SEL-2414 Transformer Automation Controller

Control Load Tap Changers (LTC), Regulate Cooling Stages, and Monitor Transformer Life in One Device

Key Features and Benefits

The SEL-2414 Transformer Automation Controller (TAC) offers transformer thermal monitoring, load tap changer (LTC) control, and cooling stage control in one economical device.

- Reduce energy losses and ensure bus voltages stay within acceptable limits.
- Optimize transformer performance for changes in loads, power flow directions, and seasonal conditions by using adaptive LTC control bands.
- Share loads across paralleled transformers and operate tap changers by using paralleling schemes that minimize circulating currents.
- Extend the lifespan of your transformer with IEEE or IEC thermal modeling and cooling stage control.
- Integrate the SEL-2414 with SCADA systems and distributed control systems (DCSs) by using communications protocols such as IEC 61850 Edition 2.1, DNP3, Modbus, and more.

Features

- **AUTO or MANUAL Modes With Remote or Local Control.** In AUTO mode, automatically regulate bus voltage according to the configured settings and system requirements. In MANUAL mode, send the RAISE and LOWER commands by using the pushbuttons or SELOGIC® control bits. Remotely issue control commands through remote input bits or virtual control bits provided by the communications interface.
- **Configurable Bandwidth Voltage Control.** Set the center-band and bandwidth for the controlled voltage for your application requirements. Specify the center-band in secondary voltages and the bandwidth in percentage. For SCADA-based controls, remotely modify the band settings by using math variables, remote analogs, or analog control variables as set points.
- **Configurable Tap Delays.** Control the first and subsequent tap change delays by using timer-based settings. Customize inverse-time delay elements that are based on linear or hyperbolic curves to dynamically change the first tap delay depending on the magnitude of the out-of-band deviation.
- **Forward and Reverse Power Flow Operation.** Regulate voltages by using the locked forward or locked reverse mode. Regulate voltages during dynamic power flow conditions by using the bidirectional or cogeneration modes.
- **Line Drop Compensation (LDC).** Compensate for resistive and reactive voltage drops on the line between the transformer and the regulation point. Configure different line drops at rated currents for forward and reverse power flow according to your line specifications. Apply reverse LDC by configuring the high-side line drop parameters.
- **Voltage Reduction.** Implement as many as three voltage reduction levels for short-term demand-side requirements. Activate the required reduction level from SCADA or logic implementation on the local device.
- **Voltage Runback (High and Low).** Initiate the automatic tap position control to bring the bus voltage within the high and low runback settings, irrespective of the center-band tap delay settings.
- **Transformer Paralleling.** Operate as many as four transformers in parallel with four integrated SEL-2414 TACs with preconfigured Ethernet-based communications. Coordinate as many as two independent parallel groups by assigning device role designations to the TACs in the network. Automate device role assignments for changing breaker and bus configurations by using SELOGIC control equations.
- **Run to Neutral.** During extreme voltage out-of-band conditions or during system maintenance for swiping the reversing switch, move the tap position to neutral sequentially.
- **Thermal Monitoring and Metering Capabilities.** Safeguard transformers from overheating by tracking thermal conditions. Track the minimum and maximum transformer top-oil temperature, hot-spot temperature, and as many as 10 RTDs or thermocouples. Calculate hot-spot temperature according to the IEEE C57.91-2011 or the IEC 60076-7:2018 Ed. 2 standards.
- **Cooling Bank Exercising and Alternation.** Manage cooling bank alternation and fan exercise to prevent motor failure and ensure balanced wear on the cooling banks.
- **Transformer Status, Alarms, and More.** Take advantage of I/O options including digital inputs for status such as oil level and sudden pressure; RTD and thermocouple inputs for measurements such as ambient, top-oil, and hot-spot temperatures; digital outputs for control and alarms; analog inputs and outputs; and ac current and voltage inputs. Easily program monitoring and control functions with powerful logic, math, timers, counters, and edge-trigger functions. These features easily integrate with new and retrofit transformer monitor applications.
- **Advanced Asset Monitoring.** Monitor critical substation assets with comprehensive transformer thermal and through-fault monitoring. Calculate top-oil, hot-spot, insulation aging acceleration factor, and loss of life while generating hourly and daily data about your transformer. Capture the maximum/minimum values of all transformer model quantities. Capture through-fault current data that could lead to increased transformer wear.
- **Custom Records.** Capture values of as many as 8 analog quantities and 16 Device Word bits at 100 ms intervals up to about an hour as compressed event report file format. Trigger the recording on and off by specifying SELOGIC settings. In LTC applications, monitor voltages, load currents, tap position values, and band condition Device Word bits. Trigger custom recordings by using operational events such as the RAISE or LOWER commands or voltage limit excursions. Store as many as 100 tap change events in the SEL-2414.
- **Tap Position Monitoring.** Monitor as many as 32 tap positions with as many as 3 neutrals by using the various input cards in the following methods:
  - 4–20 mA, ±1 mA, or 0–2 mA tap position transducers
  - Remote analog value from SCADA
  - BCD or binary format tap position indicator

- **Auxiliary Tap Position Monitoring.** Monitor tap positions by using an auxiliary tap position monitor and set up alarms on tap position monitor discrepancies.
- **Tap Position Statistics.** Analyze and record tap position statistics with two sets of resettable non-volatile counters for each tap position. One set of counters monitor operation counts since commissioning, and the other set monitor operation counts after a custom reset. Monitor the tap position extremes that are analogous to drag hands from the statistics report.
- **Tap Event Report.** Record LTC tap position change events and log time stamps of all tap position changes. The SEL-2414 time stamps the event to the closest second. Download this report over FTP, MMS, or Telnet for analysis and plotting tap position trends.
- **Control Inhibition.** Configure the SEL-2414 to inhibit or block RAISE and LOWER commands when the LTC has reached the maximum and minimum tap positions, respectively, or any other power system condition occurs.
- **Programmable Pushbuttons and LED Status Indication.** Program eight pushbuttons to quickly perform custom control commands for AUTO/MANUAL, REMOTE/LOCAL, RAISE/LOWER, etc. Configure two programmable tri-color LEDs for each pushbutton to indicate status. Use the seven programmable front-panel tri-color target LEDs to display additional statuses and alarms.
- **Touchscreen Features.** Use the optional five-inch touchscreen with intuitive screens to display thermal information, bus voltage variations, and tap position statistics. Additionally, create custom screens by using ACSELERATOR® Bay Screen Builder SEL-5036 software. The touchscreen display simplifies device data metering, monitoring, and control.

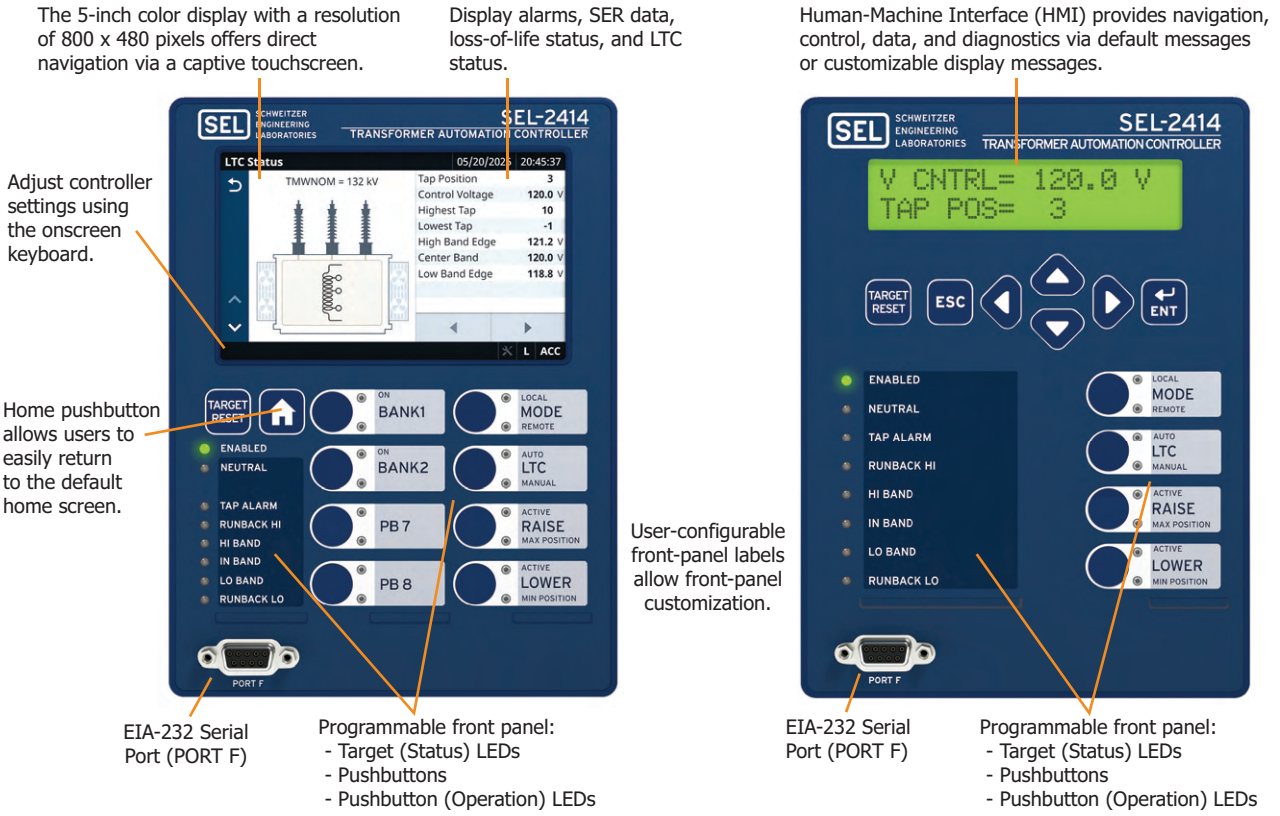
Optional

Configure the SEL-2414 with the following I/O and communications options:

- Digital I/O: 8 DI, 14 DI, 8 DO, 4 DI/4 DO, 4 DI/3 DO with 2 Form C and 1 Form B
- Analog I/O: 8 AI, 4 AI/4 AO
- Temperatures: 10 RTDs or 10 thermocouples
- Voltage and Current Measurements: 4 ACI/3 AVI, 3 ACI/3 AVI, 4 ACI, 3 AVI
- Port 1: Single/Dual 10/100BASE-T copper (RJ45 connector), Single/Dual 100BASE FX (LC connector)
- Port 2: Fiber-optic port (62.5 µm core fiber, ST connectors, SEL-2812 compatible)
- Port 4: EIA-232 or EIA-485
- Environment conformal coating for chemically harsh and high-moisture environments
- Protocols:
  - Serial: SEL, Mirrored Bits, DNP3
  - Ethernet: Modbus TCP, DNP3 LAN/WAN, FTP, Telnet, IEC 61850 GOOSE, and MMS

Functional Overview

The SEL-2414 is a versatile LTC controller with reliable I/O, accurate current and voltage measuring, thermal monitoring, an optional intuitive large display module, dependable communications, local storage of event reports, custom records, LTC event records, historical statistics, and more. Measure the load tap position by using binary-coded decimal (BCD) and/or analog transducer inputs. Issue the RAISE and LOWER commands for tap control via dedicated digital output contacts. Measure as many as ten temperatures by using resistance temperature detector (RTD) or thermocouple sensors.



