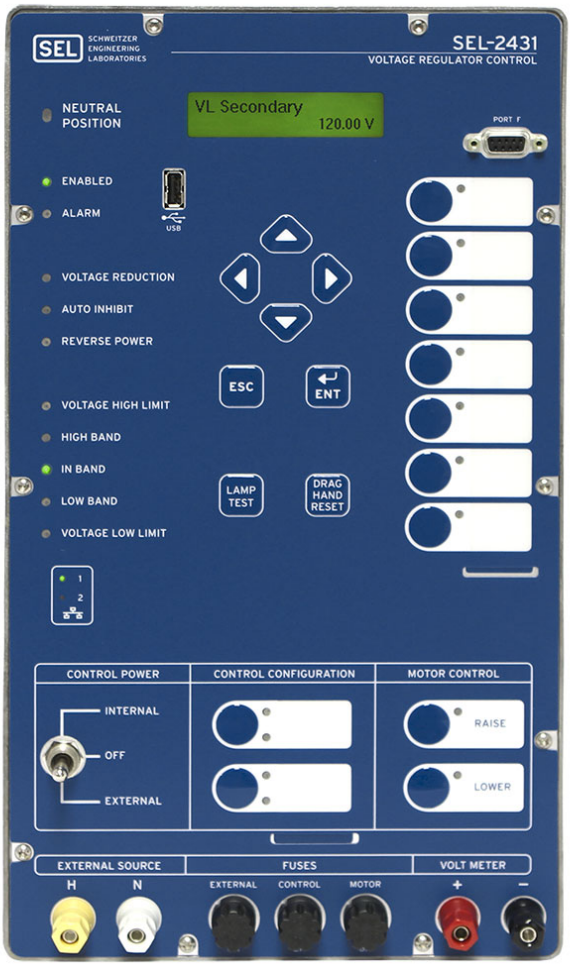
SEL-2431 Voltage Regulator Control

Optimize Your System Voltage Profile



Major Features and Benefits

- **Distribution Automation Ready.** Interface with either on-the-fly settings changes over DNP, or master controller direct-operate interface.
- **Comprehensive Operating Modes.** Adapt to complex installations with unique operating modes to support modern systems with bidirecetional current flow. Use SEL's FLEXDG control mode to optimize control for circuits that have distributed generation and multiple traditional sources.
- **Flexible Communications.** Easily interface with your network with the Industry's most network connectable regulator controller.
- **Expandable, Removable Memory.** Connect a USB flash drive and enable Automatic Backup to write all common reports to the USB for long-term storage and easy retrieval.

- **IEEE C37.118 Synchrophasor Protocol.** Identify connected phase of downstream voltage regulators by coordinating with sychrophasor measurements in the substation.
- **Communications Options.** Easily integrate into your existing communications scheme with SEL protocols, DNP, and a wide variety of Ethernet and serial communications cards.
- **Flexible Retrofit Kits.** Interface to existing regulators on your system with wiring retrofit kits.
- **System Connections.** Accommodate wye-, delta-, or open-delta regulator configurations.
- **Simple Settings.** Quickly commission new controls with a minimal number of simple settings.
- **Detailed Event Reporting.** Ease maintenance, troubleshooting, and system analysis with detailed oscillographic event reporting with motor current and Sequential Events Recorder (SER).
- **Rugged Construction.** Rely on the durability of a regulator control built and tested to protective relay standards in a die-cast aluminum chassis.
- **10-Year Warranty.** SEL stands behind its products with an unmatched world-wide 10-year warranty.
- **IRIG-B Input.** Synchronize all regulators to a single time source for improved reporting and monitoring.
- **Configurable HMI.** Customize the HMI to your needs with configurable LEDs and operator pushbuttons.
- **Extensive Metering and Monitoring.** Keep an eye on your system with comprehensive metering functions: Load Profile, Max/Min, demand, and peak demand.
- **Adaptable SELOGIC®.** Meet the unique demands of your system with customizable logic and operation functions.

