SEL-451

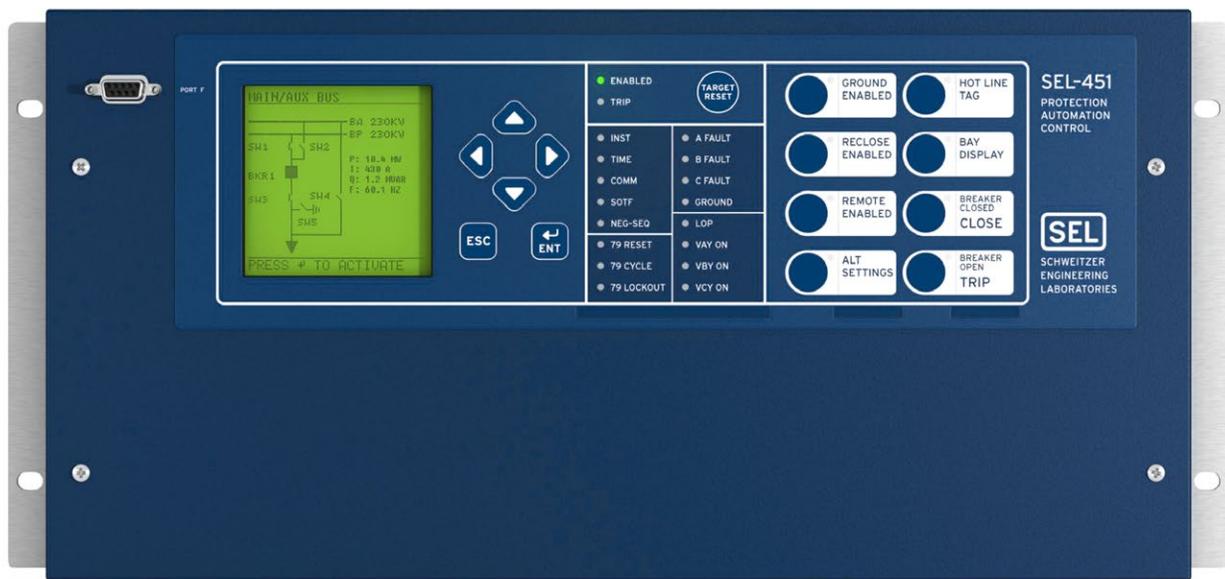## Protection, Automation, and Bay Control System

Advanced feeder protection and complete substation bay control in one economical system

- Customize distribution protection using multiple instantaneous, time-overcurrent, and directional elements.

- Detect high-impedance faults with Arc Sense™ technology (AST).

- Implement bay control with complete two-breaker control and high-speed breaker failure detection.

- Transform the way you modernize your substation with SEL Time-Domain Link (TiDL®) and Sampled Values (SV) technologies.

SEL

Functional Overview
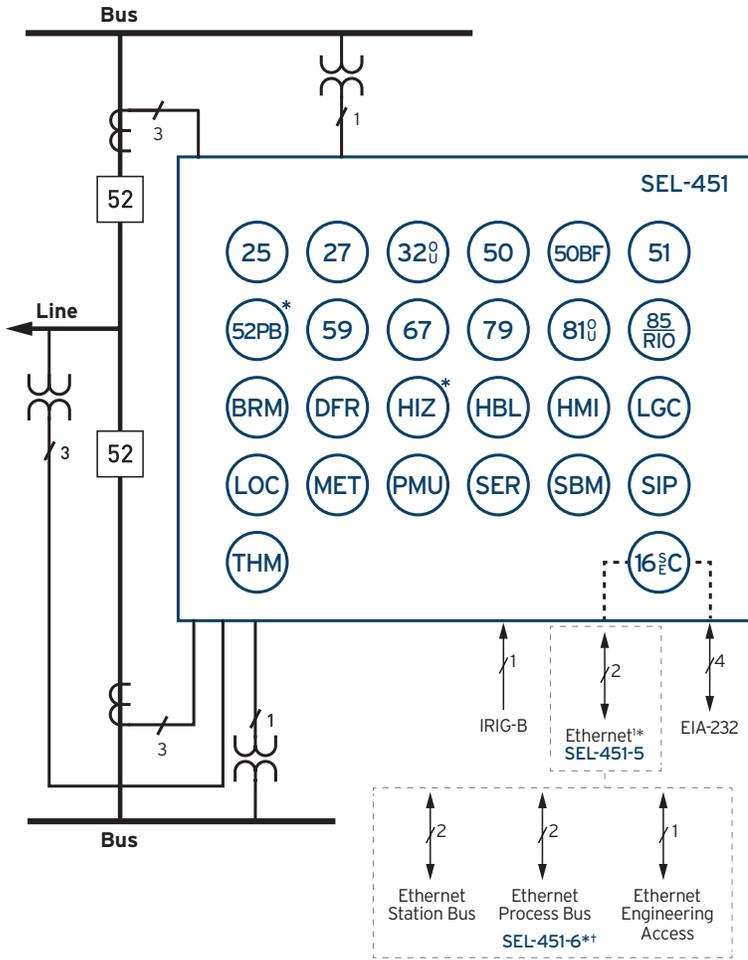
ANSI Numbers/Acronyms and Functions

25	Synchronism Check
27	Undervoltage
32 (O,U)	Over- and Underpower
50	RMS Overcurrent
50BF	Dual Breaker Failure Overcurrent
51	Time-Overcurrent
52PB	Trip/Close Pushbuttons*
59	Overvoltage
67	Directional Overcurrent
79	Autoreclosing
81 (O,U)	Over-/Underfrequency

Additional Functions

16 SEC	Access Security (Serial, Ethernet)
50G	Best Choice Ground
85 RIO	SEL Mirrored Bits® Communications
BRM	Breaker Wear Monitor
DFR	Event Reports
HBL	Harmonic Blocking
HIZ	High-Impedance Fault Detection AST*
HMI	Operator Interface
LDE	Load Encroachment
LGC	Expanded SELogic® Control Equations
LOC	Fault Locator
MET	High-Accuracy Metering
PMU	Synchrophasors
SBM	Station Battery Monitor
SER	Sequential Events Recorder
SIP	Software-Invertible Polarities
SV	IEC 61850-9-2 or IEC 61869-9 Sampled Values*†
THM	IEC 60255-Compliant Thermal Model
TiDL	Time-Domain Link Technology*†

¹Copper or fiber-optic   *Optional feature

†TiDL and SV relays receive current and voltage values from remote merging units.