The flexible I/O options allow you to meet the many needs of new or retrofit transformer installations. The SEL-2414 includes four slots for plug-in I/O cards. Use digital inputs (DI) to monitor critical transformer alarms and status points. Use analog inputs (AI) to measure pressure, oil level, temperatures, tap positions, and process-level signals (e.g., 4–20 or 0–2 mA) from transducers. Operate cooling fans, equipment, alarms, or indicators with relay-contact or solid-state digital outputs (DO) and analog outputs (AO). Measure ac currents and voltage to calculate three-phase power, demand, and energy, and record oscillograph reports. Analyze tap changer events through custom records, LTC event reports and tap position statistics reports.

Deploy the SEL-2414 to satisfy standalone or distributed monitoring and control of transformers. Choose from the flexible communications options to connect to a substation with distributed SCADA or an automation system or a SCADA master. Communications options include serial, fiber-optic, and Ethernet ports, and protocol options include ASCII, SEL Fast Message, MIRRORED BITS® communications, Modbus, and DNP3, IEC 61850 Edition 2.1 GOOSE, and MMS. *Figure 1* shows the SEL-2414 functionality.

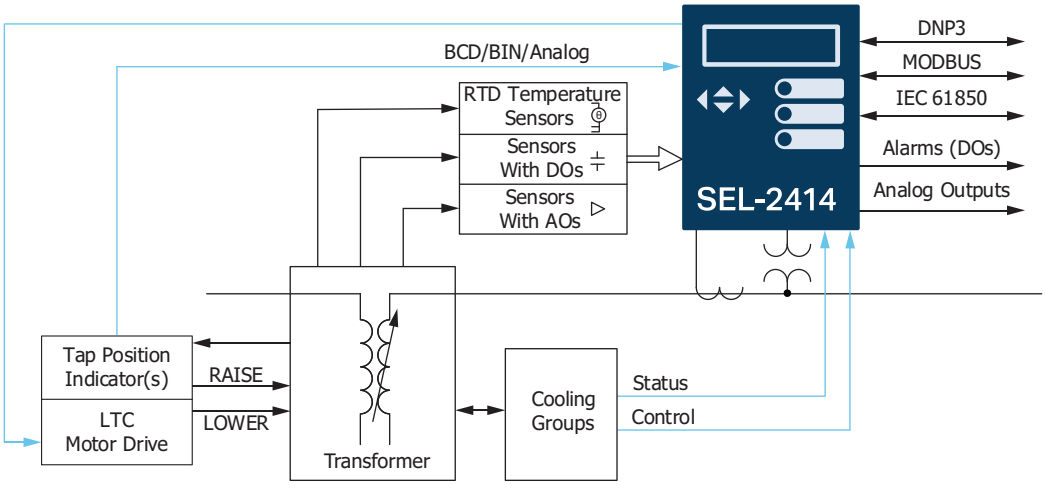


Figure 1 LTC Control and Transformer Thermal Regulation Solution

Application Examples

LTC Control

The LTC Control feature requires at least one voltage measurement and one type of tap position monitoring input. The LTC Control feature requires a load current measurement input for LDC. Connect PTs and CTs, as shown in *Figure 2*–*Figure 5*, to the SEL-2414 to provide the voltage and current measurements.

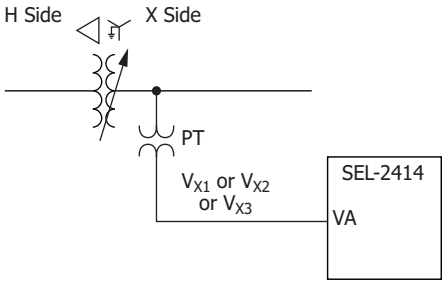


Figure 2 PT Connections to SEL-2414 for PTCTMODE = V

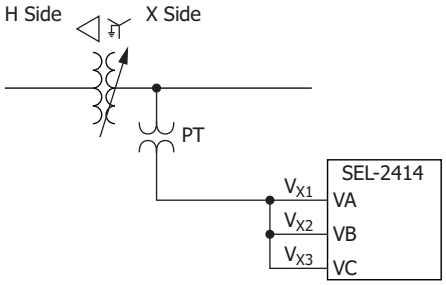


Figure 3 PT Connections to SEL-2414 for PTCTMODE = V_AVE, V_MAX, or V_MIN

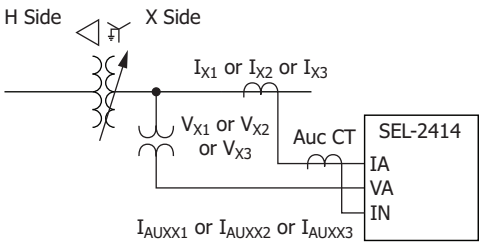


Figure 4 PT Connections to SEL-2414 for PTCTMODE = V_I. Set EN_INLTC= Y to Use IN in Calculations.

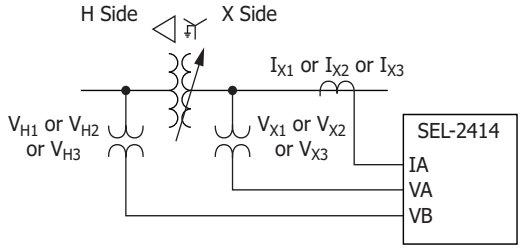


Figure 5 PT Connections to the SEL-2414 for PTCTMODE = V_I_V

Select the Device setting OPMODE based on the conditions listed in *Table 1*, which shows the power flow regions that each of the OPMODE operates in. *Figure 6* shows the control operation directions for the various power flow conditions that may occur in your system.

Table 1 Selections for Device Setting OPMODE

OPMODE Selection	Operating Mode: Scenario
LOCKFWD	Locked Forward: Power flow is always expected to be in the forward (X-side) direction.
LOCKREV	Locked Reverse: Power flow is always expected to be in the reverse (H-side) direction.
IDLEREV	Idle Reverse: Power flow is always expected to be in the forward (normal load-side) direction, but no voltage regulation should occur if power flow is indeterminate (e.g., “no load” condition).
BIDIR	Bidirectional: The power flow direction varies because of the multiple electric power system interfaces, and the control alternately operates the regulator in the forward (X-side) and reverse (H-side) directions depending on the power flow.
COGEN	Cogeneration: Power flow direction varies because of the distributed energy resources on the normal load side. During the reverse power flow, voltage is still regulated from a forward direction perspective (at the X-side).

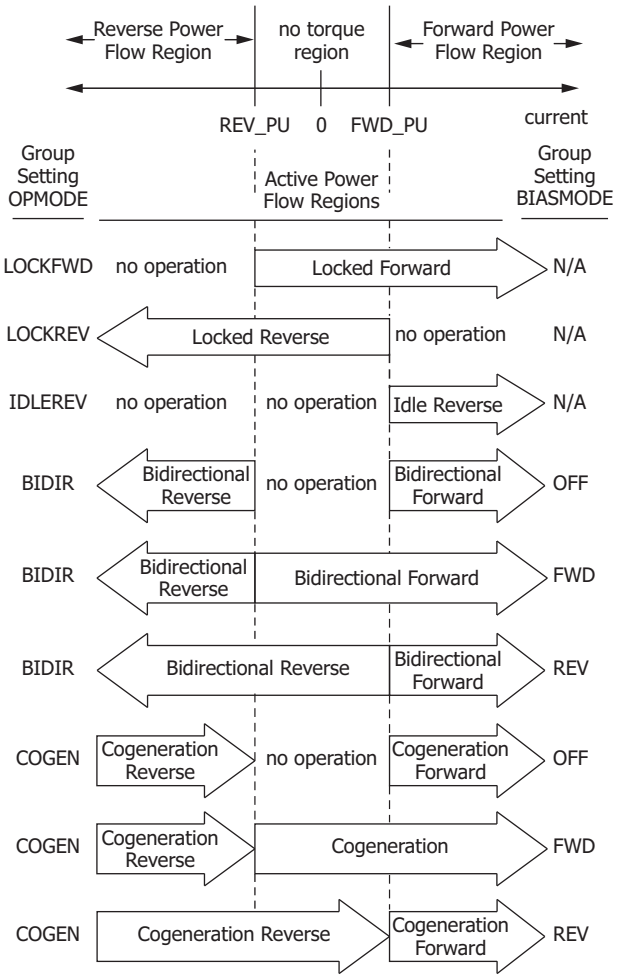
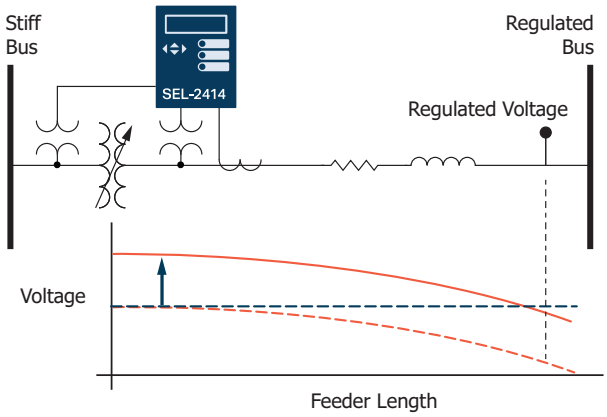


Figure 6 Active Power Flow Regions for the Different Operating Modes

Line Drop Compensation

Regulate voltage on a remote bus by using line-drop compensation. Set the nominal resistive and reactive voltage drops over the line and let the SEL-2414 calculate the compensated voltage and issue controls to keep the voltage within the required band.

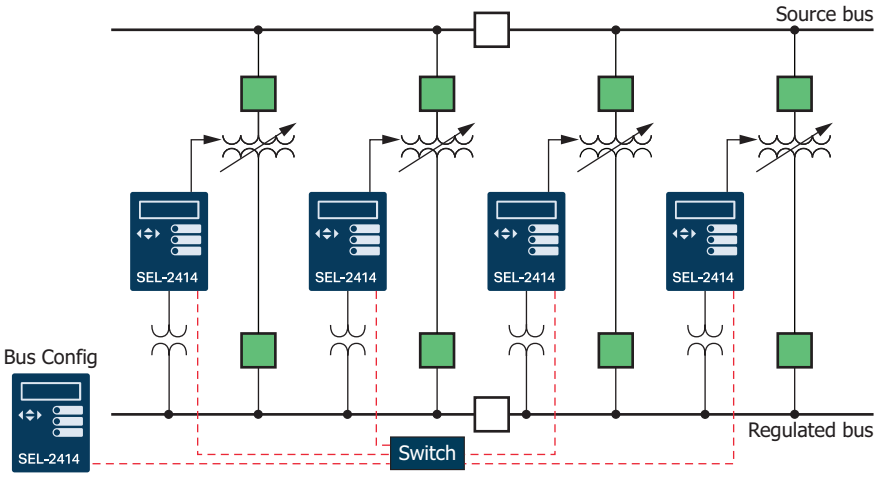


Build a Transformer Paralleling Scheme

Deploy a network of SEL-2414 TACs to implement transformer parallelling schemes for as many as four transformers and two parallel groups. Choose between the master-follower or current-angle method. Share pre-configured device states, tap position, and current angle information between the TACs over an unmanaged or managed switch. Configure an additional device to share bus configuration state changes and device role designations to the TACs that allow them to reconfigure tap changer control accordingly.

Choose one of the following methods for proper LTC parallel control:

- Master-Follower Method. The leader transformer initiates the load tap change operations and sends a command to the other parallel transformers to follow.
- Current-Angle Method. A comparison of the current angles from the parallel transformers and the power flow direction determines the transformer that will perform a tap change operation next. This method minimizes the circulating current.



I/O (Status and Alarms)

Use digital inputs to monitor critical alarms such as oil levels, pressures, and gas accumulation; they may also be used for status points such as fans on/off and breakers open/closed, as shown in *Figure 7*.

