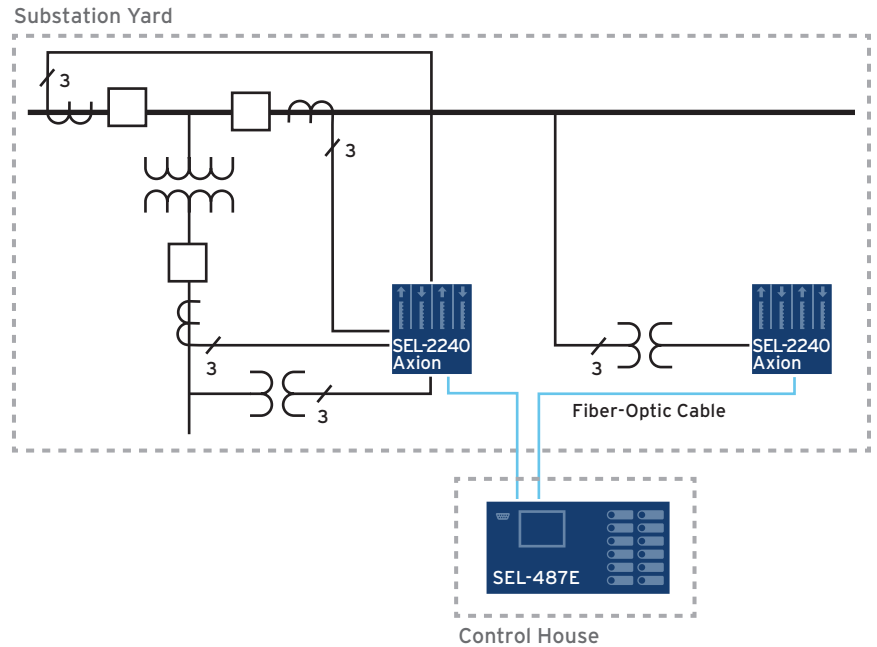
Through-Fault Monitoring

Track transformer wear with through-fault monitoring. You can gather current levels, the through-fault duration, and the date/time of each through fault. Through-fault currents can cause transformer winding displacement, leading to mechanical damage and increased transformer thermal wear. Monitoring cumulative through-fault duty helps you schedule proactive maintenance.



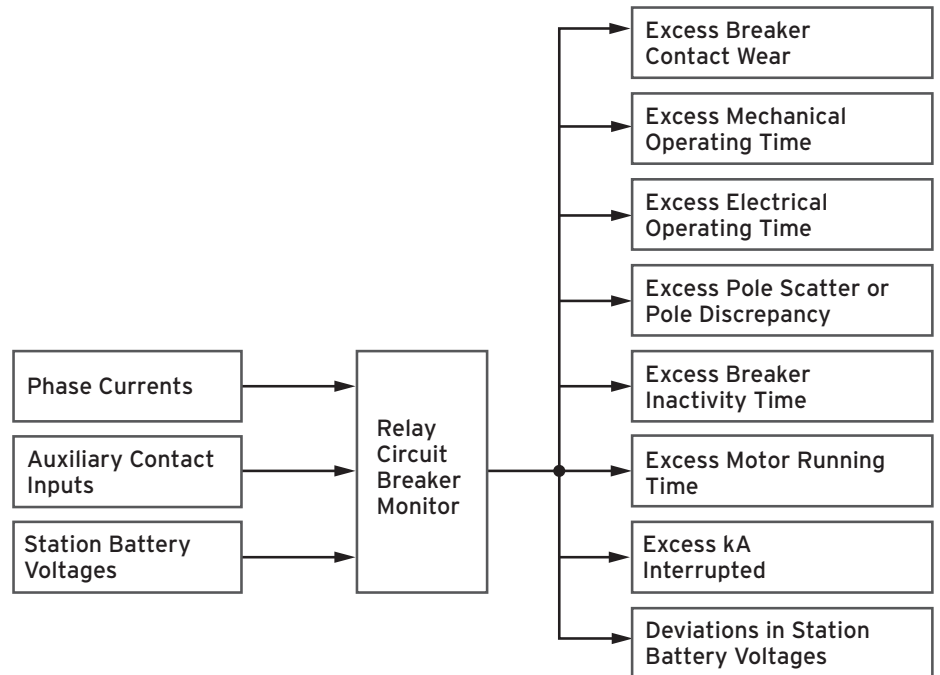
Substation Modernization With TiDL Technology

In a TiDL solution, Axion TiDL nodes in the yard close to the primary equipment will digitize discrete I/O signals and analog data. The nodes then transport these data over a fiber-optic cable to the TiDL-enabled SEL-487E in the control house. This innovative technology uses point-to-point connections and a nonroutable protocol, providing a simple and secure solution. Because it does not need an external time source or Ethernet switches, it is easy to implement with no network engineering required. TiDL combines the proven protection of the SEL-400 series relays with the modularity of the Axion, reducing training requirements and providing a scalable and flexible solution. It also provides built-in time synchronization and synchronous sampling, ensuring protection is available in the relay whether or not an external time signal is available.