Key Features

Comprehensive Feeder Protection

Customize distribution protection in the SEL-451 Protection, Automation, and Bay Control System with multiple instantaneous, time-overcurrent, and directional elements combined with SELogic control equations. AST detects high-impedance faults, while low-energy analog (LEA) voltage inputs help protect pad-mounted switchgear.

Powerful Bay Control and High-Speed Breaker Protection

Comprehensive two-breaker control and breaker failure protection complement the versatility of the SEL-451 programmable logic to meet your bay control needs. Easily control motor-operated switches, capacitor banks, and field I/O from the front panel or remotely.

Built-In Real-Time Synchrophasor Measurements

Help system operators understand the network status with real-time visual displays of system phase angles and frequency. High-accuracy synchronized phasor measurements provide information and control to match the frequency and phase angle for critical activities, such as switching, startup, and power transfer.

Monitoring That Maximizes the Capability of Substation Equipment

Fully load equipment by monitoring power, including thermal or rolling interval demand as well as peak demand on positive-, negative-, and zero-sequence current.

Digital Secondary System Technologies

Modernize your substation by applying SEL TiDL technology or SEL SV technology. Both of these digital secondary system solutions replace copper wires with fiber-optic cables to increase safety, reduce costs associated with using copper wires, and limit the impact of electromagnetic interference.

TiDL is a simple and secure point-to-point solution that is easy to implement, with no external time source or network engineering required. SEL-TMU TiDL Merging Units placed in the yard digitize signals and transmit them over fiber-optic cables to the SEL-451-6 TiDL relay in the control house.

SEL SV combines protection in the merging unit with the flexibility of IEC 61850-9-2 or IEC 61869-9. SEL-451 merging units digitize signals and transmit them via Ethernet over fiber-optic cables to SEL SV relays or other manufacturers' compliant relays in the control house.
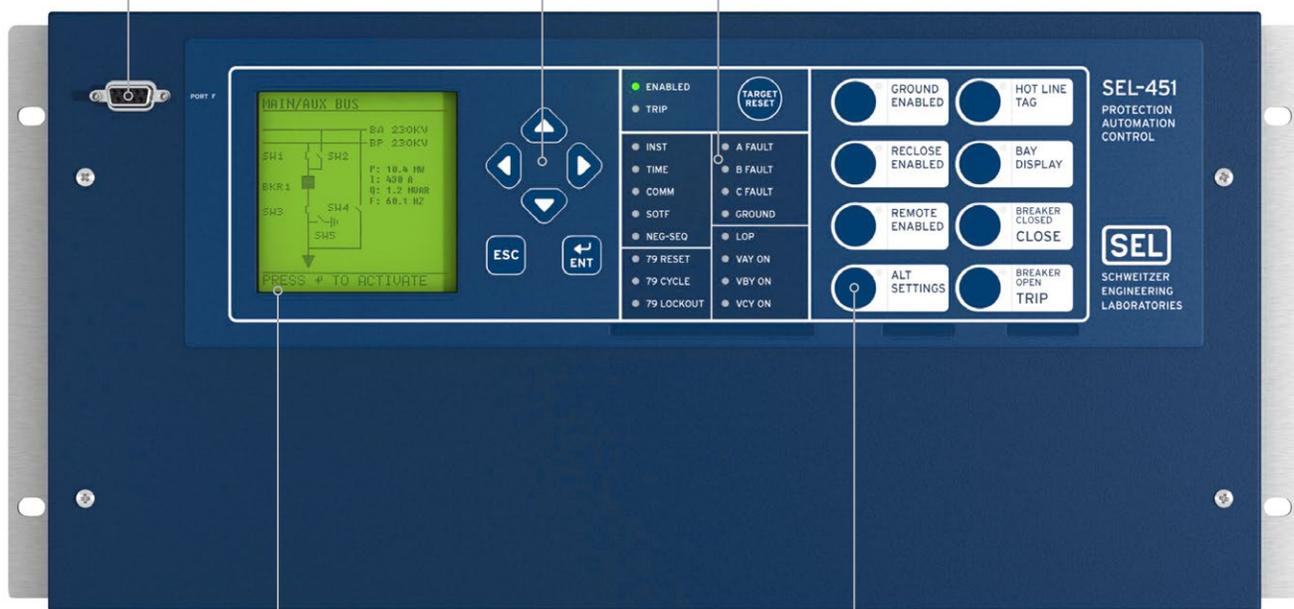
Product Overview—SEL-451-5 Relay

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

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.

Interactive bay display with user-configurable apparatus labels allows the operator to view the status of breakers and disconnect switches and to control them.

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

Choose from a vertical or horizontal, panel-mount or rack-mount chassis and different size options.

Use a maximum of 68 output contacts.[1]

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 2.1.