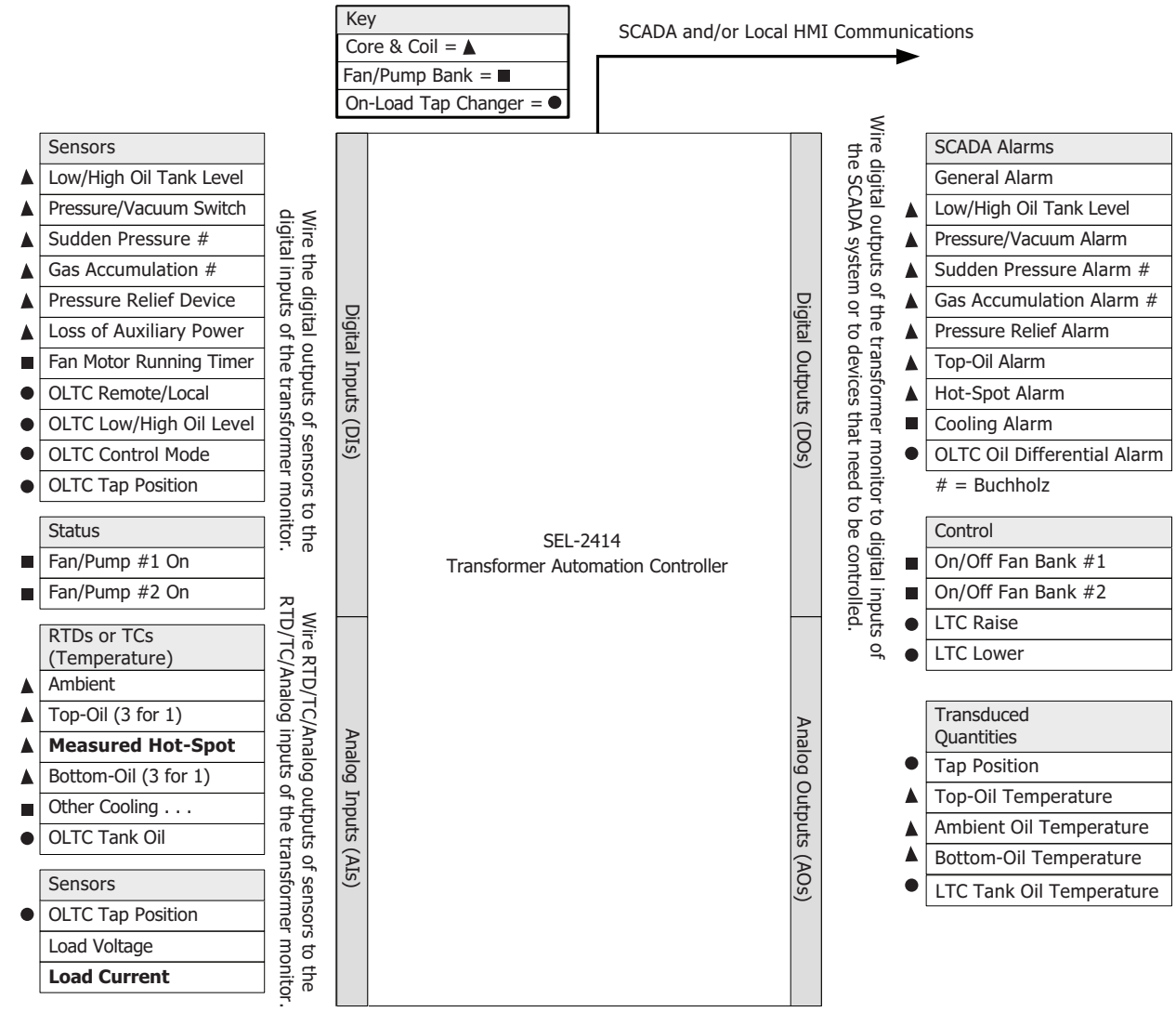


Figure 7 Transformer Monitor and Control System

Analyze Transformer Sequence of Events

Record sequence of events related to transformer events or operations with the Sequential Events Recorder (SER) function. With this function, you can analyze assertions and deassertions of digital inputs and outputs; as many as 512 state changes to the millisecond for as many as 96 different digital points. The function also captures when the device powers up and a settings change occurs.

SEL-2414 Date: 04/03/2005 Time: 07:21:19
DEVICE

#	DATE	TIME	ELEMENT	STATE
17	04/03/2005	06:25:51.120	RB01	Deasserted
16	04/03/2005	06:25:51.125	OUT102	Deasserted
15	04/03/2005	06:26:03.049	RB01	Asserted
14	04/03/2005	06:26:03.053	OUT102	Asserted
13	04/03/2005	06:51:17.748	Device Powered Up	
12	04/03/2005	06:51:20.361	OUT101	Asserted
11	04/03/2005	06:51:21.366	OUT101	Deasserted
10	04/03/2005	06:54:10.753	Device Settings Changed	
9	04/03/2005	06:54:10.762	FAN BANK #2 OFF	Asserted
8	04/03/2005	06:54:11.737	OUT101	Deasserted
7	04/03/2005	07:06:01.739	FAN BANK #2 ON	Asserted
6	04/03/2005	07:06:02.744	OUT101	Deasserted
5	04/03/2005	07:06:14.993	Device Settings Changed	
4	04/03/2005	07:06:15.002	OUT101	Asserted
3	04/03/2005	07:06:15.977	FAN BANK #1 ON	Deasserted
2	04/03/2005	07:13:22.947	OUT101	Asserted
1	04/03/2005	07:13:23.951	OUT101	Deasserted

SER Number Element or Condition Element State

Figure 8 Example SER Report

Analyze Transformer Event Waveforms

Record analog and digital waveforms at 32 samples/cycle for as many as 64 power system cycles, approximately 1 s. Use the event report to move the oscillographic data to your PC. You can plot your event report data with the SEL-5601-2 SYNCHROWAVE® Event Software or with Microsoft Excel.

Event reports contain ac currents, ac voltages, and digital inputs and outputs. The report automatically adjusts content to the I/O cards you use. Reports are stored in nonvolatile memory to protect your data even if power is lost. Event reports are optimized for recording power disturbances and relating them to your process.

Set the report to capture either 15 or 64 power system cycles of data around the trigger event. For a 60 Hz system, the event report lengths are 0.25 s and 1.07 s. For a 50 Hz system, the report lengths are 0.30 s and 1.28 s.

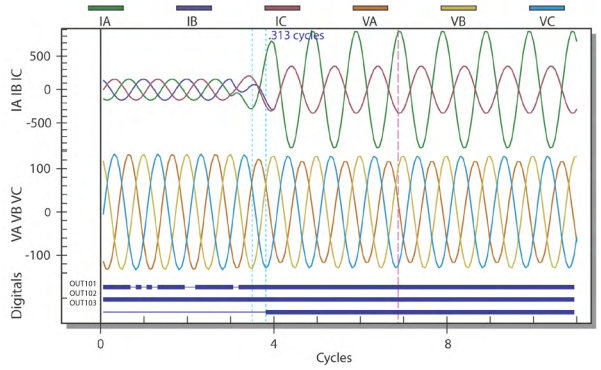


Figure 9 Example SYNCHROWAVE Event Waveform Plot

Trend Transformer Temperatures and Other Analog Inputs

Record measured ambient, transformer top-oil, transformer hot-spot and other analog data (measured or calculated) for trending with the Analog Signal Profile function. This profile (trending) function can track as many as 32 analog channels. The function records the magnitude and time of acquisition of each analog channel. Use the profile report to move trend records to your PC and quickly plot the data with Microsoft Excel or any other spreadsheet application.

```
=>>CPR <Enter>
"REC_NUM","YEAR","MONTH","DAY","HOUR","MIN","SEC","MSEC",
    "VA_MAG","VB_MAG","VC_M
AG","AI301","AI302","AI303","AI304","AI305","AI306","1D7A
    "
14,2005,9,1,12,10,4,261,2092.127,2099.499,2089.107,-
    0.001,-0.000,
    -0.001,-0.001,-
0.001,-0.001,"1190"
13,2005,9,1,12,15,3,982,2093.966,2099.176,2088.974,-
    0.001,-0.001,
    -0.001,-0.000,-
0.001,-0.001,"11AC"
12,2005,9,1,12,20,4,82,2091.636,2099.117,2089.346,-
    0.001,-0.000,
    -0.001,-0.001,-0
.001,-0.001,"115C"
11,2005,9,1,12,25,4,332,2092.435,2098.398,2088.487,-
    0.001,-0.001,
    -0.001,-0.001,-
0.001,-0.001,"119C"
10,2005,9,1,12,30,4,36,2092.907,2098.208,2089.058,-
    0.001,-0.001,
    -0.000,-0.001,-0
.001,-0.001,"115C"
9,2005,9,1,12,35,4,186,2093.153,2098.865,2089.091,-
    0.001,-0.000,
    -0.001,-0.001,-0
.001,-0.001,"116F"
8,2005,9,1,12,40,3,978,2094.284,2098.926,2089.732,-
    0.001,-0.001,
    -0.001,-0.001,-0
.001,-0.001,"1179"
```

Figure 10 Comma-Separated File Format for Easy Display, Analysis, and Archiving

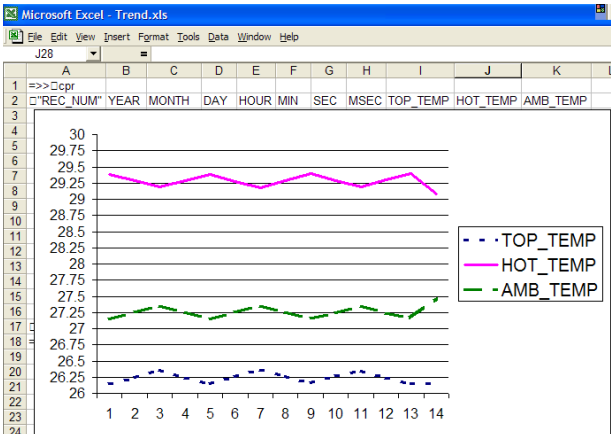


Figure 11 Excel Graph of Trend Data

Transformer Thermal Monitoring

Transformer thermal modeling, per IEEE C57.91-2011 or the IEC 60076-7:2018 Ed. 2, is a standard feature in the SEL-2414. Specify the SEL-2414 to provide this capability for monitoring and protection of a single three-phase transformer, a three-phase transformer with tertiary windings (three-winding mode with separate CT ratios), or 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 and daily data about your transformer. Operating temperature calculations are based on load currents, type of cooling system, and 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 an internal RTD/thermocouple card or from an external SEL-2600A RTD Module. While the SEL-2414 can receive temperature data at any rate, the thermal element uses the temperature data once per minute.

The thermal element operates in one of three modes, depending upon the presence or lack of measured temperature inputs: 1) measured ambient and top-oil temperature inputs, 2) measured ambient temperature only, and 3) no measured temperature inputs. If the device receives measured ambient and top-oil temperatures, the thermal element calculates hot-spot temperature. When the device 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 device uses hot-spot temperature as a basis for calculating the insulation aging acceleration factor (FAA) 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 (FAA)
- Daily loss-of-life
- Total loss-of-life

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

The thermal model can be used even if a current card is not installed. Current magnitude data can be received through communications protocols.

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 because of mechanical stress of insulation components in the transformer. The SEL-2414 through-fault event monitor gathers current level, duration, and date/time for each through fault. The monitor also calculates a I^2t and cumulatively stores these data per-phase. The SEL-2414 through-fault report also provides percent of total through-fault accumulated according to the IEEE Std. C57.109-1993, *Guide for Liquid-Immersed Transformer Through-Fault-Current Duration*. 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 device to indicate excess through-fault current over time.