Functional Overview

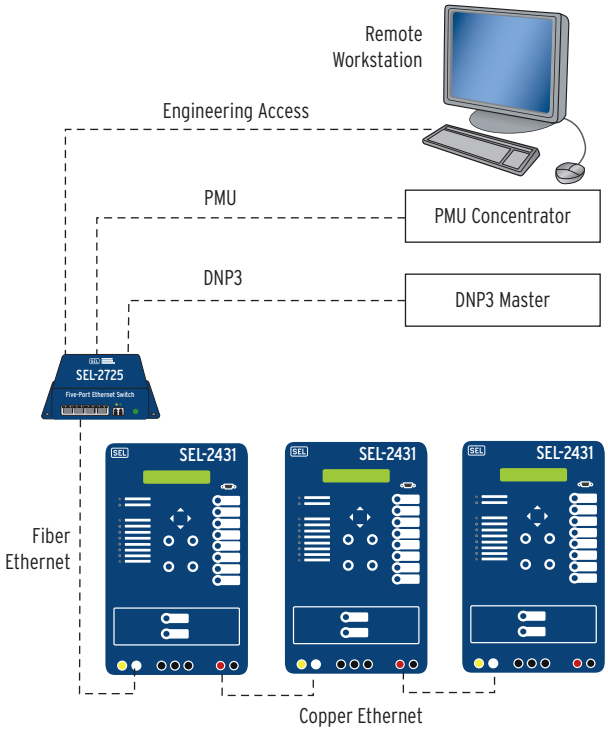


Figure 1 Ethernet-Connected Voltage Regulator Controls

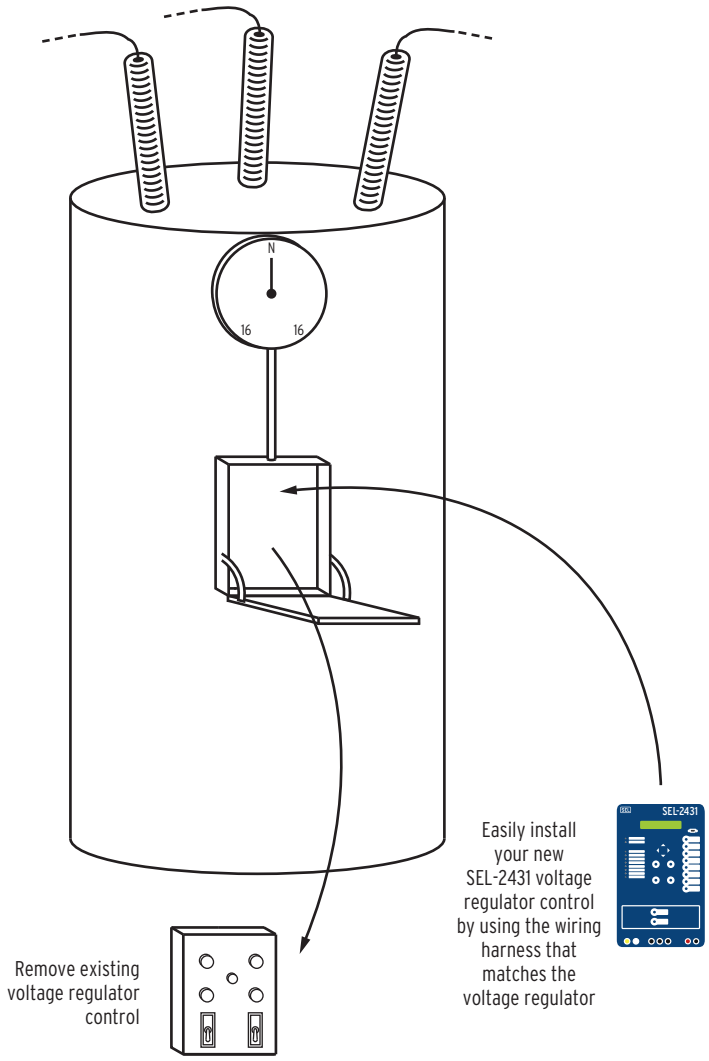


Figure 2 Voltage Regulator Control Retrofit With SEL-2431

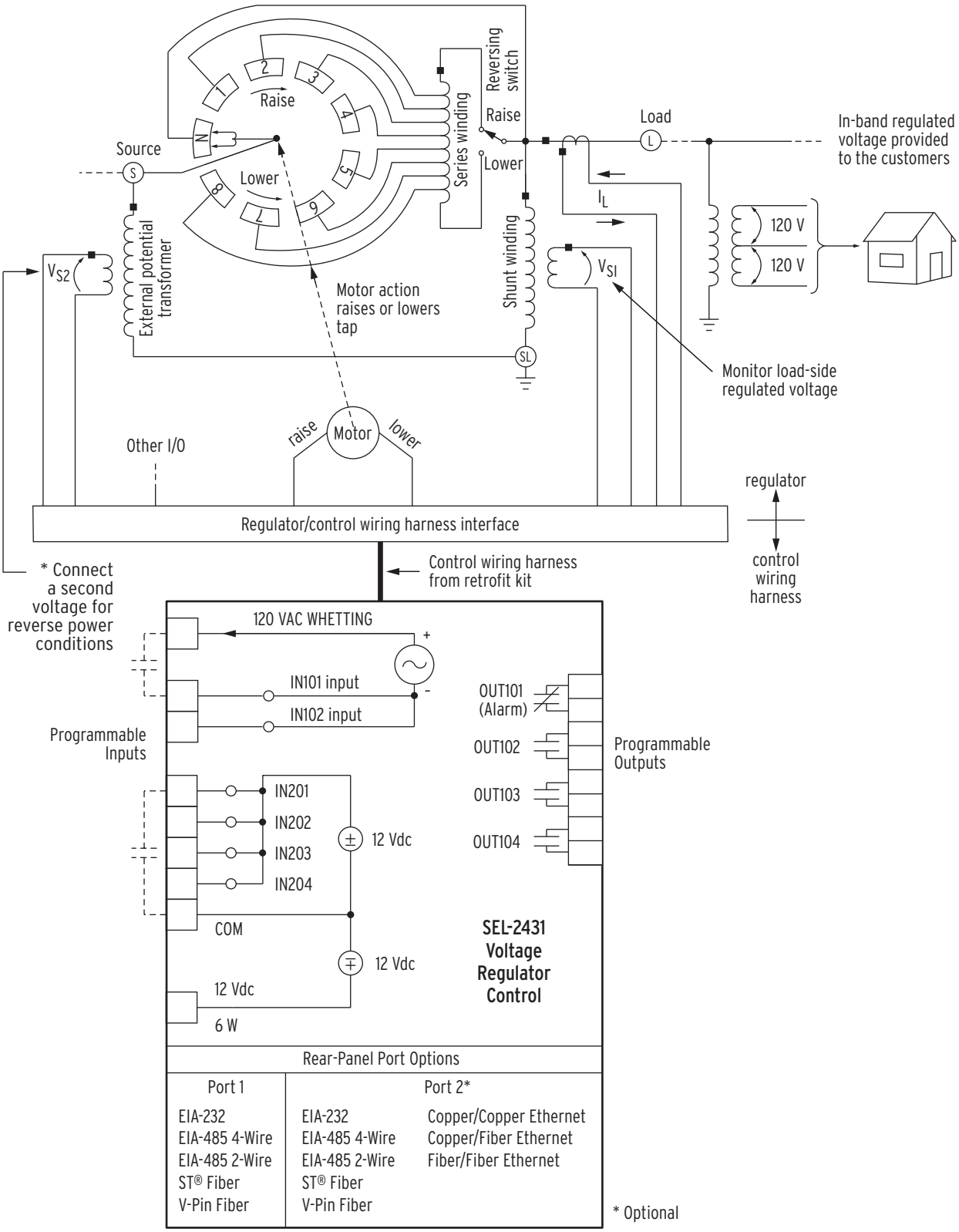
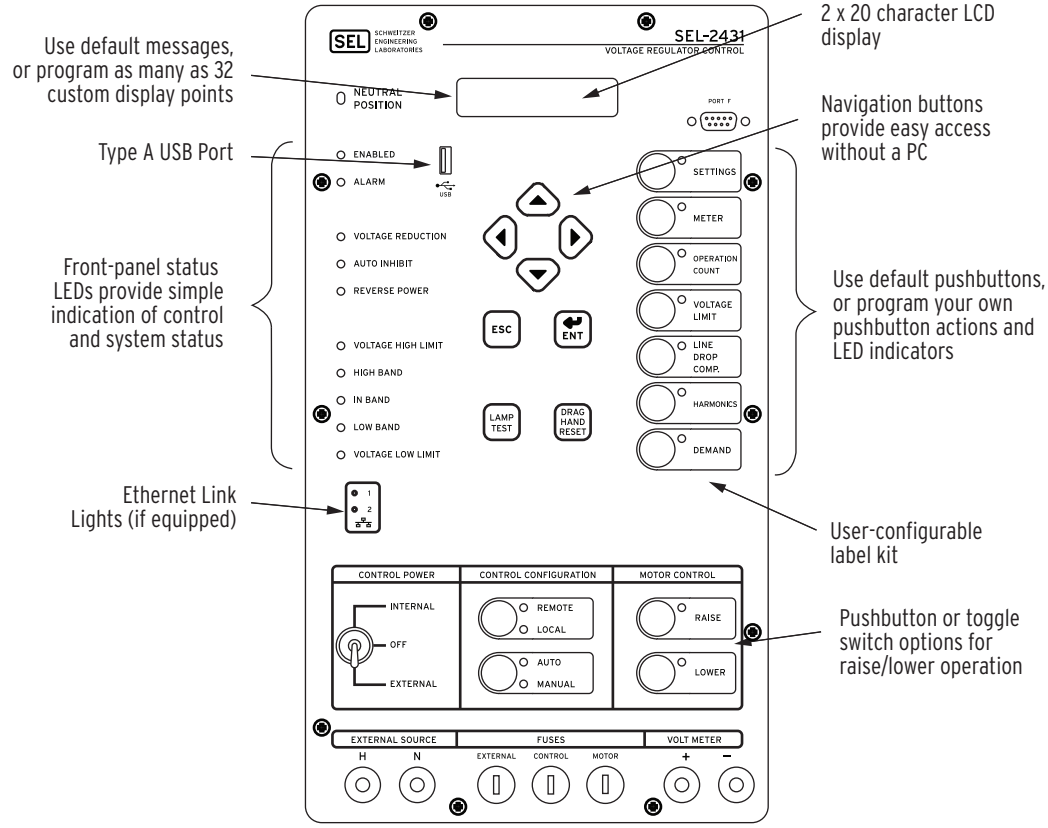
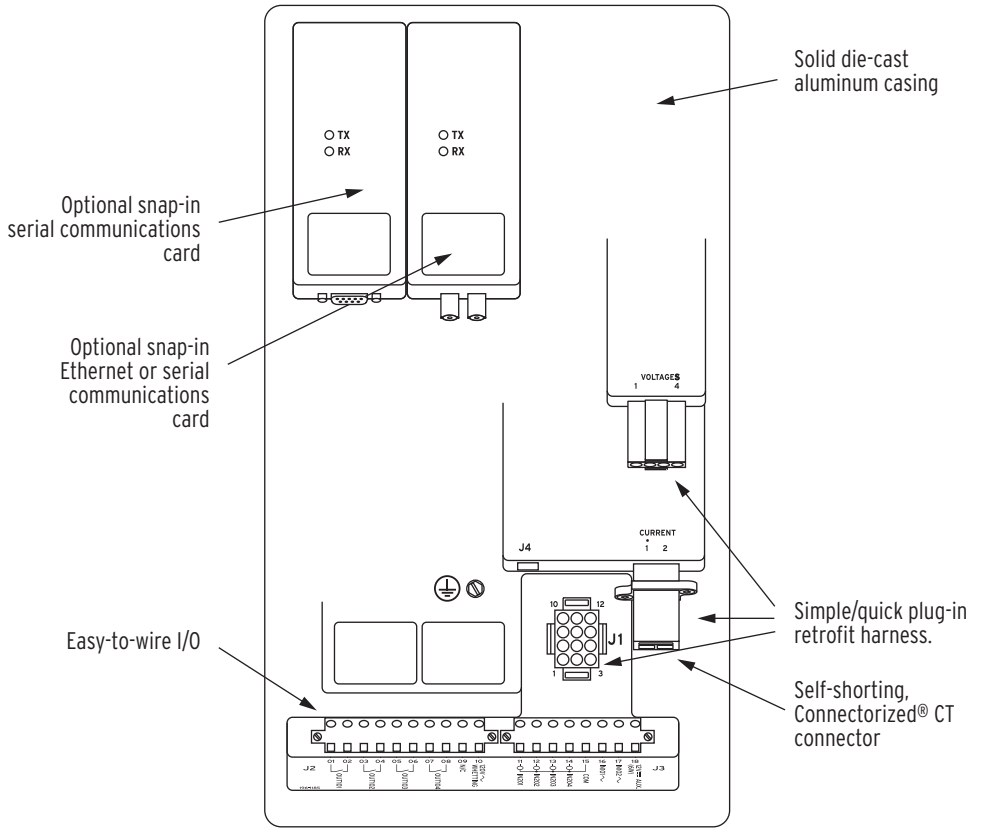