Use one front and three rear EIA-232 ports for MIRRORED BITS communications, DNP3, SCADA, and engineering access.
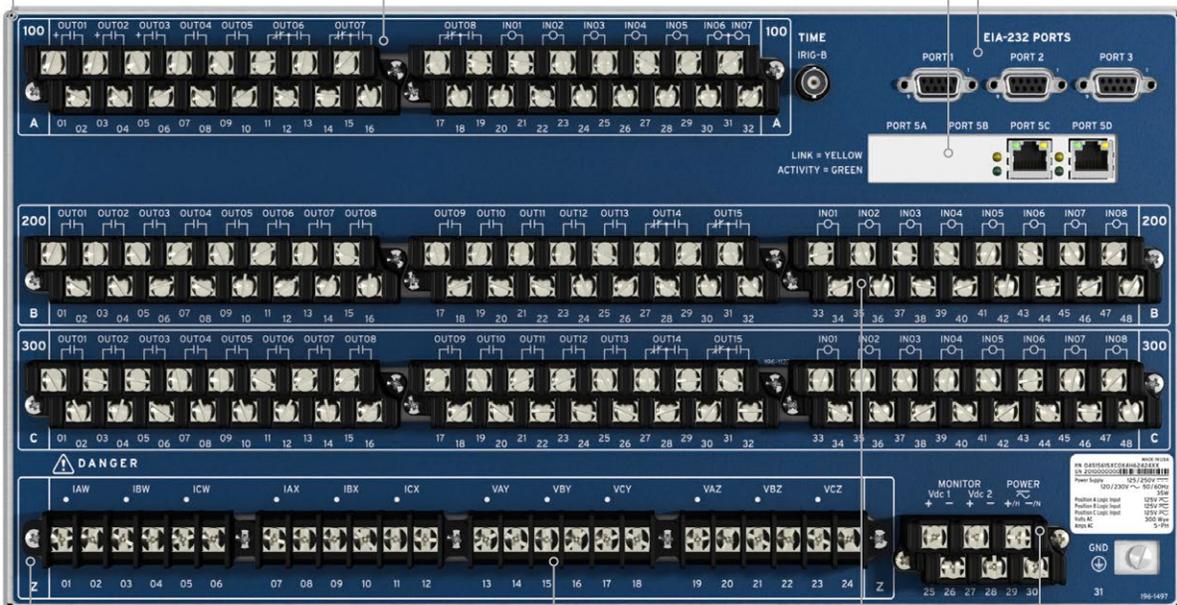
Order six current inputs in standard terminal blocks (as shown) or a Connectorized® hardware configuration.

Use a maximum of 103 input contacts.[1]

Choose six voltage inputs in either standard terminal blocks, a Connectorized hardware configuration, or an LEA hardware configuration.

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.

[1]Requires 8U chassis

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

Applications

Protection
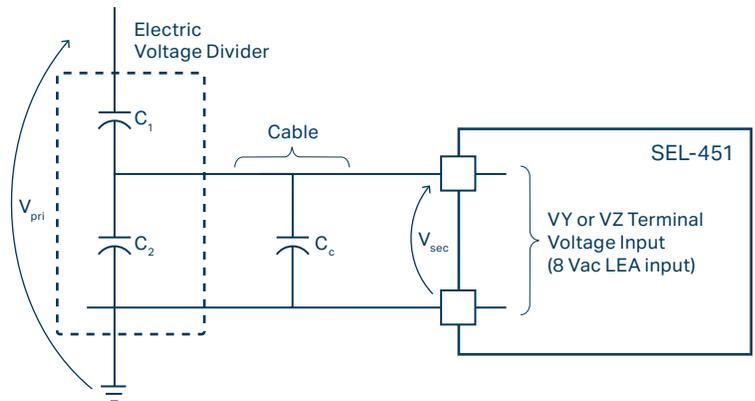
Complete Overcurrent Protection

Customize distribution protection with multiple instantaneous and time-overcurrent elements combined with SELogic control equations. You can select from four phase, four negative-sequence, and four ground instantaneous overcurrent elements to best fit your application. Best Choice Ground Directional Element® logic optimizes directional element performance and eliminates the need for many directional settings.

High-Impedance Fault Detection

Detect high-impedance faults with AST. High-impedance faults are a common result of a downed conductor on surfaces with poor conductivity. With AST, alarm or trip for faults that produce low fault current and are undetectable with conventional overcurrent relays.

Pad-Mounted Switchgear Protection

Protect pad-mounted switchgear using the SEL-451 with LEA voltage inputs. This helps reduce overall system costs by eliminating amplification electronics between the line sensor and the relay. Having fewer devices leads to a simpler system, a reduction in labor costs, and the elimination of a possible point of failure.

Electric Voltage Divider
C_1
C_2
V_{pri}
Cable
C_c
V_{sec}
SEL-451
VY or VZ Terminal Voltage Input (8 Vac LEA input)

Bay Control

Two-Breaker Bay Control

Meet your bay control needs with complete two-breaker control and high-speed breaker failure detection. You can easily control motor-operated switches, capacitor banks, and field I/O from the front panel or remotely. Configurable labels make it easy to customize the relay controls to match your application. Different bus configurations are available, including single- and dual-busbar, transfer bus, tie-breaker, breaker-and-a-half, ring-bus (shown in the figure), double-bus/double-breaker, and source-transfer configurations.

Flexible I/O Options

Select different combinations of I/O boards to match each application. The SEL-451 supports up to four additional I/O boards for a total of up to 103 inputs and up to 68 outputs depending on configuration.

Racked Breaker Support

Support racked breakers where they are used. Racked breaker mosaics provide visual indication of not only whether the breaker is open or closed but also for which position the breaker is in (racked in, test, or racked out).

### Disconnect Monitoring and Control

Use up to 20 disconnects for bay control applications. All disconnects can be either controlled or in a monitor-only state. A setting for each disconnect allows you to tailor it for each application.
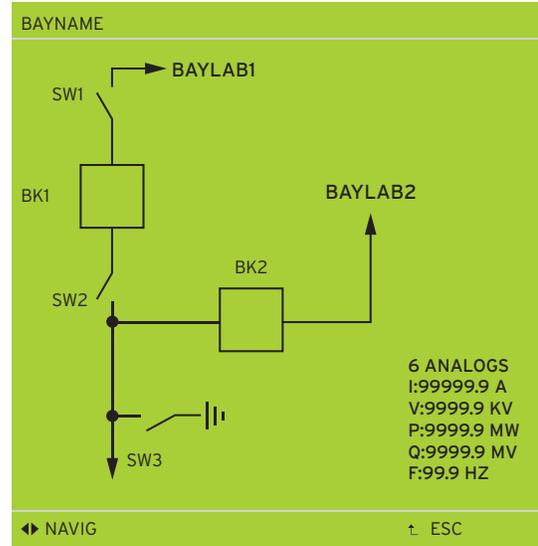
Panel Integration

Improve efficiency and simplify installation with more target LEDs and operator pushbuttons. The 4U, 5U, and 8U chassis have options for an additional eight target LEDs and four operator control pushbuttons. You can also include arc-suppressed trip/close pushbuttons for an enhanced solution.