Load Tap Position and Control Monitoring

The SEL-2414 supports load tap position and control (LTPC) monitoring by using digital inputs in the binary-coded decimal (BCD) or binary format, or dc current analog inputs in –2 mA to 2 mA, or 4 to 20 mA range. It can monitor as many as 32 tap positions with one or three neutral tap positions. Additionally, it monitors the raise and lower controls to assert alarms for tap position change failures or unexpected tap positions.

Tap Statistics

The SEL-2414 logs all tap position changes and operation counts, which are available in the Tap Statistics Report. The report displays the following information over the range of minimum and maximum tap positions set:

- Total tap operation counts (both lifetime and since reset)
- Tap operation counts for each position since the device started monitoring tap positions or since a lifetime reset command was executed
- Tap operation counts for each position since device reset or tap reset commands were used
- Extreme (Minimum and Maximum) Tap Positions reached since reset
- The date and time of the most recent resets for the Lifetime, since reset, and Extremes counter

Custom Records

Configure the custom recorder to record as many as 8 Analog Quantities and 16 Device Word bits at 100 ms sampling interval and trigger with SELOGIC control equations. The custom records can span multiple LTC change events. The device stores as many as 100 custom records. The device samples these quantities at 100 ms and stores them as a .cev file. Download these files via FTP or MMS protocols for analysis in SYNCHROWAVE Event.

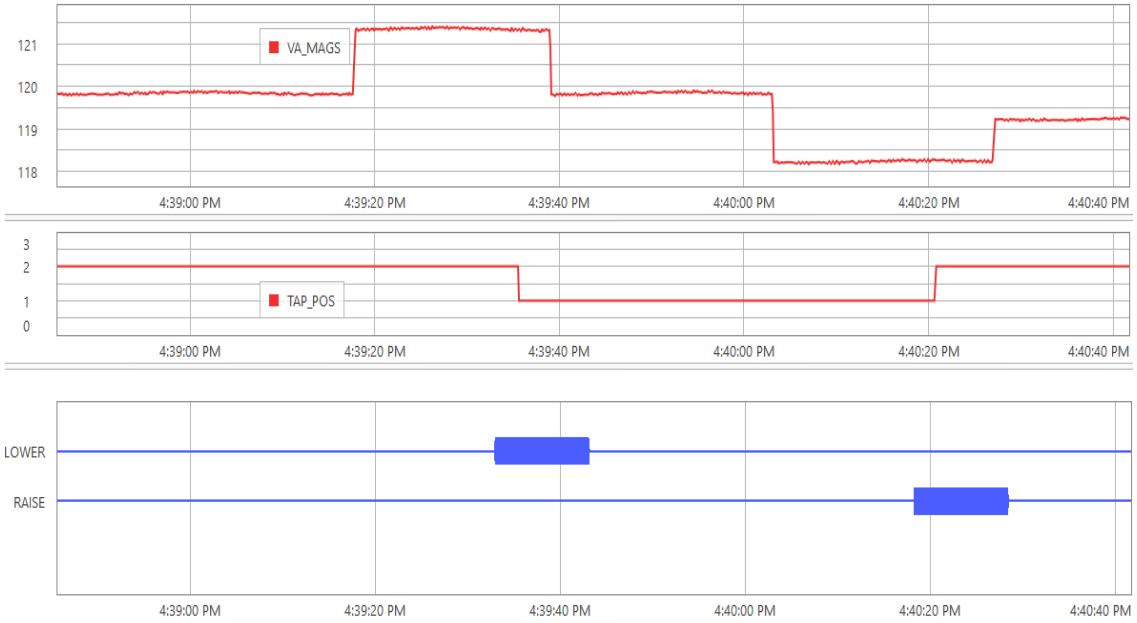


Figure 12 Custom Record File Open in SYNCHROWAVE Event Showing a Raise and Lower Event

Lifetime Counts (LTC) Events

Analyze operation counts trending data with the LTC Events Report. The SEL-2414 logs every tap position change in a comma-separated file stored in the /Reports folder. The device attaches a time stamp at 1 second resolution to these events. The report also contains a total lifetime count and operation counts now. You can use the data to operation counts trending plot in a spreadsheet analysis software.

```
Lifetime Counts at Reset: 345
Total Lifetime Counts Now: 22
REC_NUM,DATE TIME,TAP_POS,EVENT
   22,12/24/2025 00:42:04, 1,RAISE
   21,12/24/2025 00:42:19, 2,RAISE
   20,12/24/2025 00:42:34, 3,RAISE
   19,12/24/2025 00:42:49, 4,RAISE
   18,12/24/2025 00:43:04, 5,RAISE
   17,12/24/2025 00:43:19, 6,RAISE
   16,12/24/2025 00:43:34, 7,RAISE
   15,12/24/2025 00:43:50, 8,RAISE
   14,12/24/2025 00:44:05, 9,RAISE
   13,12/24/2025 00:44:20,10,RAISE
   12,12/24/2025 00:44:35,11,RAISE
   11,12/24/2025 00:44:50,12,RAISE
   10,12/24/2025 00:45:05,13,RAISE
    9,12/24/2025 00:45:20,14,RAISE
    8,12/24/2025 00:45:35,15,RAISE
    7,12/24/2025 00:45:50,16,RAISE
    6,12/24/2025 00:52:19,-1,UNEXPECTED
    5,12/24/2025 00:52:30,-2,UNEXPECTED
    4,12/24/2025 00:52:57,-1,UNEXPECTED
    3,12/24/2025 00:53:06, 0,UNEXPECTED
    2,12/24/2025 00:53:13, 1,UNEXPECTED
    1,12/24/2025 00:53:20, 0,UNEXPECTED
```

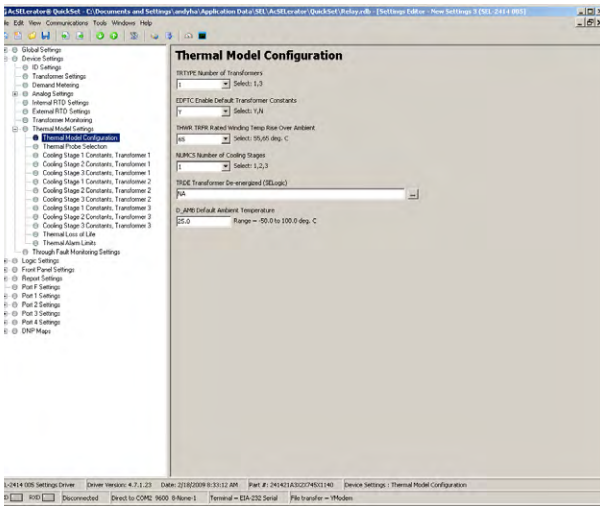
Figure 13 Example Contents of LTC_EVENTS.csv File

Configuration and Commissioning Software

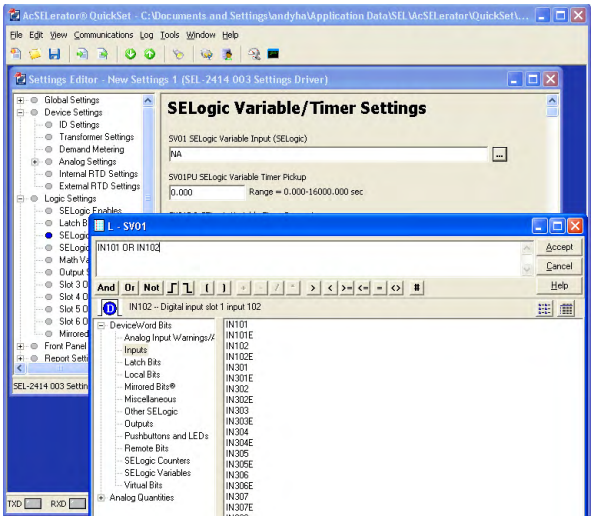
The included QuickSet software simplifies device configuration in addition to providing commissioning and analysis support for the SEL-2414.

- Access settings creation help online.
- Organize settings with the device database manager.
- Load and retrieve settings by using a simple PC communications link.
- Analyze event records with the integrated waveform and harmonic analysis tool.
- Use the PC interface to remotely retrieve reports and other system data.
- Monitor analog data, device I/O, and logic point status during commissioning tests.
- Remotely operate and monitor by using the device overview as a virtual front panel.

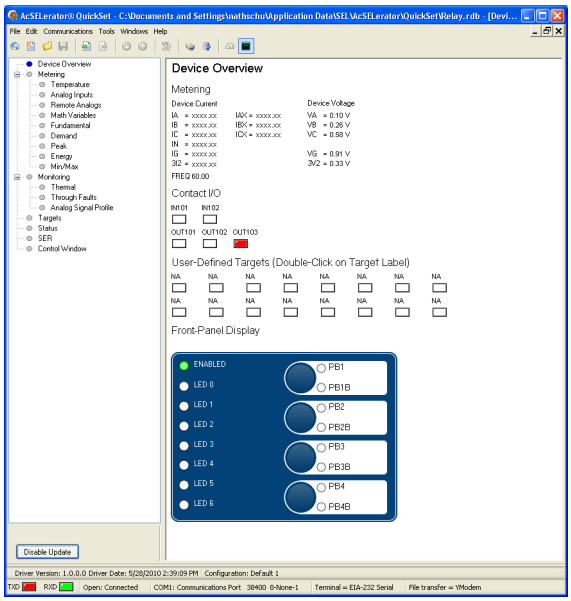
Settings—Develop Settings Offline With an Intelligent Settings Editor That Only Allows Valid Settings.



Settings—Create SELOGIC Control Equations With a Drag and Drop Editor and/or Text Editor.



HMI—Device Overview.



ACSELERATOR Bay Screen Builder SEL-5036 Software

The SEL-2414 with the touchscreen display option provides you with the ability to design bay configuration screens to meet your system needs. You can display the bay configuration as a single-line diagram (SLD) on the touchscreen. You can use ANSI and IEC symbols, along with analog and digital labels, for the SLD to indicate the status of the breaker and disconnects, bus voltages, and power flow through the breaker. In addition to SLDs, you can design the screens to show the status of various device elements via Device Word bits or to show analog quantities for commissioning or day-to-day operations. You can design these screens with the help of Bay Screen Builder in conjunction with QuickSet (see *Figure 14*). Bay Screen Builder provides an intuitive and powerful interface to design bay screens to meet your application needs.