Circuit Breaker Monitoring

The SEL-487E features advanced circuit breaker monitoring. The relay processes phase currents, circuit breaker auxiliary contacts, and substation dc battery voltages to detect out-of-tolerance and maximum-life circuit breaker parameters. These parameters include interrupted current, operating times, and contact wear. By using SEL-487E monitoring, maintenance personnel can determine the extent of a developing circuit breaker problem and select an appropriate response to correct the issue.



Synchrophasor Data for All CT and PT Channels

Improve power system quality and save money with SEL synchrophasors that are simultaneously available from all 24 analog channels (6 voltage and 18 current sources). With synchrophasors over serial or Ethernet communications, you can easily detect reactive loop flows, turn state estimation into state measurement, and provide early warning of potential system instability.

Simplify your system architecture and improve system operations with UDP multicast synchrophasor data. Configurable data streams allow you to select analog and binary information for up to five independent IEEE C37.118 data streams over Ethernet.

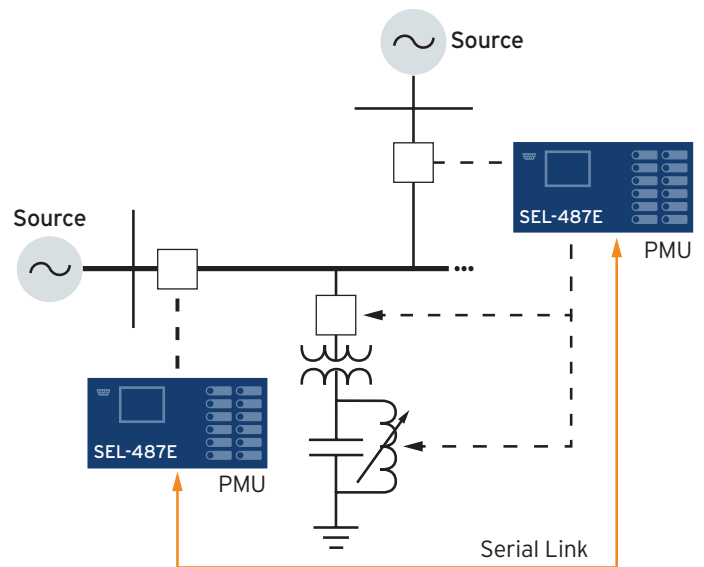


The SEL-487E exceeds the IEEE C37.118 standard with up to 50 messages per second at 50 Hz or up to 60 messages per second at 60 Hz.

Real-Time Control

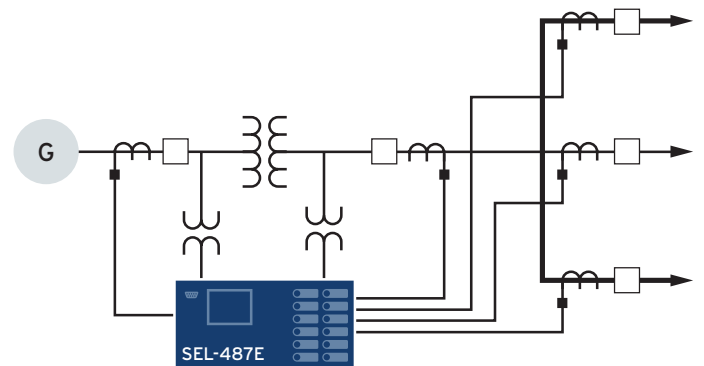
Improve system stability and reduce remote control requirements with real-time control. Direct relay-to-relay communication of synchrophasor values lets you apply remote measurements to local control. You can employ real-time values from remote transmission ends to control circuit breakers, static VAR compensators (SVCs), and power system stabilizers. The SEL-487E can control devices based on the voltage or current magnitude and phase angle, real or reactive power, or rate of change of the input quantities.

Share synchrophasor data between two or three SEL-487E Relays for special protection schemes or custom logic. Remote measurements are available in SELoLogic control equations for protection or automation.



Station-Wide Synchrophasor Application

The SEL-487E is also a station-wide synchrophasor measurement and recording system. With 120 seconds of IEEE C37.118 binary synchrophasor data recording for all 24 analog channels, it can serve as a central PMU in any substation or power generation facility. The SEL-487E measures voltage magnitudes and current phase angle relationships at generators and transformers, which are key source nodes for stability studies and load angle measurements.