Display the breaker status and control the breaker position, even if the relay is not powered, with auxiliary breaker trip/close control pushbuttons and indicating lamps. The 24 target LEDs indicate the relay state and various trip conditions and are configurable for specific applications. You can modify the 12 operator pushbuttons to replace traditional panel switches and meet operator control needs.
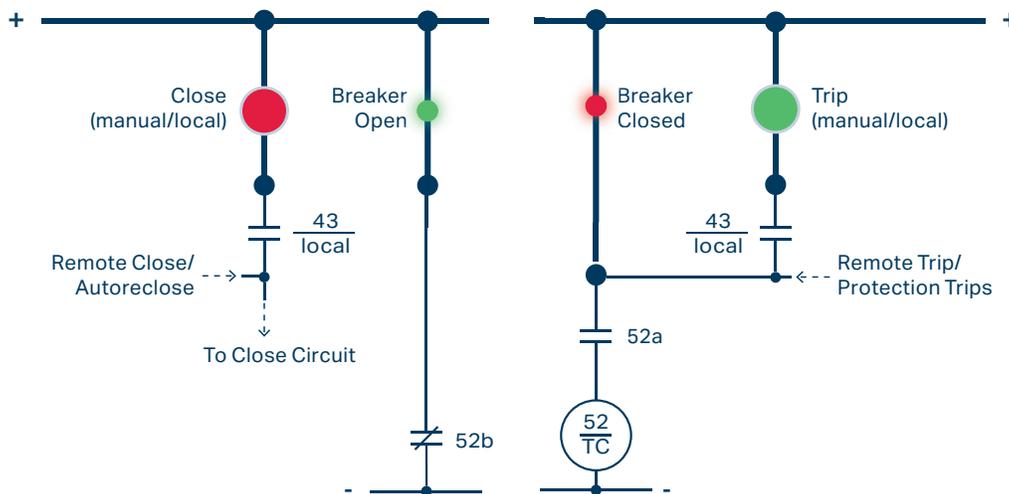
Automation

Custom Automation With SELOGIC Control Equations

Create your own custom applications using powerful SELOGIC control equations. This allows you to:
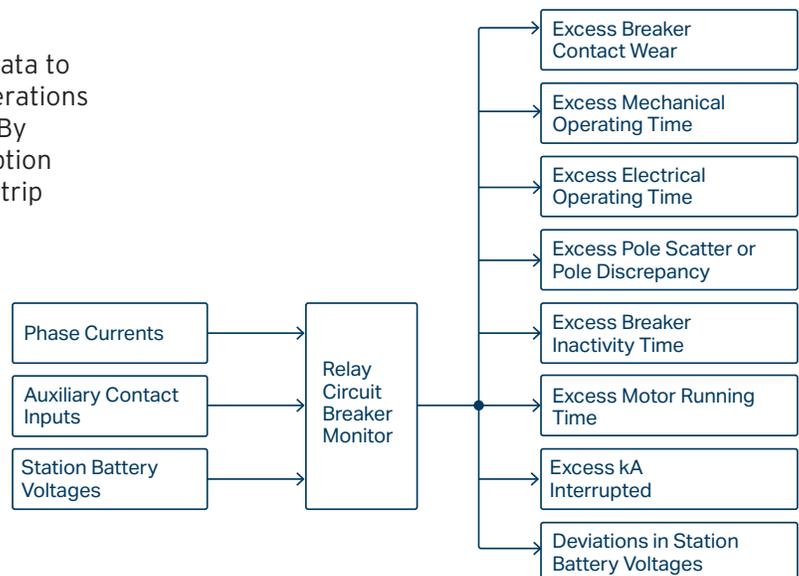
- Prevent cascading voltage collapse using VAR-supervised time-undervoltage elements.

- Monitor VAR loading, and trip only the feeders with high VAR demand to prevent voltage collapse.

- Create an adaptive inverse-time overcurrent characteristic to adjust pickup based on load conditions.

- Protect ungrounded-wye shunt capacitor banks.

- Create your own custom curves.

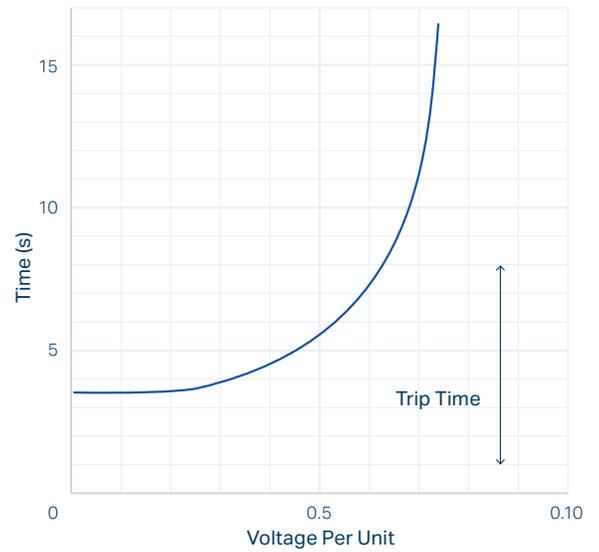**VAR-Supervised Time-Undervoltage Characteristic**

Harmonic Monitoring

Apply the second-, fourth-, and fifth-harmonic elements with individual threshold settings to detect transformer energization and overexcitation conditions. You can use the output from these harmonic detection elements for a variety of functions. For example, modifying the relay settings can improve security, and event reporting makes the identification of transformer energization events fast and simple.