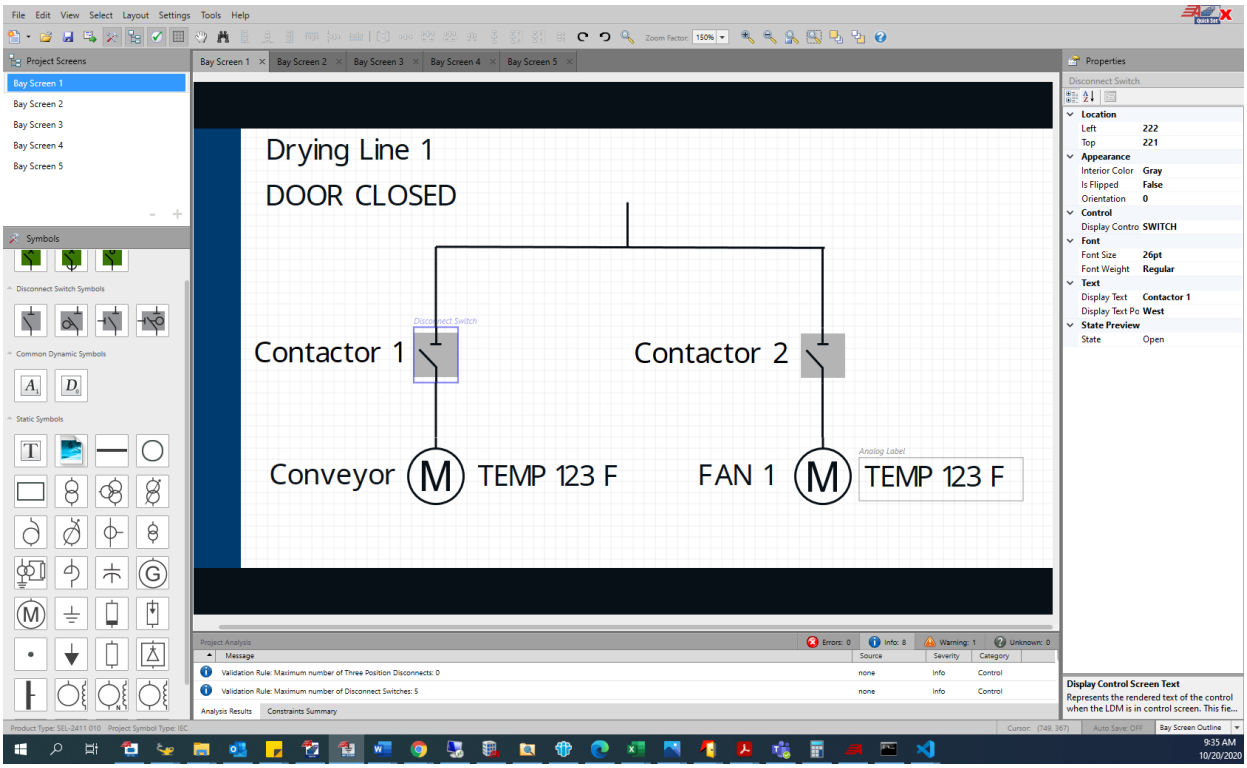


Figure 14 Bay Screen Builder

Metering

The SEL-2414 provides extensive metering capabilities. See *Specifications* for metering and power measurement accuracies. As shown in *Table 2*, metering includes current and voltage based metering and analog input, math variable, and remote analog metering. Fundamental, maximum and minimum, and demand metering typically includes phase voltages and currents; sequence voltages and currents; and power, frequency, and energy.

Table 2 Metering Types

Standard	
Fundamental	IA, IB, IC, VA, VB, VC
Energy	Real and Reactive (In and Out)
Maximum and Minimum	Frequency, Voltages (VA, VB, VC), Currents (IA, IB, IC, 3I2), Reactive, and Real Power
Demand and Peak Demand	IA, IB, IC, IG, 3I2
Analog Input	AIx01–AIx08
Math Variable	MV01–MV32
Remote Analog	RA001–RA128
Analog Signal Profiling	
Optional	
➤ Temperature and thermal (with the external SEL-2600 RTD Module, internal RTD option, or internal RTD/TC option)	
➤ Maximum and Minimum Temperatures	

Touchscreen Display

You can order the SEL-2414 with an optional touchscreen display (5-inch, color, 800 x 480 pixels). The touchscreen display makes relay data metering, monitoring, and control quick and efficient. The touchscreen display option in the SEL-2414 features a straightforward application-driven control structure and includes intuitive and graphical screen designs.

The touchscreen display allows you to:

- View and control bay screens
- Access metering and monitoring data
- Visualize Transformer Thermal reports
- Inspect targets
- View event history, summary data, and SER information
- View relay status and configuration
- Control relay operations
- View and edit settings
- Enable the rotating display
- Program control pushbuttons to jump to a specific screen

You can navigate the touchscreen by tapping the folders and applications. The folders and applications of the **Home** screen are shown in *Figure 15*. Folders and applications are labeled according to functionality. Additional folder and application screens for the SEL-2414 touchscreen display option can be seen in *Figure 16* through *Figure 31*.

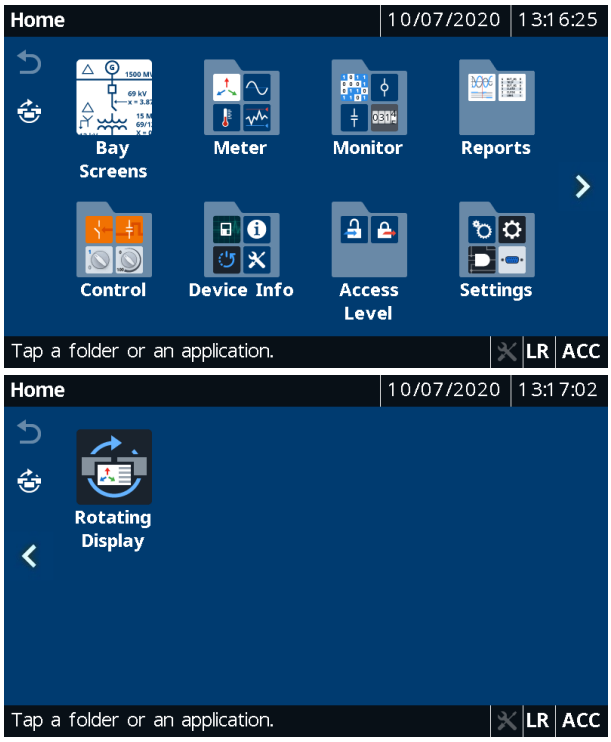


Figure 15 Home (Default FPHOME Screen)

Bay Screen Application

The SEL-2414 with the touchscreen display option provides you with the ability to design bay configuration screens to meet your system needs. The bay configuration can be displayed as an SLD on the touchscreen. You can create as many as five bay screens with one controllable breaker, eight controllable two-position disconnects, and two controllable three-position disconnects. ANSI and IEC symbols, along with analog and digital labels, are available for you to create detailed SLDs of the bay to indicate the status of the breaker and disconnects, bus voltages, and power flow through the breaker. *Figure 16* shows the default SLD for the touchscreen display option.

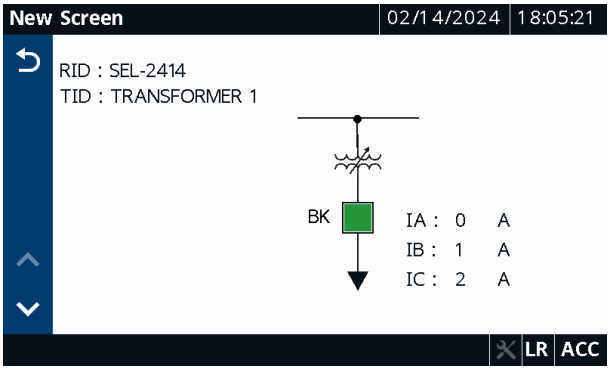


Figure 16 Default Bay Screen

Meter Folder Applications

The applications in the Meter folder are part-number dependent. Only those metering applications specific to your part number appear in the Meter folder. Tapping an application in the Meter folder shows you the report for that particular application. Tap the **Phasor** application to view the current and voltage phasors (see *Figure 17*).

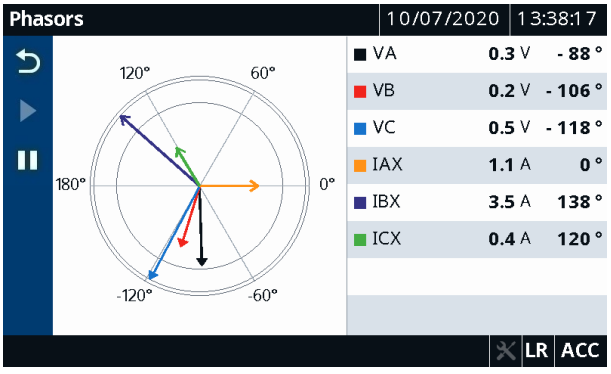


Figure 17 Meter Phasors

Tap the **Energy** application to view the energy metering quantities (see *Figure 18*). A reset feature is provided for the Energy, Max/Min, Demand, and Peak Demand appli-

cations. Tap the **Reset** button (see *Figure 18*) to navigate to the reset confirmation screen. Once you confirm the reset, the data are reset to zero.

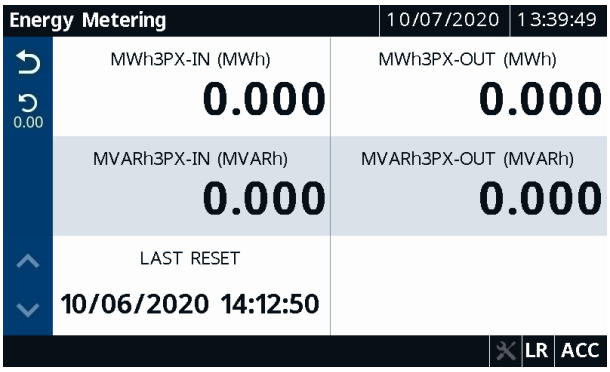


Figure 18 Meter Energy

Monitor Folder Applications

Tapping the **Monitor** folder navigates you to the screen where you can access the status of the Device Word bits, digital outputs, digital inputs, SELOGIC counters, Display Points, and Transformer Thermal report applications. *Figure 19* through *Figure 24* show example screens for each of these applications.