Figure 3 Functional Diagram

Device Overview





Compatibility and Retrofit Kits

SEL-2431 Voltage Regulator Control retrofit kits are available for the supported regulator makes and models. The kits can be included as part of the SEL-2431 part number at the time a control is ordered, or they can be ordered separately using the part numbers in *Table 1*.

Table 1 SEL-2431 Retrofit Kits

Retrofit Kit	Part Number
Siemens/Allis-Chalmers: 10-position Polarized Disconnect Switch (PDS) Interface[a]	9253002
Howard Industries: 10-position Connector Terminal Strip (CTS) Interface[a]	9253003
Cooper/McGraw-Edison: 18-/10-position Fanning Strip (Traditional Interface)[a]	9253004
Cooper: 20-position Connector (Dead-front Interface)[a]	9253005
GE: Fork-terminal Connections (Traditional Interface to Cabinet NN Terminals)[a]	9253006
GE: 24-position Connector (Power Disconnect Interface)[a]	9253007
Generic Fork Terminals for Cooper/ McGraw-Edison[b]	9253055
Generic Fork Terminals for Siemens/ Allis-Chalmers/Howard/GE[b]	9253001

[a] Includes mounting hardware (hinges and latch), and all necessary wiring harnesses (including PDS, CTS, Fanning Strip, or other applicable enclosure connector for mating with existing voltage regulator interfaces).

[b] Does not include mounting hardware (hinges and latches). Includes wiring harness only. If mounting hardware is required, select appropriate kit from Table 2.

Table 2 shows the mounting hardware kits available for the SEL-2431. These kits are orderable using the part numbers shown in *Table 2*.

Table 2 SEL-2431 Mounting Hardware Kits

Mounting Hardware Kit	Part Number
Siemens/Allis-Chalmers Mounting Hardware Kit[a]	9253059
Howard Mounting Hardware Kit	9253060
Cooper/McGraw-Edison Mounting Hardware Kit	9253058
GE Mounting Hardware Kit	9253057

[a] Use this kit for mounting in a Toshiba CR-3 voltage regulator.

Attach mounting hardware (hinges and latch—see *Figure 4*) and mount the SEL-2431 in the existing voltage regulator enclosure. Ground the SEL-2431 chassis. Connect the SEL-2431 to the voltage regulator with the wiring harness.

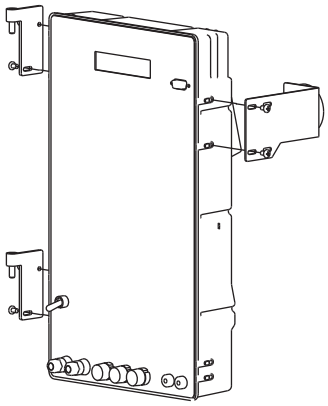


Figure 4 Attach Hinges and Latch and Mount the SEL-2431 in the Existing Voltage Regulator Enclosure

Traditional and New Features

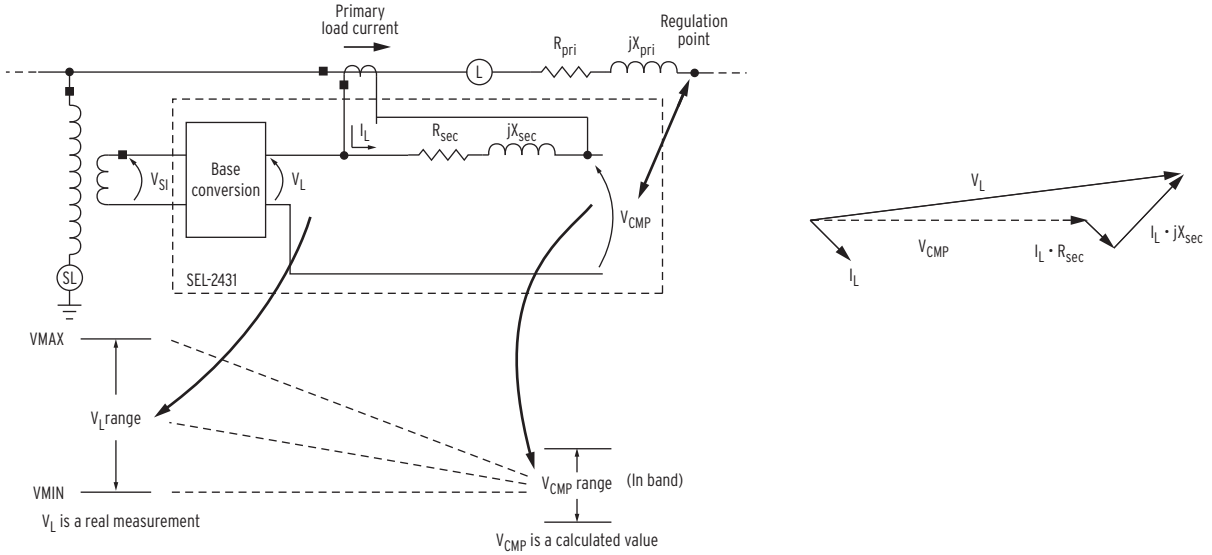


Figure 5 Line-Drop Compensation Keeps Voltage Constant at the Regulation Point

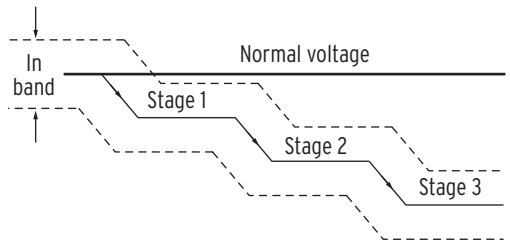
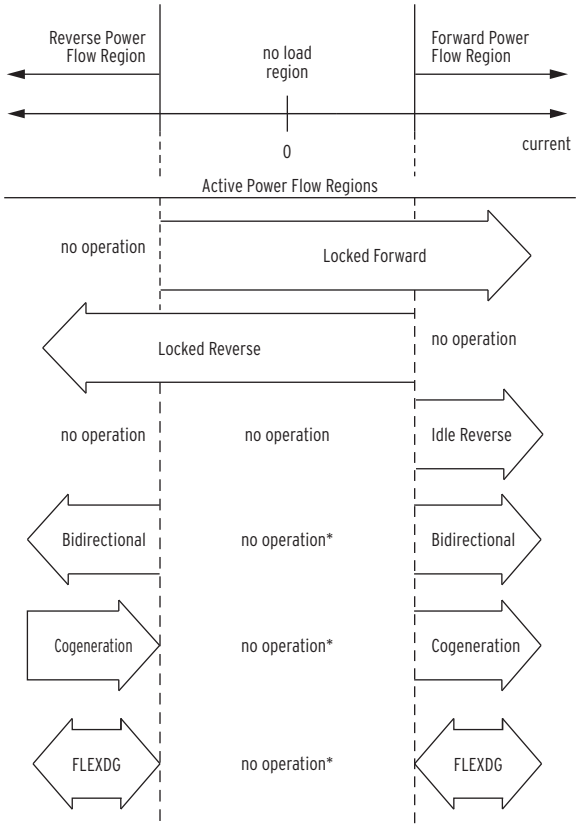