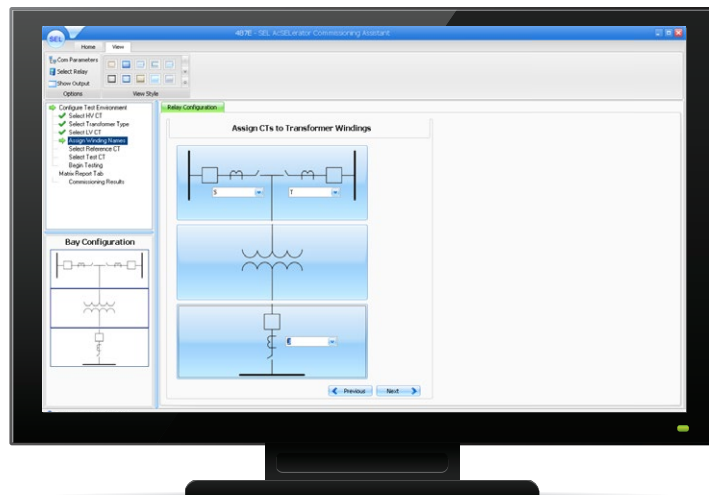
Setting and Commissioning Software

Save Time and Eliminate Costly Errors With SEL Commissioning Assistant Software

SEL Commissioning Assistant Software recommends matrix compensation settings after automatically identifying incorrect field wiring and improper CT configurations, such as incorrect CT polarities, inconsistent CT ratios, or crossed phases.

Apply the Commissioning Assistant in Five Easy Steps

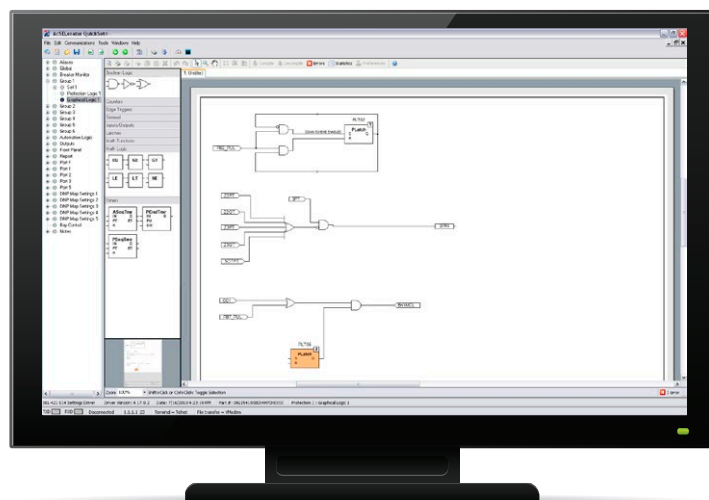
1. Define the system one-line diagram.
2. Assign any two windings to conduct a test.
3. Validate the current flow, CT ratios, and polarity.
4. Run the test to start the matrix calculation process.
5. Document and implement the correct compensation matrix recommended for the transformer application.



Simplify the SEL-487E Configuration Process With the Graphical Logic Editor (GLE)

With the GLE, you can view SELogic control equations graphically and document settings files for easier validation and commissioning. You can also convert existing SELogic control equations to easy-to-read diagrams and save diagrams with your ACSELERATOR QuickSet® SEL-5030 Software settings.

The GLE capability in QuickSet makes it easy to design new SELogic control equations with the convenient diagram navigation tool, drag-and-drop interface, function block diagrams, and automatic layout function. You can manage your control diagrams with a full element palette. The GLE aids in reducing design errors and reducing the time and expense of commissioning relays.



Specifications

General

AC Current Inputs (18 total)	5 A nominal 1 A nominal 1 A/5 A nominal (Y terminal only [REF])
AC Voltage Inputs (6 total)	300 V _{L-N} continuous, 600 Vac for 10 seconds
LEA Voltage Inputs	0–8 V _{L-N} continuous, 300 Vac for 10 seconds
Serial	1 front-panel and 3 rear-panel EIA-232 serial ports 300–57,600 bps
Ethernet	Communications protocols include FTP, Telnet, synchrophasors, DNP3 LAN/WAN, PRP, PTPv2, and IEC 61850 Edition 2 (optional). Choose from the following port options: Two 10/100BASE-T twisted-pair network ports Two 100BASE-FX fiber-optic network ports One 10/100BASE-T twisted-pair network port and one 100BASE-FX fiber-optic network port
TiDL Ports	Fiber-optic ports: 8 Range: ~2 km Data rate: 100 Mbps
Precise-Time Input	Demodulated IRIG-B time input and PTPv2
Synchrophasors	IEEE C37.118 standard Up to 60 messages per second
Processing	AC voltage and current inputs: 8,000 samples per second Protection and control processing: 8 times per power system cycle
Power Supply	24–48 Vdc 48–125 Vdc or 110–120 Vac 125–250 Vdc or 110–240 Vac
Operating Temperature	–40° to +85°C (–40° to +185°F) Note: LCD contrast is impaired for temperatures below –20°C (–4°F) and above +70°C (+158°F).

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+1.509.332.1890 | info@selinc.com | selinc.com