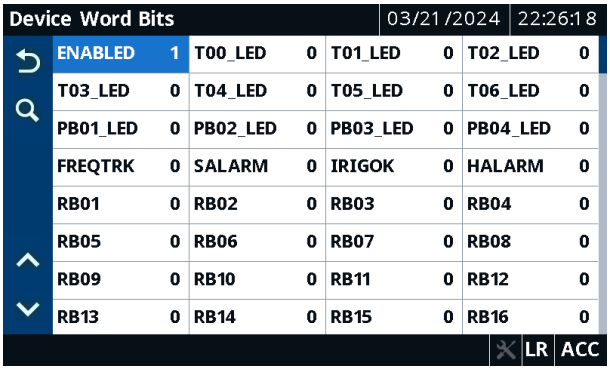


Figure 19 Sequential Events Recorder

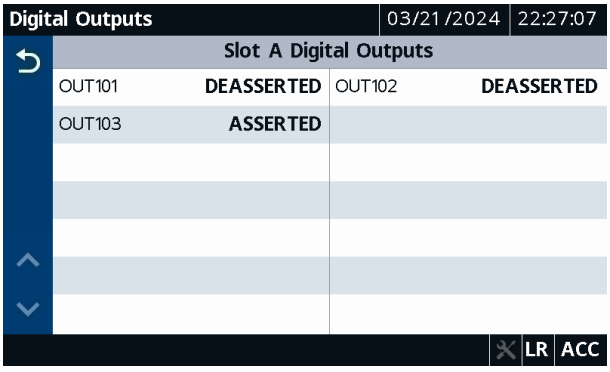


Figure 20 Digital Outputs

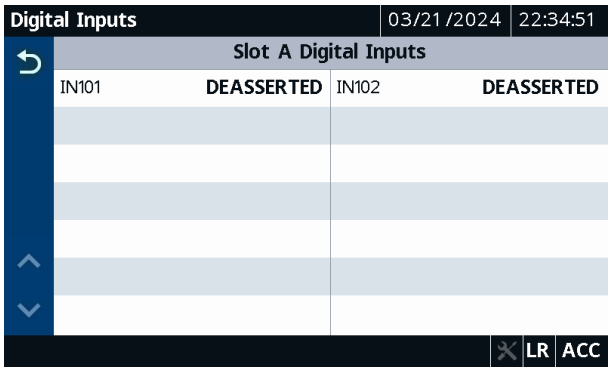


Figure 21 Digital Inputs

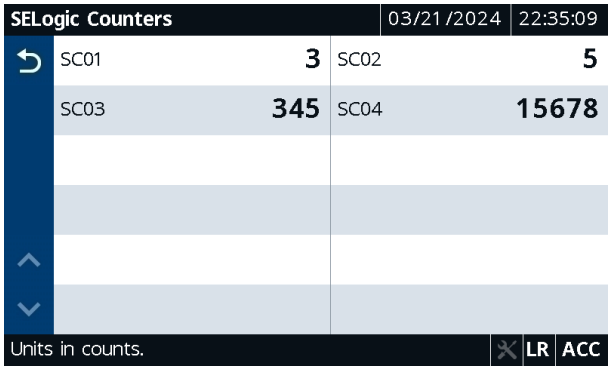


Figure 22 SELOGIC Counters

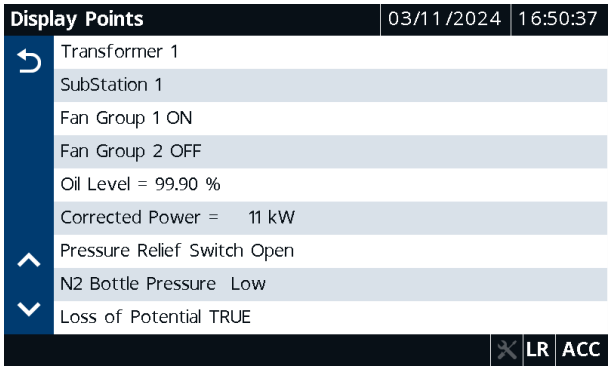


Figure 23 Display Points

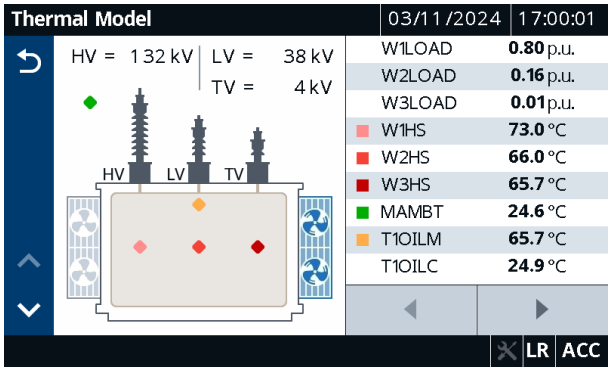


Figure 24 Transformer Thermal Reports

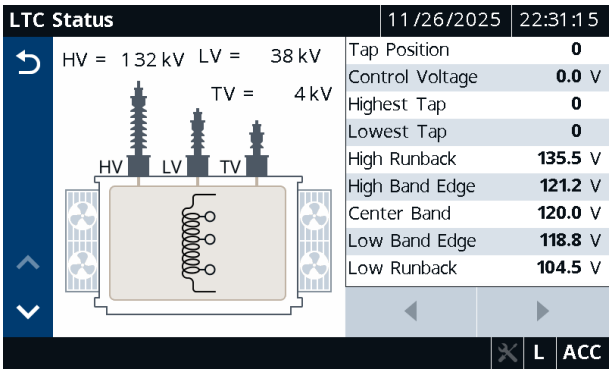


Figure 25 LTC Tap Position Status

Reports Folder Applications

Tapping the **Reports** folder navigates you to the screen where you can access the Events, HIF Events (if available), and SER applications. Use these applications to view events and the SER records. To view the event summary (see *Figure 26*) of a particular event record, tap the event record on the Event History screen (for Events and HIF Events). You can also trigger an event report from the Event History screen.

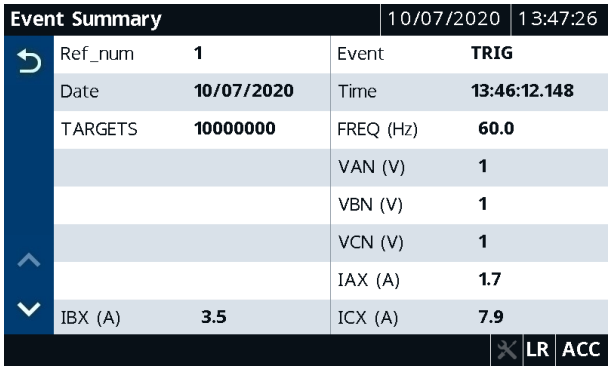


Figure 26 Event Summary

Tap the **Sequential Events Recorder** application to view the SER history report (see *Figure 27*).

Figure 27 SER History Report

Tapping the **Trash** button, shown in *Figure 27*, on the Event History, HIF Event History, and Sequential Events Recorder screens and confirming the delete action removes the records from the relay.

Control Folder Applications

Tapping the **Control** folder navigates you to the screen where you can access the Breaker Control, Output Pulsing, and Local Bits applications. Use the applications to perform breaker control operations, pulse output contacts (*Figure 28*), and control the local bits (*Figure 29*).

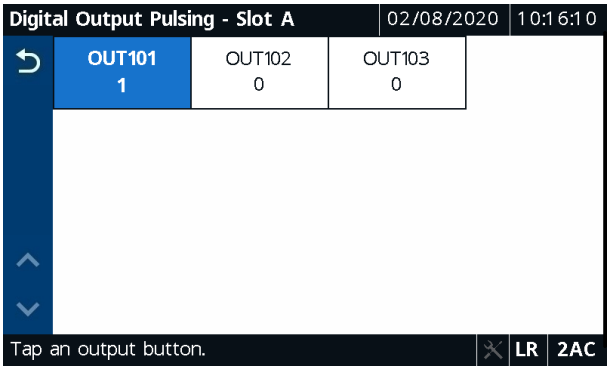


Figure 28 Digital Output Pulsing – Slot A

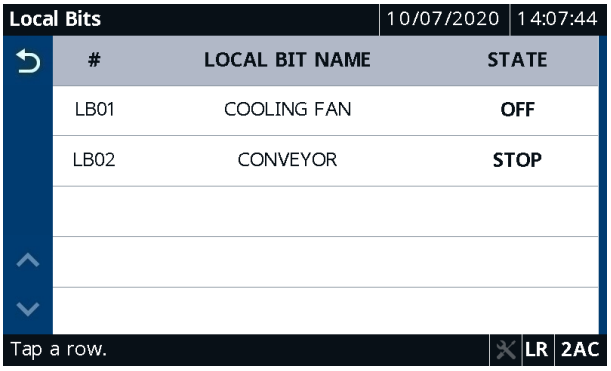


Figure 29 Local Bits

Device Info Folder Applications

Tapping the **Device Info** folder navigates you to the screen where you can access specific device information applications (Status, Configuration, and Trip & Diag. Messages) and the Reboot application. Tap the **Status** application to view the relay status, firmware version, part number, etc. (see *Figure 30*).

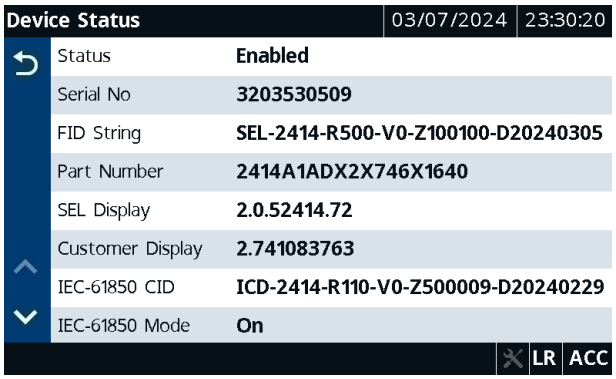


Figure 30 Device Status

To view the trip and diagnostic messages, tap the **Trip & Diag. Messages** application (see *Figure 31*). When a diagnostic failure, trip, or warning occurs, the relay displays the diagnostic message on the screen until it is either overridden by the restart of the rotating display or the inactivity timer expires.

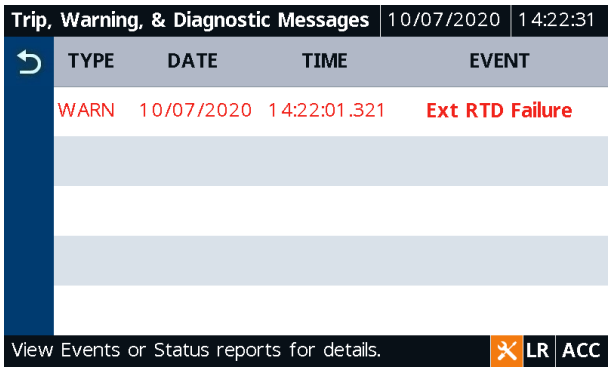


Figure 31 Trip and Diagnostic Messages

Automation

Flexible Control Logic and Integration Features

The SEL-2414 is equipped with as many as four independently operated serial ports: one EIA-232 port on the front, one EIA-232 or EIA-485 port on the rear, one fiber-optic port, and one EIA-232 or EIA-485 port option card. The device does not require special communications software. Use any system that emulates a standard terminal system for engineering access to the device. Establish communications by connecting computers, modems, protocol converters, printers, an SEL communications processor, SCADA serial port, and an RTU for local or remote communication. Apply an SEL communications processor as the hub of a star network, with point-to-point fiber or copper connection between the hub and the SEL-2414. Included communications protocols are listed below.

Standard Protocols

- Modbus RTU
- SEL ASCII
- SEL Compressed ASCII
- SEL Fast Meter
- SEL Fast Operate
- SEL Fast SER
- SEL Fast Message
- SEL MIRRORED BITS

SEL-2414 logic improves integration in the following ways.

Replaces Traditional Panel Control Switches

Eliminate traditional panel control switches with operator control pushbuttons or the 32 local bits, available through the menu system. Program the four conveniently sized operator pushbuttons to control fan banks and fan lockout. Set, clear, or pulse local bits with the front-panel pushbuttons and display. Program the local bits into your control scheme with SELOGIC control equations. Use the local bits to perform functions such as breaker trip/close.

Replaces Traditional Indicating Panel Lights

Replace traditional indicating panel lights with 32 programmable displays. Define custom messages (e.g., Fan On, Fan Off) to report transformer or device conditions on the front-panel display. Use advanced SELOGIC control equations to control which messages the device displays.

Replaces Traditional Temperature Gauges

Replace traditional temperature gauges that show the temperature, and the maximum and minimum temperature since last reset. The SEL-2414 Max/Min metering records and time stamps the maximum and minimum temperatures and transformer thermal model quantities.

Replaces Traditional Latching Relays

Replace as many as 32 traditional latching relays for such functions as “remote control enable” with latch bits. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the nonvolatile latch bits by using optoisolated inputs, remote bits, local bits, or any programmable logic condition. The latch bits retain their state when the device loses power.

Eliminates External Timers

Eliminate external timers for custom protection or control schemes with 32 general purpose SELOGIC control equation timers. Each timer has independent time-delay pickup and dropout settings. Program each timer input with any desired element (e.g., time qualify a current element). Assign the timer output to control scheme logic.

Eliminates RTU-to-Device Wiring

Eliminate RTU-to-Device wiring with 32 remote bits. Set, clear, or pulse remote bits using serial port commands. Program the remote bits into your control scheme with SELOGIC control equations. Use remote bits for SCADA-type control operations such as trip and close.