Figure 6 Set Up Three Voltage-Reduction Stages for System Stability Support

Table 3 Select the Appropriate Operating Mode

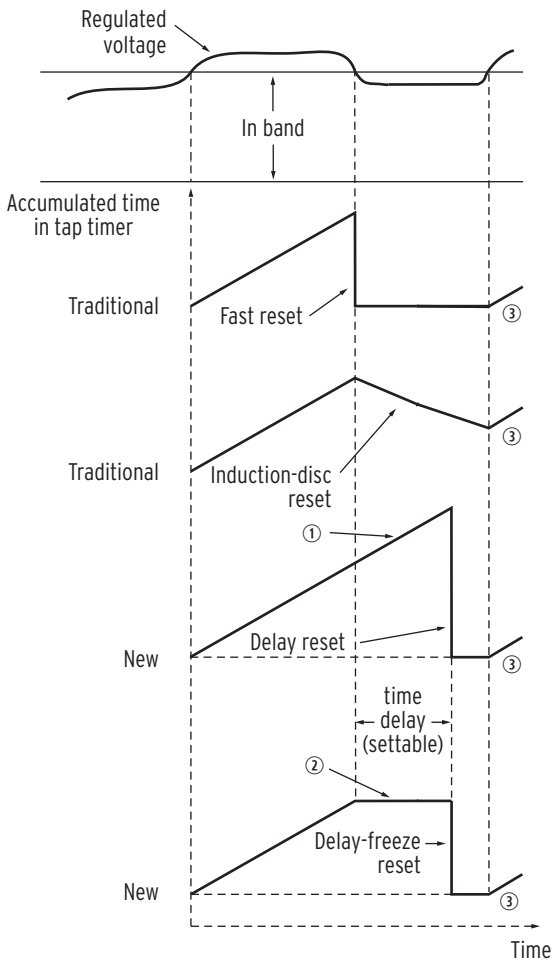
Operating Mode	Scenario
Locked Forward	Power flow expected to always be in the forward (normal load-side) direction.
Locked Reverse	Power flow expected to always be in the reverse (normal source-side) direction.
Idle Reverse	Power flow expected to always be in the forward (normal load-side) direction, but no voltage regulation should occur if power flow is indeterminate (e.g., "no load" condition).
Bidirectional	Power flow direction varies due to multiple electric power system interfaces and the control alternately operates the regulator in the forward (normal load-side) and reverse (normal source-side) directions depending on power flow.
Cogeneration	Power flow direction varies due to distributed energy resources on the normal load side, and during reverse power flow, voltage is still regulated from a forward direction perspective (at the normal load-side terminal).
Flexible Distributed Generation	Power flow direction varies and can be due to distributed energy resources or feeders with multiple electric power system interfaces. Since regulation direction cannot be determined by power flow alone, the control determines regulation direction based on the resultant voltage regulation effectiveness of the issued tap changes.



Note: Large arrow blocks indicate voltage regulation direction.

*BIASMODE user setting allows the control to assume a current direction when measured current is in the no load region, allowing the control to operate when control would otherwise be inhibited.

Figure 7 Active Power Flow Regions for Different Operating Modes



① Do not interrupt timing if in-band voltage excursion is less than a settable time delay.

② Temporarily "freeze" timing if in-band voltage excursion is less than a settable time delay.

③ Tap timer starts timing again when the in-band voltage excursion ends.

Figure 8 Choose First-Tap Timer Reset Response for In-Band Voltage Excursions

Synchrophasor Measurements

Use IEEE C37.118-2005 protocol to send synchrophasor data to SEL synchrophasor applications. Send data to SEL Phasor Data Concentrators like the SEL-3373 Station Phasor Data Concentrator (PDC), SEL-3378 Synchrophasor Vector Processor (SVP), SEL-3530 Real-Time Automation Controller (RTAC), and the SEL-5073 SYNCHROWAVE® Phasor Data Concentrator Software.

The SEL-2431 phasor measurement accuracy meets the highest IEEE C37.118-2005 Level 1 requirement of one percent total vector error (TVE). This means you can use the low-cost SEL-2431 in any application that otherwise would have required purchasing a separate dedicated phasor measurement unit (PMU).

Use with the SEL communications processors, or the SEL-3530 RTAC, to change nonlinear state estimation into linear state estimation. If all necessary lines include synchrophasor measurements then state estimation is no longer necessary. The system state is directly measured.

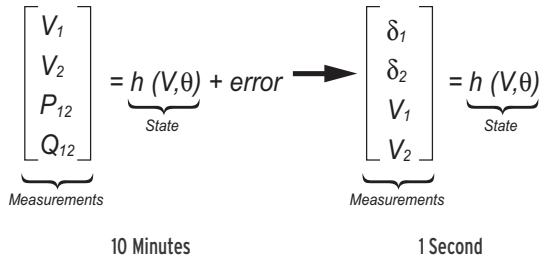


Figure 9 Synchrophasor Measurements Turn State Estimation Into State Measurement

Improve Situational Awareness

Provide improved information to system operators. Advanced synchrophasor-based tools provide a real-time view of system conditions. Use system trends, alarm points, and preprogrammed responses to help operators prevent a cascading system collapse and maximize system stability. Awareness of system trends provides operators with an understanding of future values based on measured data.

- Increase system loading while maintaining adequate stability margins.
- Improve operator response to system contingencies such as overload conditions, transmission outages, or generator shutdown.
- Advance system knowledge with correlated event reporting and real-time system visualization.
- Validate planning studies to improve system load balance and station optimization.

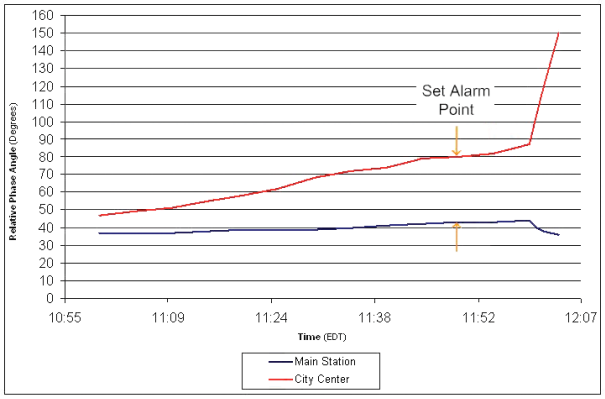


Figure 10 Visualization of Phase Angle Measurements Across a Power System

Figure 11 SEL-5702 SYNCHROWAVE Console Real-Time Wide-Area Visualization Tool

Flexible Communications and User Interface

Flexible Communications Options

Serial Communications Cards

- 200 µm multimode fiber with Vpin connectors
- 62.5 µm fiber with ST connectors
- 4-Wire EIA-485 with DB-9 connector
- 2-Wire EIA-485 with Euro connector
- EIA-232 with DB-9 connector