Harmonic Analysis
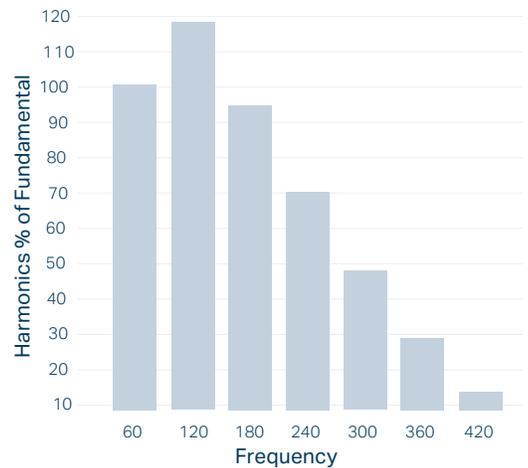

Breaker Wear Monitoring

Compare the breaker manufacturer's published data to the actual interrupted current and number of operations for two breakers, and create alarms accordingly. By monitoring the mechanical and electrical interruption time per pole, you can compare average and last trip times for maintenance scheduling.

Enhanced Event Analysis Software

Use the SEL-451 as a multichannel (six voltages, six currents) digital fault recorder. With SEL-5601-2 SYNCHROWAVE® Event Software, you can view COMTRADE files from the SEL-451 and other digital fault recorders. Event resolutions from 1 to 8 kHz and event report lengths from 0.25 to 24.00 seconds (1 kHz resolution) are possible. You can perform harmonic analysis of any voltage or current and select the prefault, fault, or post-fault portion of the event report to examine.

Synchrophasors

Significantly improve your system's performance with SEL's complete synchrophasor solutions, including hardware, communications, viewing and analysis software, data collection, and data archiving. The SEL-451 provides real-time system state measurement with time-synchronized voltages and currents in the IEEE C37.118 standard format. In addition, SEL-5078-2 SYNCHROWAVE Central Software or third-party software allow you to view and analyze system phase angles, load oscillations, voltage profiles, and other critical system information.

SEL TiDL Process Bus Solutions

SEL TiDL technology is a protection-centered digital secondary system solution engineered with simplicity in mind. This technology minimizes cybersecurity risks and network engineering by using point-to-point communications and a nonroutable protocol. A TiDL-based solution does not require an external time reference.

Simple Architecture

SEL-TMU devices are placed in the yard close to the primary equipment and digitize discrete I/O signals and analog data, such as voltages and currents. These data are then transported over fiber-optic cables to an SEL-451-6 TiDL relay in the control house. The point-to-point architecture simplifies implementation and drives overall maintenance and maintenance costs down.

Data-Sharing Capabilities

Each SEL-TMU can be paired with up to four SEL-400 series TiDL relays. This data-sharing capability allows design flexibility, and point-to-point connections simplify system expansion.

Built-In Data Synchronization

TiDL relays measure the path delay between the relay and the merging unit on each connected port to align current and voltage measurements acquired from different merging units. This eliminates the need for external time sources, such as GPS clocks, for synchronization. All data from the SEL-TMU devices are synchronized with each other regardless of the number of units connected to the SEL-451-6 relay or the length of the fiber.

Strong Cybersecurity Posture

The dedicated, deterministic TiDL system helps secure mission-critical systems. The isolated point-to-point connections and the absence of switches and routers reduce the electronic security perimeter and limit attack points. This security-minded architecture prevents remote access, and its simplicity eliminates the need for managing port access.

Minimal Training Required

The relay settings for the SEL-451-6 TiDL relay are the same as those in all popular SEL-400 series models, providing consistency and simplicity. You can use the same protection schemes and applications for complete feeder protection.

Flexible Communications Options

The SEL-451 can be configured with a five-port Ethernet card supporting PRP or failover functionality to increase system availability. Use PTPv2 on process bus or station bus ports to provide time synchronization.

This card also features dedicated ports and IP addresses for station bus and engineering access networks to provide selective access control.

Use the small form-factor pluggable (SFP) transceivers on process bus, station bus, and engineering access ports. Single- and multimode communications options provide increased flexibility.
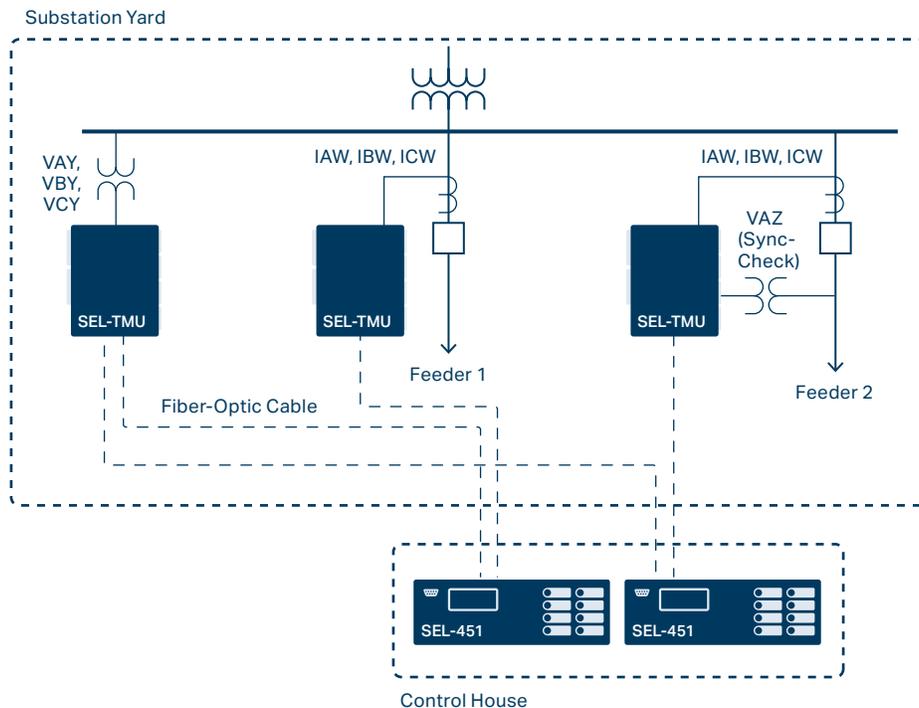
SEL-451-6 With TiDL Technology

4U or 5U chassis with horizontal mounting options (panel or rack) accommodates your application needs.