Communications Architectures

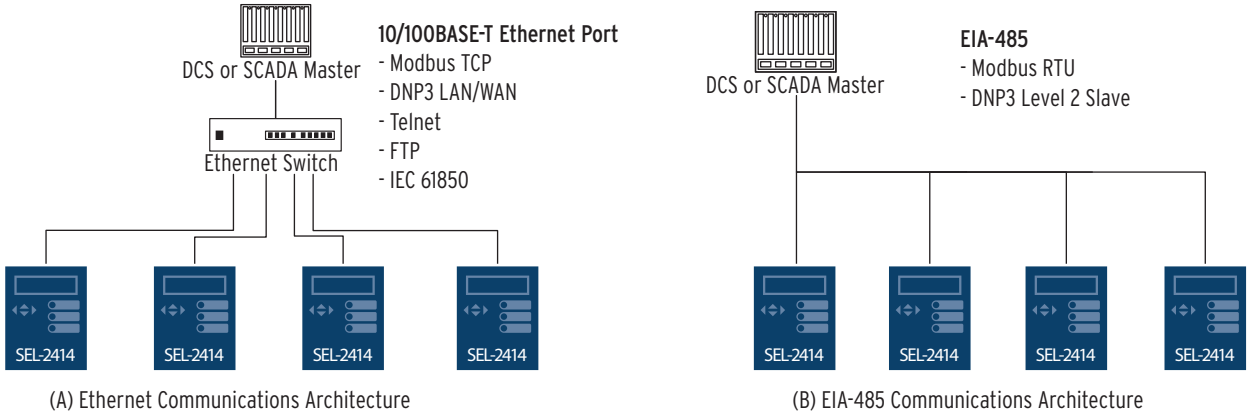


Figure 32 Typical Ethernet and EIA-485 Communications Architectures

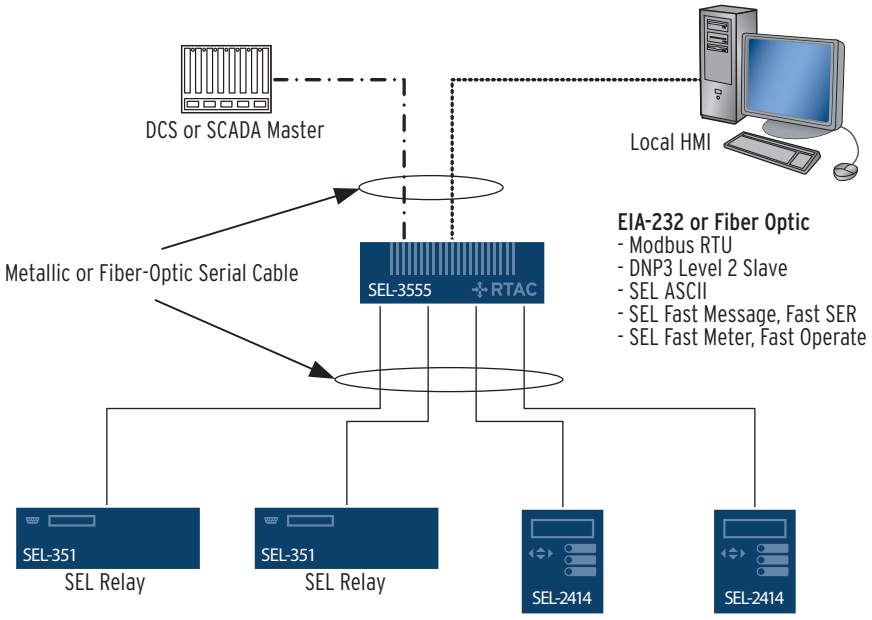
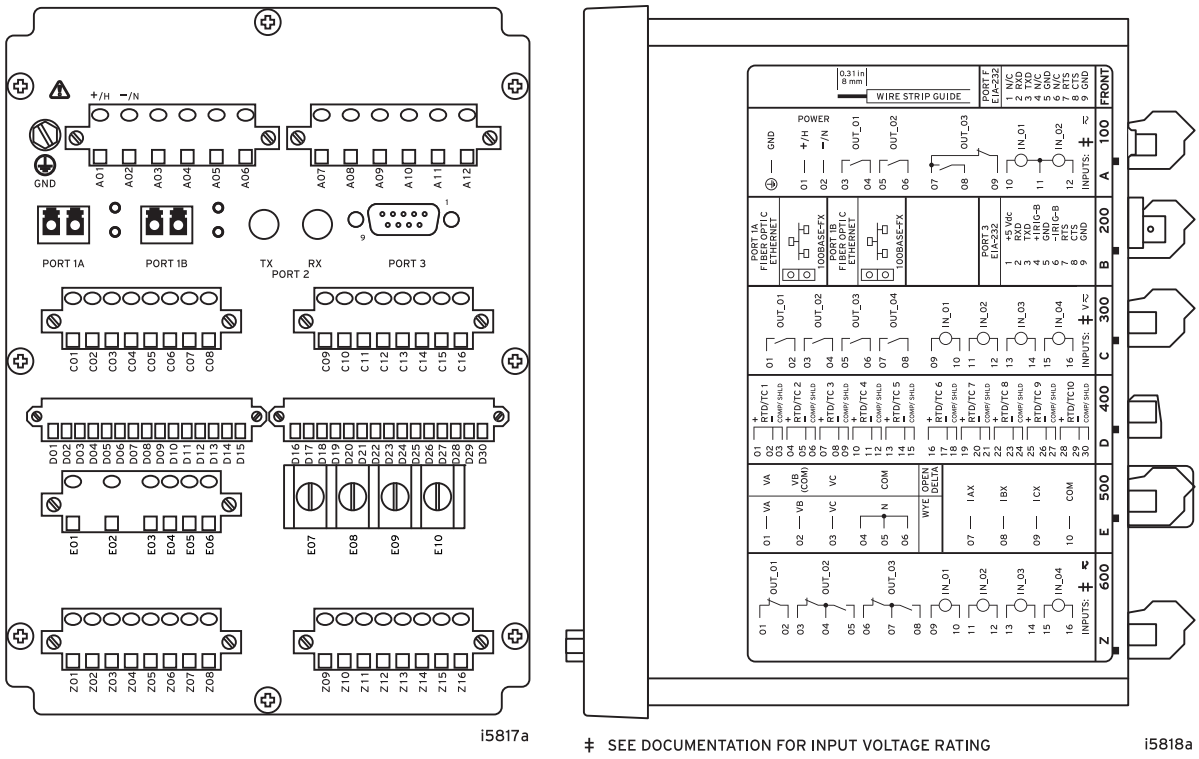


Figure 33 Typical EIA-232 and Fiber-Optic Communications Architecture

Diagrams and Dimensions



(A) Rear-Panel Layout

(B) Side-Panel Input and Output Designations

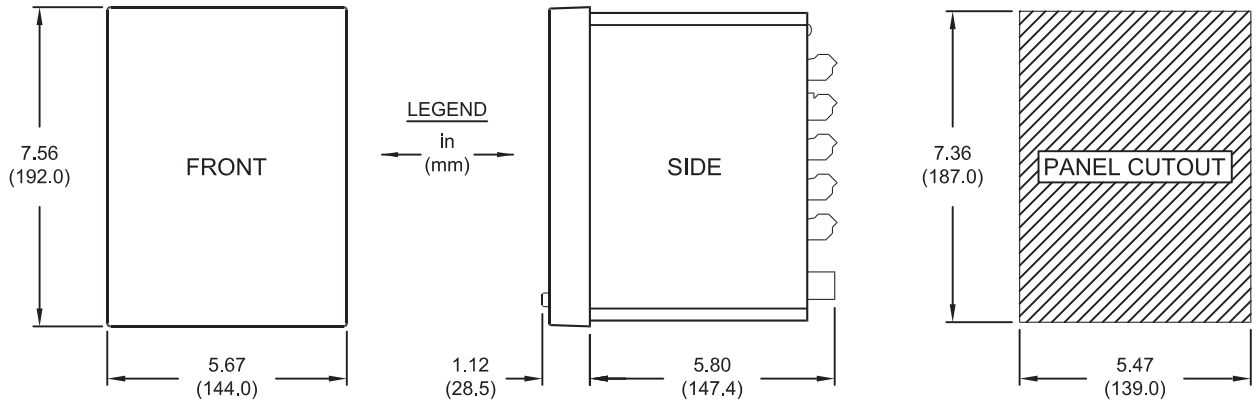


Figure 34 Transformer Automation Controller Panel-Mount

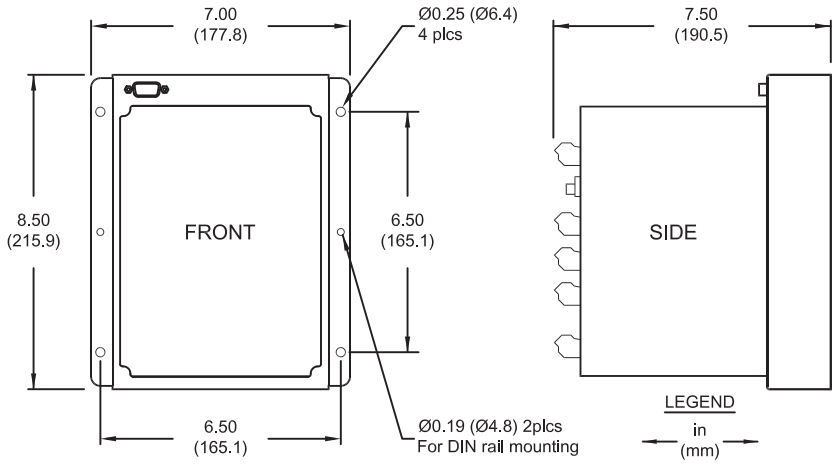


Figure 35 Transformer Automation Controller Surface-Mount Dimensions

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B, Class A

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

CE Mark in accordance with the requirements of the European Union.

RCM Mark in accordance with the requirements of Australia.

UKCA Mark in accordance with the requirements of United Kingdom.

Normal Locations

UL Listed to U.S. and Canadian safety standards (File E220228; NRAQ, NRAQ7)

–20°C ≤ Ta ≤ 40°C

Hazardous Locations

UL Listed for Hazardous Locations to Canadian and U.S. Standards (File E475839; NRAG, NRAG7)

CL 1, DIV 2; GP A, B, C, D; T3C

–20°C ≤ Ta ≤ 40°C

EU

SEL 19 ATEX 0001X
II 3 G
Ex ec nC IIC T3 Gc

–20°C ≤ Ta ≤ 50°C

EN 60079-0:2018
EN 60079-7:2015/A1:2018
EN 60079:15:2019

Note: Where so marked, ATEX and UL Hazardous Locations Certification tests are applicable to rated supply specifications only and do not apply to the absolute operating ranges, continuous thermal, or short circuit duration specifications.

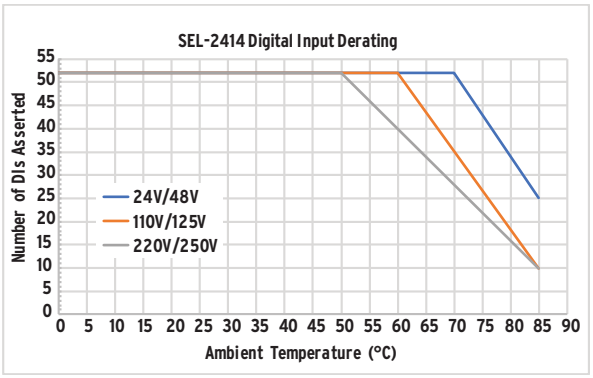
General

Operating Temperature Range

IEC Performance Rating: –40° to 85°C (–40° to 185°F)
IEC 60068-2-1 and 60068-2-2

Note: Not applicable to UL applications.

Note: The front-panel display is impaired for temperatures below –20°C and above 70°C.