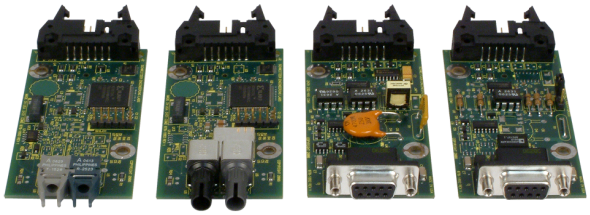


Figure 12 Serial Communications Cards

Ethernet Communications Cards

- Dual fiber Ethernet 100BASE-FX (multimode) LC connectors
- Dual copper Ethernet (10/100BASE-T) RJ45 connectors
- One copper Ethernet (10/100BASE-T) RJ45 connector and one fiber Ethernet 100BASE-FX (multimode) LC connector
- Dual fiber Ethernet 100BASE-LX10 (single-mode) LC connectors
- One copper Ethernet (10/100BASE-T) RJ45 connector, and one fiber Ethernet 100BASE-LX10 (single-mode) LC connector

Figure 13 Ethernet Communications Cards

Front-Panel Targets and Messages

Program front-panel LEDs to indicate any control element operation, and modify front-panel labeling via configurable slide-in cards. Extra cards and a Microsoft® Word template are available.

The control automatically determines the operating conditions and displays this information on the front-panel display.

- Neutral position
- Voltage reduction active
- Automatic operation inhibited
- Reverse power
- Voltage high limit
- High band
- In band
- Low band
- Voltage low limit

Simple or Advanced Settings

Easy to Use

The SEL-2431 provides two ways to get your regulator running quickly and easily. For fast, basic operation, simply enter 10–15 values of nameplate data and voltage regulation set points directly into the front panel or use Windows®-based ACSELERATOR QuickSet® SEL-5030 Software to guide you through the settings process.

Use ACSELERATOR QuickSet to Set, Monitor, and Control the SEL-2431

- Save engineering time while keeping flexibility. Communicate with the SEL-2431 through any ASCII terminal or use the ACSELERATOR QuickSet graphical user interface.
- Develop settings offline with a menu-driven interface and completely documented help screens. Speed installation by copying existing settings files and modifying application-specific items. Interface supports Windows operating systems.
- Simplify the settings procedure with rules-based architecture to automatically check interrelated settings. Out-of-range or conflicting settings are highlighted for correction.
- Transfer settings files by using a PC communications link with the SEL-2431.

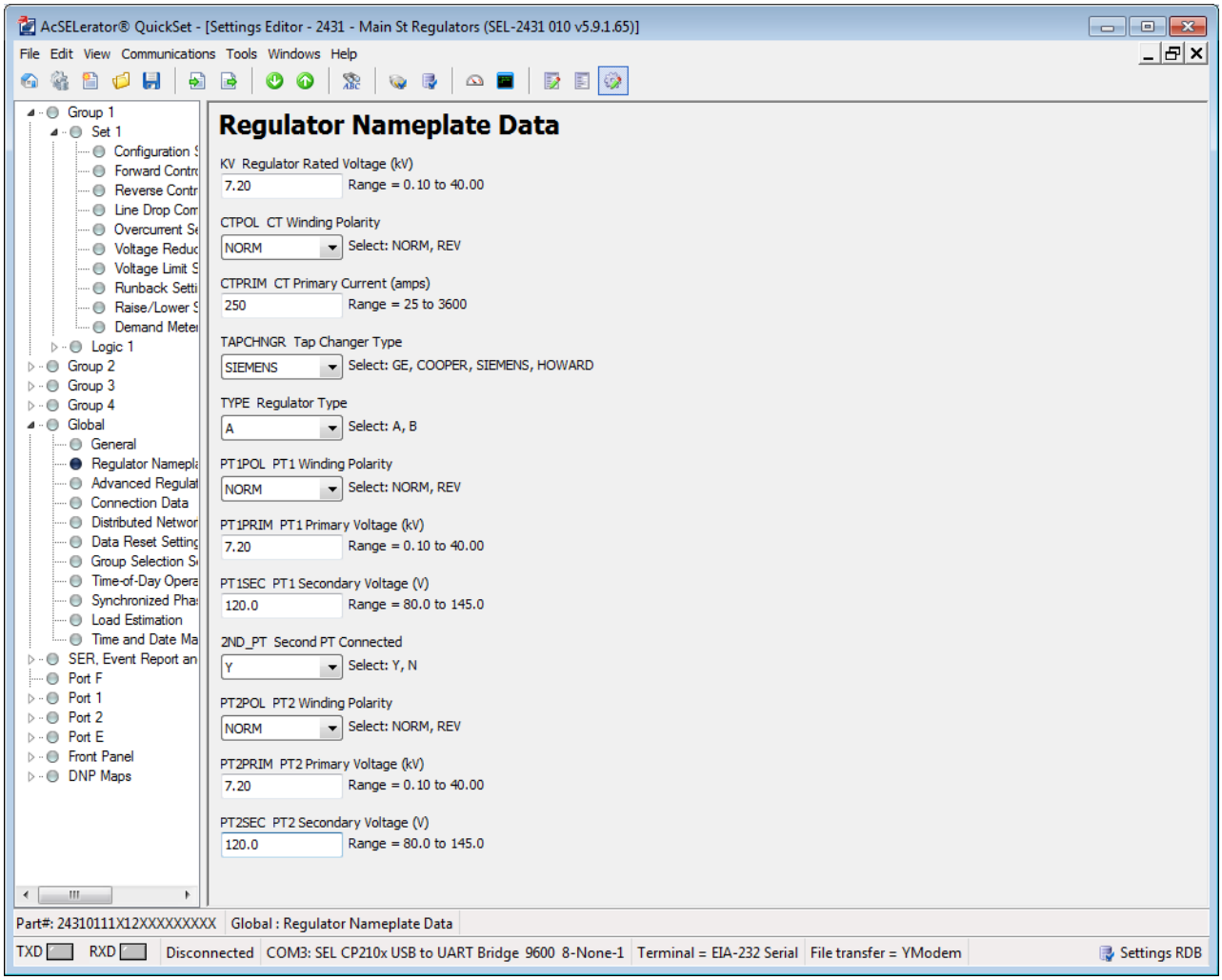


Figure 14 ACSELERATOR QuickSet Nameplate Data Screen

Tap-Change Reporting and Troubleshooting

Event and Tap-Change Reports

The SEL-2431 captures as many as 32 30-cycle event reports and creates an event summary in response to user-programmable conditions. View the summary by using the front-panel LCD or by connecting to a computer. Event summaries contain useful data about tap changes.

- Event number, date, and time
- Magnitudes of the load current and voltage, tap position, and system frequency

Download and view full event reports by using ACSELERATOR QuickSet. Event reports contain current and voltage oscillography, and the state of the control elements. The pretrigger length is adjustable from 1–29 cycles.

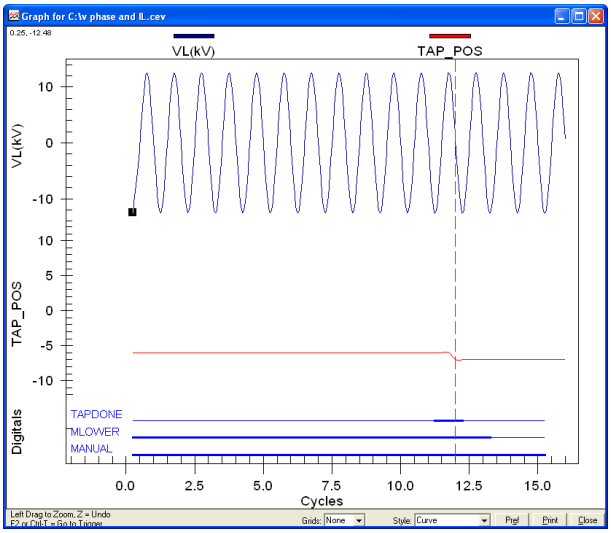


Figure 15 ACSELERATOR QuickSet Event Report

Sequential Events Recorder (SER)

The SEL-2431 tracks the pickup and dropout of selectable regulator elements, control inputs, and contact outputs. The date and time of the 1000 most recent transitions are available in an SER report. This chronological report helps you determine the order and cause of events and assists in troubleshooting and root-cause analysis. Connect a USB flash drive and expand the SER report to thousands of entries, limited only by the size of the USB flash drive.