Select a five-port Ethernet card for dedicated station bus and engineering access ports.

Eight SFP ports allow the TiDL relay to connect with eight remote SEL-TMU devices and to receive remote analog and digital data.

LEDs for viewing the connection status to an SEL-TMU on a per-port basis.

SEL SV-Based Process Bus Solutions

SEL SV-based solutions are communications-centric, network-based solutions that combine protection in the merging unit with the flexibility of IEC 61850-9-2 or IEC 61869-9 protocols.

Networked Architecture

The SEL-451-6 SV relay (subscriber) in the control house receives digitized analog signals from SV merging units (publishers) in the yard via a fiber-based Ethernet network. SEL SV-based solutions allow you to create a flexible Ethernet-based network using tools such as software-defined networks or VLANs. You can use SEL software-defined networking (SDN) switches to provide centralized traffic engineering and improve Ethernet performance. SEL SDN switches act as transparent PTP clocks that support the IEEE C37.238 power system profile, ensuring submicrosecond time synchronization of the end devices.

Merging Units With Built-In Protection

Apply the SEL-451-6 SV publisher to provide full SEL-451 protection locally while sending digitized voltage and current signals to other SV relays. All SEL SV merging units offer local protection for a variety of applications, depending on the model. If network communications are lost, the SEL merging units continue to provide standalone protection.

Interoperability

SEL SV devices are fully compliant with IEC 61850-9-2 and the UCA 61850-9-2LE guideline as well as IEC 61869-9. You can use them with primary equipment that generates SV streams or with other manufacturers' SV-compliant units.

## Advanced Network Monitoring and Diagnostic Tools

The SEL-451-6 SV relay provides advanced network monitoring and diagnostic tools through standard IEC 61850 logical nodes. Additional diagnostic information and statistics are available through COM SV, GOO, ETH, and COM PRP commands, which aid in troubleshooting. The TEST SV command allows you to check the network connectivity as well as the CT and PT ratios between publisher and subscriber devices.

Flexible Communications Options

The SEL-451 can be configured with a five-port Ethernet card supporting PRP or failover functionality to increase system availability. Use PTPv2 on process bus or station bus ports to provide time synchronization.

This card also features dedicated ports and IP addresses for station bus and engineering access networks to provide selective access control.

Use the SFP transceivers on process bus, station bus, and engineering access ports. Single- and multimode communications options provide increased flexibility. All ports support 100 Mbps SFPs, and process bus ports also support 1 Gbps SFPs.
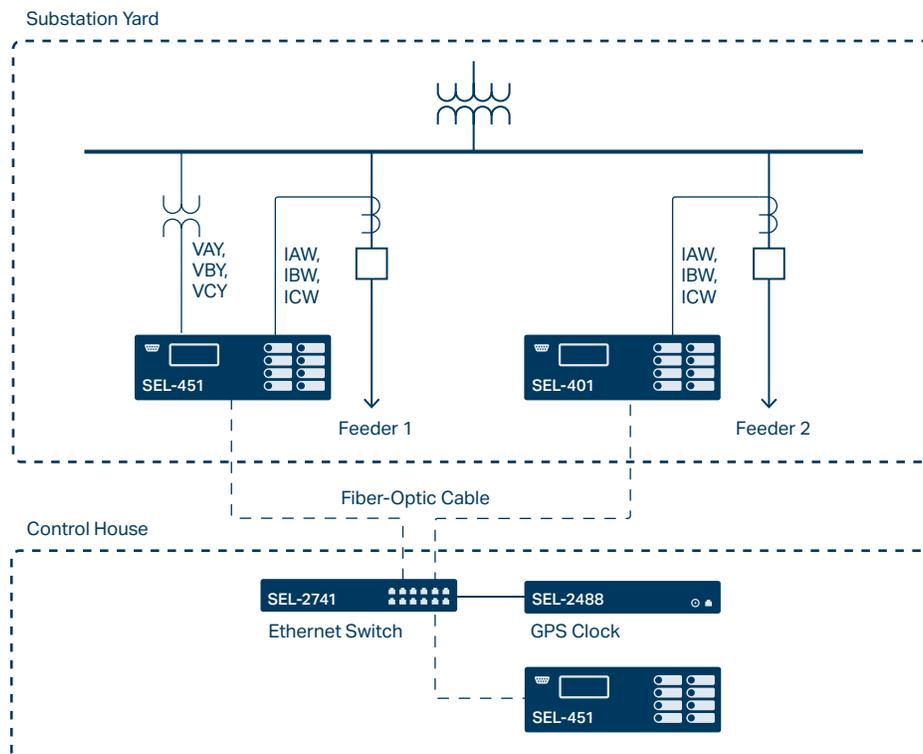
SEL-451-6 SV Merging Unit

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

Choose an SFP transceiver to match application requirements. Process bus ports support 100 Mbps and 1 Gbps connections. Station bus and engineering access support 100 Mbps connections. Select single- or multimode fiber.

Select a five-port Ethernet communications card for dedicated process bus, station bus, and engineering access ports.