Metering

The SEL-2431 provides extensive and accurate metering capabilities, as shown in *Table 4*. See *Specifications on page 17* for metering accuracies. THD elements for the current and voltage channels are available for harmonics-based decisions or operations.

Table 4 Available Metering Quantities (Sheet 1 of 2)

Instantaneous Quantities	Fundamental Values
Current	
I_L	L—Bushing current (primary and secondary)
Voltages	Values for both Source and Load voltage channels (primary and secondary)
V_L	L—Bushing voltage
V_S	S—Bushing voltage
V_{COMP}	Compensated voltage
Power	
Real (kW)	kilowatts
Reactive (kVAR)	kilovars
Apparent (kVA)	kilovolt-amperes
Power Factor	Power factor (with leading or lagging indication)
FREQ	System frequency
TAP	Tap position
Demand Quantities	**Present and Peak, Forward and Reverse (Time-Stamped Peaks)**
Current	
I_L	L—Bushing current (primary)
Power	
Real (kW)	kilowatts
Reactive (kVAr)	kilovars
Apparent (kVA)	kilovolt-amperes
Energy Quantities	**Forward and Reverse (Energy Out and In)**
MWh	megawatt hours
MVArh	megavar hours
Maximum/Minimum Quantities	**Forward and Reverse (Time-Stamped Maximums)**
Current	
I_L	L—Bushing current (primary)
Voltages	Values for both Source and Load voltage channels (primary and secondary)
V_L	L—Bushing voltage
V_S	S—Bushing voltage
V_{COMP}	Compensated voltage

Table 4 Available Metering Quantities (Sheet 2 of 2)

Power	
Real (kW)	kilowatts
Reactive(kVAr)	kilovars
Apparent (kVA)	kilovolt-amperes
PF	Power factor (at max/min kVA)
FREQ	System frequency
TAP	Tap position
Harmonic Quantities and Total Harmonic Distortion (THD)	**2nd Through the 15th Harmonic**
Current	
I_L	L—Bushing current
Voltages	
V_L	L—Bushing voltage

Load Profile

The load profile recorder in the SEL-2431 is capable of recording as many as 16 selectable analog quantities at a periodic rate (5, 10, 15, 30, or 60 minutes) and storing the data in a report in nonvolatile memory. The SEL-2431 will also store the data to a connected USB flash drive if the Automatic Report Backup feature is enabled. Choose any of the analog quantities listed in *Table 4* (except peak demands, 2–15 harmonic, and max/min values). At a fifteen-minute periodic recording rate and with 16 selected analog quantities, as many as 90 days of load profile data can be stored in the onboard memory. Selecting a longer recording period or fewer analog quantities increases the number of days of storage available. Enabling the Automatic Report Backup feature increases the amount of storage available based on the size of the connected USB flash drive.

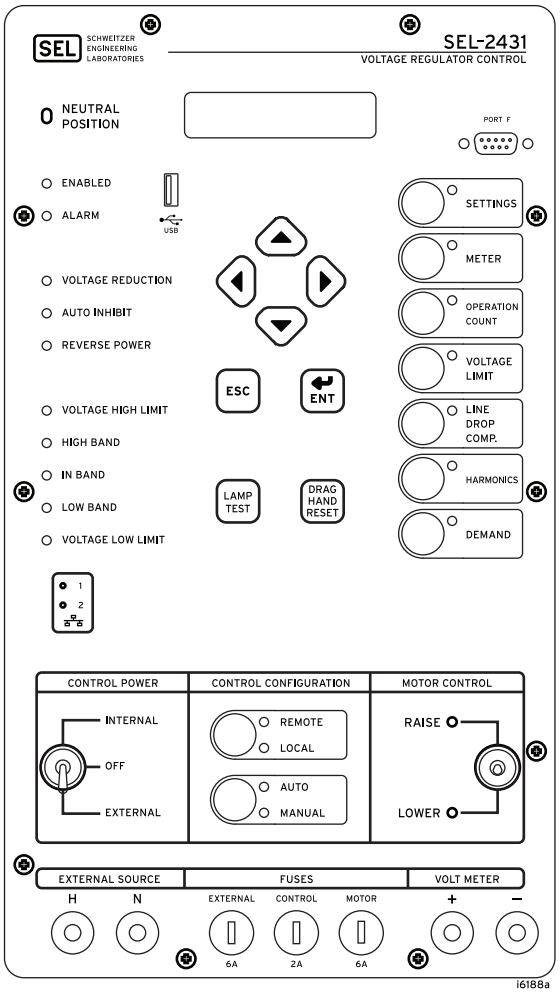
Built to Relay Standards

The SEL-2431 Voltage Regulator Control is designed, built, and tested with the same practices, processes, and standards that we use for our protective relays, recloser controls, and other products. This includes compliance with IEEE and IEC standards for the following:

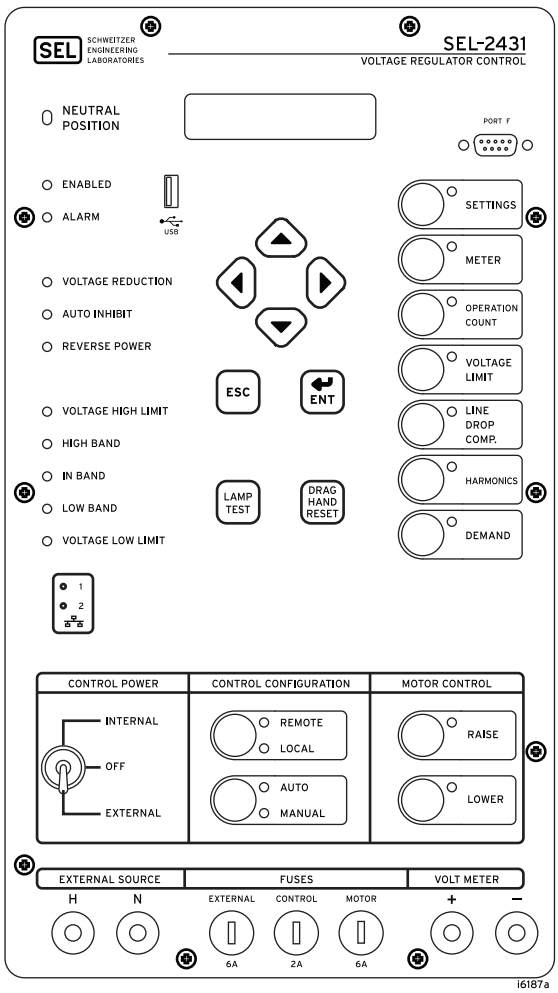
- Radio frequency interference
- Environmental stress
- Dielectric strength
- Impulse
- Electrostatic discharge
- Fast transients
- Surge withstand capability
- Shock and bump
- Vibration
- Object penetration

Refer to *Specifications on page 17* for detailed test data.

Front- and Rear-Panel Diagrams



Front Panel With Raise/Lower Toggle Switch Option



Front Panel With Raise/Lower Pushbuttons Option

Figure 16 SEL-2431 Front Panels

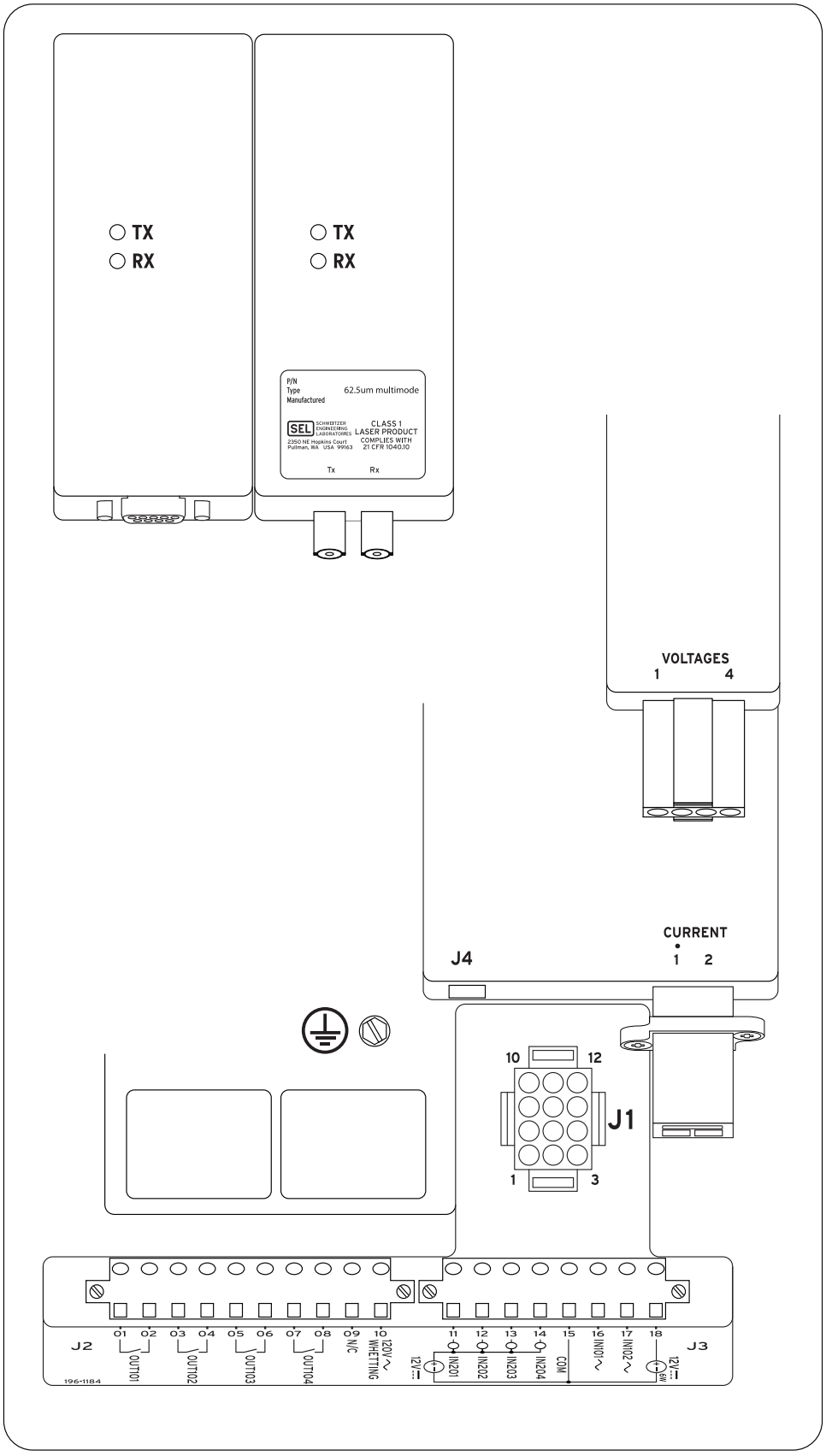


Figure 17 SEL-2431 Rear Panel

Dimensions

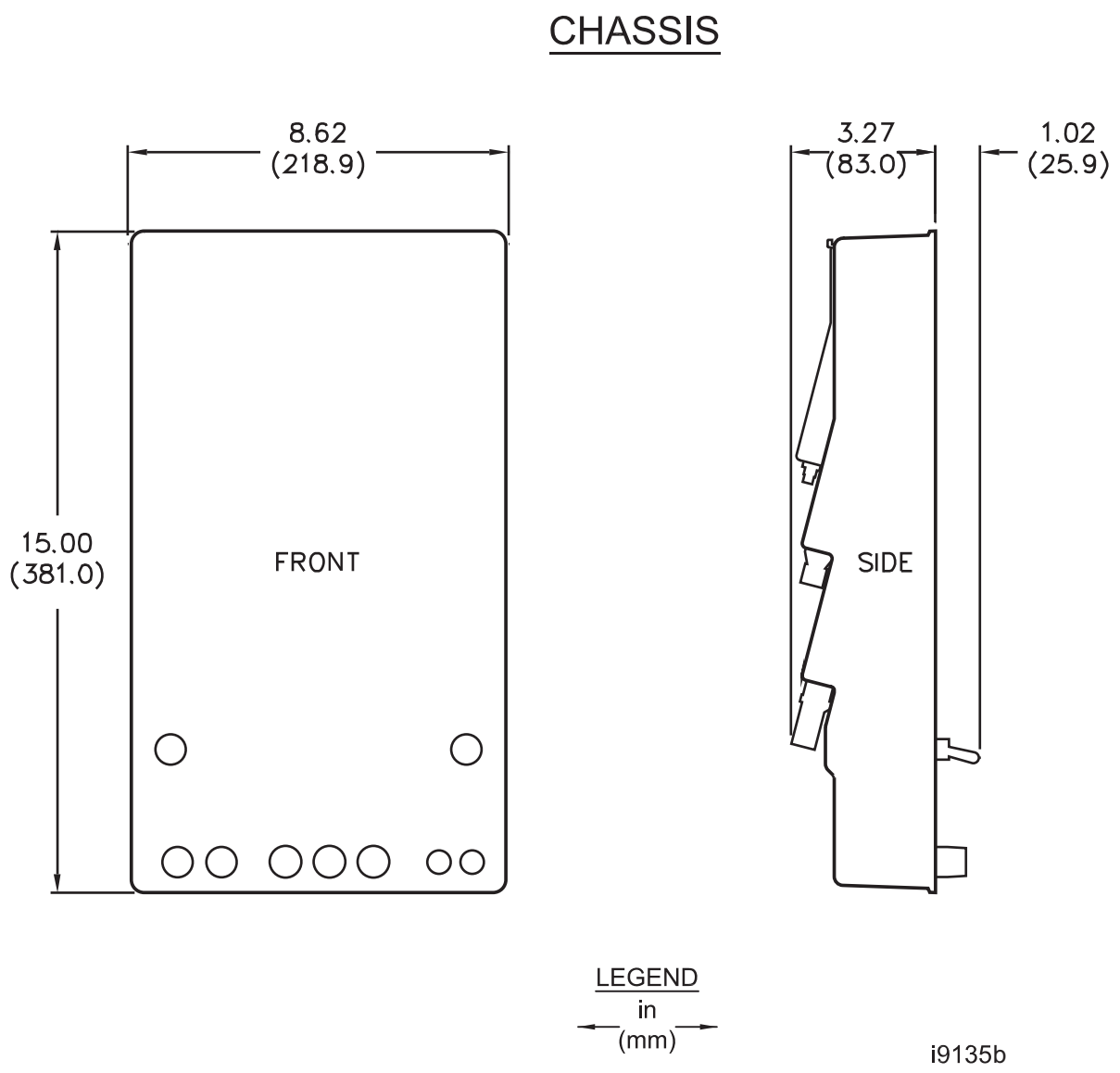


Figure 18 SEL-2431 Dimensions

Specifications

Compliance

ISO 9001:2008 Certified

General

AC Current Input

0.2 A nominal:	0.64 A continuous, 4 A for 1 s, linear to 2.18 A symmetrical. 20 A for 1 cycle.
Burden:	<1 VA

Power Supply

120 Vac

Range:	88–132 Vac
Burden:	≤35 VA
Interruption:	≤50 ms at 120 Vac per IEC 60255-11

120 Vac Whetting Source

Range:	88–132 Vac
Rated current:	6 A (motor fuse)

12 Vdc Auxiliary Output Source

Range:	11–14 Vdc
Output power:	6 W at 12 Vdc

Output Contacts

Make:	30 A
Carry:	3 A continuous carry at 120 Vac
MOV Protection:	270 Vac/360 Vdc; 40 J
Pickup Time:	≤16 ms
Dropout Time:	≤16 ms
Update Rate:	1/16 cycle

Breaking Capacity (10000 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 cycle/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

Note: Make per IEEE C37.90:1989; Breaking and Cyclic Capacity per IEC 60255-23 [IEC 255-23]:1994.