SEL-451-6 SV Relay

# Accessibility and Communications

Built-In Web Server

Access basic SEL-451 information on a standard Ethernet network with the built-in web server. From there you can view the relay status, Sequential Events Recorder (SER) data, metering information, and settings with easy access within a local network. For increased security, web server access requires a relay password and the information is limited to a read-only view.
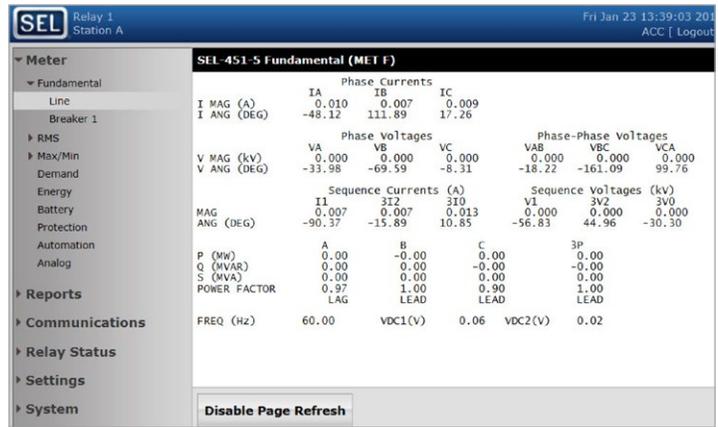

MIRRORED BITS Communications

This field-proven technology provides simple and powerful bidirectional digital communications between devices. MIRRORED BITS communications can transmit/receive information between upstream relays and downstream recloser controls to enhance coordination and generate faster tripping for downstream faults.

MIRRORED BITS® Communications
Digital, Analog, or Virtual Terminal
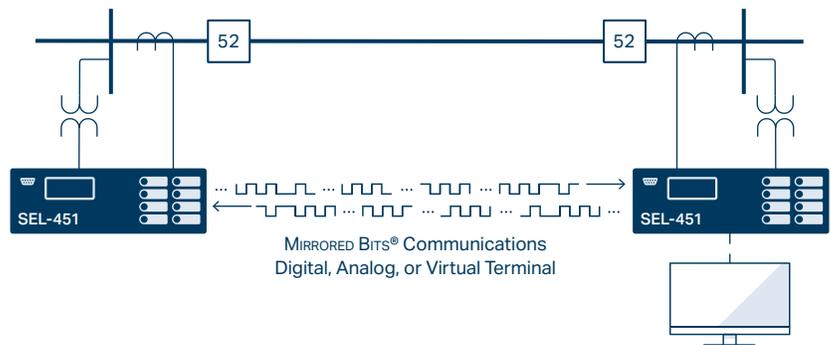
Ethernet-Based Communications

An Ethernet communications card enables you to communicate using a variety of protocols, including FTP, HTTP, DNP3, PTPv2, PRP, Telnet, synchrophasors, and IEC 61850 Edition 2.1. Select between copper, fiber, or a combination of port types.
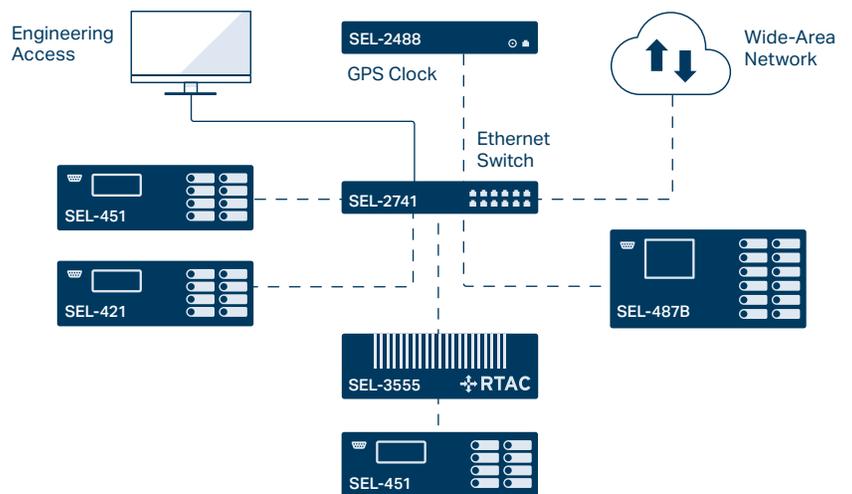
Setting and Commissioning Software