Raise/Lower Outputs

Carry:	6 A continuous at 120 Vac

Optoisolated Inputs

120 Vac:	Pickup 80–145 Vac
12 Vdc:	Pickup 9.6–14.4 Vdc

Note: 12 Vdc optoisolated inputs draw approx. 10 mA of current.

Frequency

System Frequency:	50 or 60 Hz

Communications Ports

Standard:	1 front EIA-232 (300–38400 bps)
Optional:	1 or 2 rear-mounted serial communications cards, or 1 rear-mounted serial communications card and 1 rear-mounted Ethernet communications card
Available Serial Communications Card Types:	EIA-232 (300–57600 bps) 2-Wire EIA-485 (300–57600 bps) 4-Wire EIA-485 (300–57600 bps) 200 µm multimode fiber with VPIN connector (300–38400 bps) 62.5 µm fiber with ST connector (300–57600 bps)
Available Dual Ethernet Communications Card Types:	Dual Fiber Ethernet 100BASE-FX (Multimode) LC Connectors Dual Copper Ethernet (10/100BASE-T) RJ45 Connectors One Copper Ethernet (10/100BASE-T) RJ45 Connector and One Fiber Ethernet 100BASE-FX (Multimode) LC Connector Dual Fiber Ethernet 100BASE-LX10 (Single-mode) LC Connectors One Copper Ethernet (10/100BASE-T) RJ45 Connector, and One Fiber Ethernet 100BASE-LX10 (Single-mode) LC Connector

Operating Temperature

–40° to +85°C (–40° to +185°F)
Note: LCD contrast impaired for temperatures below –20° and above +70°C (–4° and +158°F, respectively)

Time-Code Input

Device accepts demodulated IRIG-B time-code input at Port 1 if Port 1 contains either an EIA-232 card, a 4-Wire EIA-485 card, or a fiber-optic serial card.

Clock Synchronization Accuracy

C37.118 IRIG-B:	10 µs
IRIG-B:	5 ms
DNP3:	2 s

Unsynchronized Clock Drift

Control Powered:	26.5 minutes per year, typical

Routine Dielectric Strength

AC current inputs:	2500 Vac for 10 s

Weight

<4.5 kg (10.0 lb)

Type Tests

Environmental Tests

Cold:	IEC 60068-2-1:2007 Test Ad; 16 hr at –40°C
Damp Heat Cyclic:	IEC 60068-2-30:2005 Test Db; 25° to 55°C, 6 cycles, 95% humidity
Dry Heat:	IEC 60068-2-2:2007 Test Bd: 16 hr at +85°C

Dielectric Strength and Impulse Tests

Dielectric:	IEC 60255-5:2000 IEEE C37.90-2005, Section 8—Insulation Tests 3100 Vdc on general contact outputs and CT input; 2200 Vdc on EIA-485 communications port; 2000 Vdc on all other connectors
Impulse:	IEC 60255-5:2000 IEEE 37.90-2005 0.5 J, 5000 V

Electrostatic Discharge Test

ESD:	IEC 60255-22-2:2008 IEC 61000-4-2:2008 IEEE C37.90.3-2001 2, 4, 6, 8 kV contact discharge 2, 4, 6, 8, 15 kV air discharge

RFI and Interference Tests

Fast Transient Disturbance:	IEC 60255-22-4:2008 IEC 61000-4-4:2011, Class A, 4 kV
Radiated RFI:	IEC 6100-4-3:2010, 10 V/m IEC 60255-22-3:2007, 10 V/m IEEE C37.90.2-2004, 35 V/m
Radiated Radio Frequency (1.89 GHz):	ENV 50204:1995, 10 V/m
Surge Withstand:	IEEE C37.90.1-2002 2.5 kV oscillatory; 4 kV fast transient IEC 60255-22-1:2007 2.5 kV peak common mode, 1.0 kV peak differential mode
Surge Immunity:	IEC 61000-4-5:2005 IEC 60255-22-5:2008 1 kV line-to-line, 2 kV line-to-earth
Conducted Immunity:	IEC 61000-4-6:2008 IEC 60255-22-6:2001 10 Vrms Installed RF Ferrite Choke (Fair Rite part #0443164151) on copper Ethernet cables. Contact the SEL factory for this complimentary part if needed.
Power Frequency Magnetic Field Immunity:	IEC 61000-4-8:2009 100 A/m (60 sec), 1000 A/m (3 sec)
Pulse Magnetic Field Immunity:	IEC 61000-4-9:2001 1000 A/m
Damped Oscillatory Magnetic Field Immunity:	IEC 61000-4-10:2001 100 A/m
Power Supply Variation and Interruption:	IEC 60255-11:2008 IEC 6100-4-11:2004 IEC 61000-4-17:2002 IEC 61000-4-29:2000

Vibration and Shock Tests

Shock and Bump:	IEC 60255-21-2:1988 Class 1: Shock Withstand, Bump Class 2: Shock Response IEC 60255-21-3:1993 Class 2
Sinusoidal Vibration:	IEC 60255-21-1:1988 Class 1: Endurance Class 2: Response

Object Penetration

Object Penetration:	IEC 60529:2001 IP 20, excluding terminal blocks

Processing Specifications

Analog Data Acquisition:	32 samples per power system cycle, frequency tracking
Control Processing Rate:	Once per power system cycle, frequency tracking
Data Filtering:	Full-cycle cosine filter after low-pass analog filtering
Filtered Data Averaging (voltage and currents):	10 cycles (except for fault overcurrent element)

Control Accuracies

Voltage Control Accuracy—Steady State (V secondary)

Measured Channels:	±0.3% (–40° to + 85°C, 108–132 Vac) (IEEE C57.15-1999)
Calculated Values:	±1.0% (–40° to + 85°C, 108–132 Vac)

Overcurrent Accuracy—Steady State (A secondary)

General Overcurrent Elements:	±0.3% ±500 µA (0.002–0.700 A)
Fault Overcurrent Element:	±0.3% ±500 µA (0.4–2.0 A)

Overcurrent Element Response (Applied Current > 2x Pickup Setting)

General Overcurrent Elements:	<10 cycles
Fault Overcurrent Element:	<3 cycles

Metering Accuracy

Load Current:	±0.3% ±500 µA (0.001–2.000 A) and ±0 .5° (0.020–2.000 A)
Harmonics (2nd–15th):	Current: ±5% of fundamental (0.02–0.64 A)
Voltages:	±0.3% and ±0.5° (80–145 Vac)

Synchrophasor Accuracy

Maximum Data Rate in Messages per Second

IEEE C37.118 Protocol:	60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
IEEE C37.118 Accuracy:	Level 1 at maximum message rate when frequency-based phasor compensation is enabled (PHCOMP = Y) PMDOK bit will deassert due to inclusion of out-of-band interfering signal.
Nominal Current:	450 mA
Current Range:	45 mA to 540 mA
Frequency Range:	±5 Hz of nominal (50 to 60 Hz)
Voltage Range:	80 V to 145 V (Voltage range is limited by power supply ratings)
Phase Angle Range:	–180° to +180°

Notes

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