Simplify the SEL-451 Configuration Process With the Graphical Logic Editor (GLE)
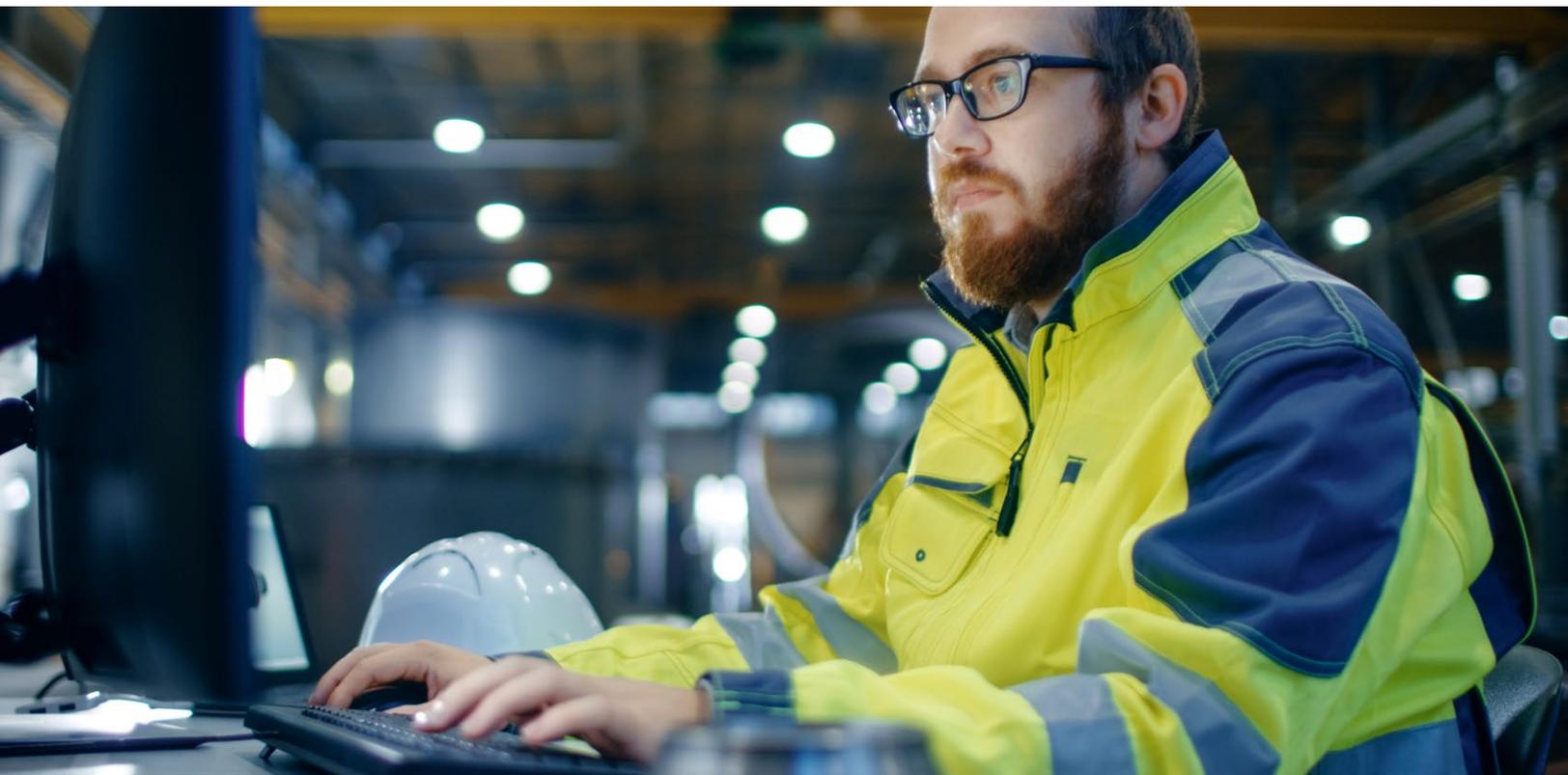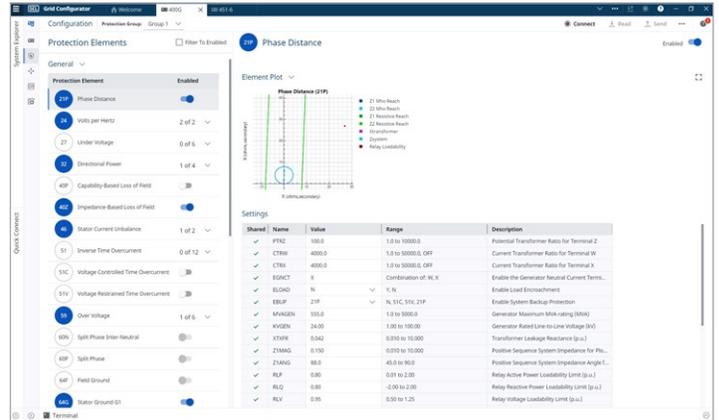
With the GLE, you can view SELOGIC control equations graphically and document settings files for easier validation and commissioning. You can also convert existing SELOGIC control equations to easy-to-read diagrams and save diagrams with your ACSELERATOR QuickSet® SEL-5030 Software settings.

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.
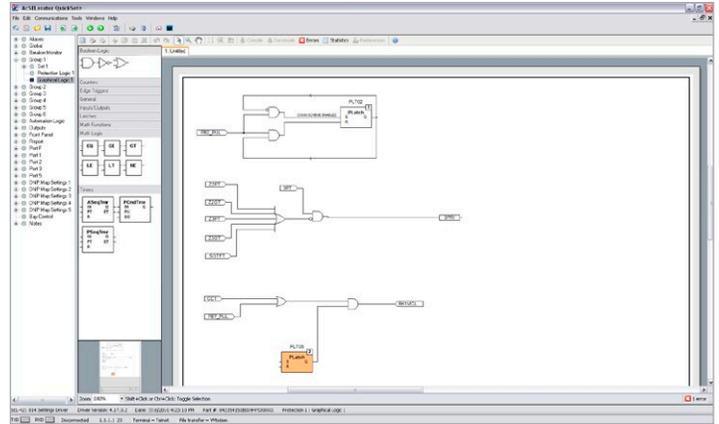
Next-Generation Configuration Software

Included with the TiDL and SV relays, SEL Grid Configurator allows engineers and technicians to quickly create, manage, and deploy settings for SEL power system devices. It features a modern interface designed for ease of use, with powerful protection visualization and comprehensive reporting to reduce device deployment complexity.

SEL-451 Specifications

General

AC Current Inputs (6 total)	5 A nominal
	1 A nominal
AC Voltage Inputs (6 total)	0—300 V_{L-N} operational
LEA Voltage Inputs	0—8 V_{L-N} operational
Communications Protocols	FTP, HTTP, Telnet, SEL ASCII, SEL Fast Message, synchrophasors, DNP3, PRP, PTPv2, and IEC 61850 Edition 2.1 (optional)
Communications Ports	**Serial Ports** One front-panel and three rear-panel EIA-232 serial ports 300—57,600 bps **Two-Port Ethernet Card** Two 100BASE-FX fiber-optic network ports **Four-Port Ethernet Card** Four 10/100BASE-T twisted-pair network ports, or Four 100BASE-FX fiber-optic network ports, or Two 10/100BASE-T twisted-pair network ports and two 100BASE-FX fiber-optic network ports **Five-Port Ethernet Card** Two 100/1000BASE SFP ports Three 100BASE SFP ports

TiDL Ports	Fiber-optic ports: 8 Range: ~2 km Data rate: 100 Mbps Protocol: SEL T-Protocol
SV Ports	Subscriber: As many as 7 SV data streams Data rate: 4.8 kHz Protocol: IEC 61850-9-2 or IEC 61869-9
Precise-Time Input	Demodulated IRIG-B time input and PTPv2 (default, IEEE C37.238:2011, and IEC 61850-9-3:2016 profiles)
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)