UL/CSA Thermal Derating

Design to ensure that no more than 30 digital I/O are simultaneously energized. This applies to all outputs carrying less than 2 A current and digital inputs rated above 100 V. Inputs rated below 100 V only add half the heat.

Operating Environment

Insulation Class	1
Pollution Degree:	2
Overvoltage Category:	II
Atmospheric Pressure	80–110 kPa
Relative Humidity:	5%–95%, noncondensing
Maximum Altitude Without Derating (Consult the Factory for Higher Altitude Derating):	2000 m

Dimensions

See *Figure 34* and *Figure 35*.

Weight

2.0 kg (4.4 lb)

Power Supply

Rated Supply Voltage

Low-Voltage Model:	24/48 Vdc
High-Voltage Model:	125/250 Vdc 120/240 Vac, 50/60 Hz

Input Voltage Range

Low-Voltage Model:	19.2–60 Vdc
High-Voltage Model:	85–300 Vdc 85–264 Vac

Power Consumption (With Front-Panel LCD)

AC:	<40 VA
DC:	<15 W

Power Consumption (With Front-Panel 5-Inch Color Touchscreen)

AC:	<75 VA
DC:	<25 W

Interruptions

Low-Voltage Model:	10 ms @ 24 Vdc 50 ms @ 48 Vdc
High-Voltage Model:	50 ms @ 125 Vac/Vdc 100 ms @ 250 Vac/Vdc

Fuse Rating

High-Voltage Model:	3.15 A, high breaking capacity, time lag T, 250 V (5x20 mm, T3.15AH 250 V)
Low-Voltage Model:	3.15 A, high breaking capacity, time lag T, 250 V (5x20 mm, T3.15AH 250 V)

Inputs

AC Current Input Phase

I_{NOM}	I_{NOM} = 5 A	I_{NOM} = 1 A
Rated Range:	0.1–96.0 A (according to IEC 60255-5, 60664-1)	0.02–19.20 A

Note: This is a linearity specification and is not meant to imply continuous operation.

Continuous Thermal Rating:	15 A (according to IEC 60255-6, IEEE C37.90-1989)	3 A
1-Second Thermal:	500 A (according to IEC 60255-6)	100 A
Rated Frequency:	50/60 ±5 Hz	50/60 ±5 Hz
Burden (Per Phase):	< 0.050 VA	< 0 .002 VA
Measurement Category:	II	

AC Current Input Neutral

I_{NOM}	I_{NOM} = 5 A	I_{NOM} = 1 A	I_{NOM} = 200 mA
Rated Range:	0.05–10.00 A (according to IEC 60255-5, 60664-1)	0.01–2.00 A	2–400 mA

Note: This is a linearity specification and is not meant to imply continuous operation.

Continuous Thermal Rating:	15 A (according to IEC 60255-6, IEEE C37.90-1989)	3 A	4 A
1-Second Thermal:	500 A (according to IEC 60255-6)	100 A	500 A
Rated Frequency:	50/60 ±5 Hz		
Burden (Per Phase):	<0.1VA@5 A	<0.01VA@1 A	<0.01VA@0.2 A
Measurement Category:	II		

AC Voltage Input (300 V)

Rated Operating Voltage (U_e):	60–250 Vac
Rated Insulation Voltage:	300 Vac
10-Second Thermal:	600 Vac
Rated Frequency:	50/60 ±5 Hz
Burden:	< 0.1 W

DC Transducer (Analog) Inputs

Input Impedance:	
Current Mode:	200 Ω, 2000 Ω
Voltage Mode:	>10 kΩ
Input Range (Maximum):	
Current Mode:	±20 mA, ±2 mA
Voltage Mode:	±10 V
Sampling Rate:	At least 5 ms
Step Response:	1 s
Accuracy at 25°C:	
ADC:	16 bit
With user calibration:	0.05% of full scale (current mode) 0.025% of full scale (voltage mode)
Without calibration:	Better than 0.5% of full scale at 25°C
Accuracy Variation With Temperature:	
± 0.015% per °C of full scale (± 20 mA, ±2 mA, or ±10 V)	

DC Transducer (Analog) Inputs Extended Range Option

Input Impedance:	
Voltage Mode:	>10 kΩ
Input Range (Maximum):	
Voltage Mode:	±300 V
Sampling Rate:	At least 5 ms
Step Response:	1 s
Accuracy at 25°C:	
ADC:	16 bit
With user calibration:	0.025% of full scale (voltage mode)
Without calibration:	Better than 0.5% of full scale at 25°C
Accuracy Variation With Temperature:	
± 0.015% per °C of full scale (±10 V)	
CMRR Typical:	65 db at 60 Hz

Optoisolated Control Inputs

When Used With DC Control Signals:

250 V	ON for 200–275 Vdc	OFF below 150 Vdc
220 V	ON for 176–242 Vdc	OFF below 132 Vdc
125 V	ON for 100–135.5 Vdc	OFF below 75 Vdc
110 V	ON for 88–121 Vdc	OFF below 66 Vdc
48 V	ON for 38.4–52.8 Vdc	OFF below 28.8 Vdc
24 V	ON for 15–30 Vdc	OFF for < 5 Vdc

When Used With AC Control Signals:

250 V	ON for 170.6–275 Vac	OFF below 106 Vac
220 V	ON for 150.3–264 Vac	OFF below 93.2 Vac
125 V	ON for 85–150 Vac	OFF below 53 Vac
110 V	ON for 75.1–132 Vac	OFF below 46.6 Vac
48 V	ON for 32.8–60 Vac	OFF below 20.3 Vac
24 V	ON for 14–27 Vac	OFF below 5 Vac

Current Draw at Nominal DC Voltage:	2–4 mA (Except for 240 V, 8 mA)
Rated Insulation Voltage:	300 Vac
Rated Impulse Withstand Voltage (U_{imp}):	4000 V

RTD Input Card

Number of Channels:	Ten 3-wire RTDs
Input Type: Supports the following RTD types on each independent input.	100 Ω platinum (PT100) 100 Ω nickel (NI100) 120 Ω nickel (NI120) 10 Ω copper (CU10)
Measuring Range:	–200° to 850°C (PT100) –80° to 250°C (Ni100, Ni120) –200° to 250°C (Cu10)
ADC Resolution:	24 bit
Accuracy:	
CU10, PT100, NI100, NI120:	±0.1°C typical at 25°C ±2°C worst case
Resolution:	0.1°C
Update Rate:	<3 s
CMRR (typical):	100 dBv
Noise Rejection:	Up to 1 Vrms 50/60 Hz

Universal Temperature Input Card

Number of Channels:	Ten (thermocouples or 3-wire RTDs)
Input Type: Supports the following RTD or TC types on each independent input.	100 Ω platinum (PT100) 100 Ω nickel (NI100) 120 Ω nickel (NI120) 10 Ω copper (CU10) J, K, T, E

Measuring Range:

RTDs:

PT100:	–200° to 850°C
NI100:	–80° to 250°C
CU10:	–200° to 250°C

Thermocouples (TCs):

J:	–200° to 1200°C
K:	–200° to 1370°C
T:	–200° to 400°C
E:	–200° to 950°C

ADC Resolution:	24 bit

Accuracy:

RTDs:

PT100, NI100, NI120, CU10:	±0.1°C typical at 25°C ±2°C worst case

TCs:

J, K, T, E:	±1°C with field calibration ±3°C without field calibration
Resolution:	0.1°C
Update Rate:	< 3 s
CMRR (typical):	100 dBv
Noise Rejection:	Up to 1 Vrms 50/60 Hz

Isolation

Number of Banks:	Two Banks (5 channels each)
Max. Working Common Mode:	250 Vdc
Cold Junction Compensation:	Automatic

Time-Code Input

Format:	Demodulated IRIG-B
On (1) State:	$V_{ih} \geq$ 2.2 V
Off (0) State:	$V_{ih} \leq$ 0.8 V
Input Impedance:	2 kΩ
Accuracy:	±3 ms

Time-Code Input (SNTP)

High-Priority Server Accuracy:	±5 ms
Accuracy:	±25 ms

Time-Code Input (PTP)

IEEE 1588-2008 Firmware-Based Accuracy:	±1 ms

Outputs

General

OUT103 is Form C Trip Output, all other outputs are Form A.

Dielectric Test Voltage:	2000 Vac
Impulse Withstand Voltage (U_{imp}):	4000 V
Mechanical Durability:	10M no load operations

DC Output Ratings

Electromechanical

Rated Operational Voltage:	250 Vdc
Rated Voltage Range:	19.2–275 Vdc
Rated Insulation Voltage:	300 Vdc
Make:	30 A @ 250 Vdc per IEEE C37.90
Continuous Carry:	6 A @ 70°C; 4 A @ 85°C
Continuous Carry (UL/CSA Derating with All Outputs Asserted):	5 A @ <60°C; 2.5 A 60 to 70°C
Thermal:	50 A for 1 s
Contact Protection:	360 Vdc, 40 J MOV protection across open contacts
Operating Time (coil energization to contact closure, resistive load):	Pickup or Dropout time ≤ 8 ms typical

Breaking Capacity (10,000 operations) per IEC 60255-0-20:1974:			
	24 Vdc	0.75 A	L/R = 40 ms
	48 Vdc	0.50 A	L/R = 40 ms
	125 Vdc	0.30 A	L/R = 40 ms
	250 Vdc	0.20 A	L/R = 40 ms
Cyclic Capacity (2.5 cycles/second) per IEC 60255-0-20:1974:	24 Vdc	0.75 A	L/R = 40 ms
	48 Vdc	0.50 A	L/R = 40 ms
	125 Vdc	0.30 A	L/R = 40 ms
	250 Vdc	0.20 A	L/R = 40 ms

Fast Hybrid (high-speed high current interrupting)

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 (maximum voltage):	250 Vac/330 Vdc
Pickup Time:	< 50 µs, resistive load
Dropout Time:	8 ms, resistive load
Update Rate:	1/8 cycle

Breaking Capacity (10000 operations):

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

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

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

Note: Per IEC 60255-23:1994, using the simplified method of assessment.
Note: Make rating per IEEE C37.90-1989.

AC Output Ratings

Electromechanical

Maximum Operational Voltage (U_e) Rating:	240 Vac
Insulation Voltage (U_i) Rating (excluding EN 61010-1):	300 Vac
Utilization Category:	AC-15 (control of electromagnetic loads > 72 VA)
Contact Rating Designation:	B300 (B = 5 A, 300 = rated insulation voltage)
Voltage Protection Across Open Contacts:	270 Vac, 40 J
Rated Operational Current (I_e):	3 A @ 120 Vac 1.5 A @ 240 Vac
Conventional Enclosed Thermal Current (I_{the}) Rating:	5 A
Rated Frequency:	50/60 ±5 Hz
Pickup/Dropout Time:	≤ 8 ms (coil energization to contact closure)
Electrical Durability Make VA Rating:	3600 VA, cosϕ = 0.3
Electrical Durability Break VA Rating:	360 VA, cosϕ = 0.3

Fast Hybrid (high-speed high current interrupting)

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 (maximum voltage):	250 Vac/330 Vdc
Pickup Time:	< 50 µs, resistive load
Dropout Time:	8 ms, resistive load
Update Rate:	1/8 cycle

Breaking Capacity (10000 operations):

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

Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

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

Note: Per IEC 60255-23:1994, using the simplified method of assessment.
Note: Make rating per IEEE C37.90-1989.

Analog Outputs

Current Ranges (Max):	±20 mA
Voltage Ranges (Max):	±10 V
Output Impedance For Current Outputs:	≥100 kΩ
Output Impedance For Voltage Outputs:	≤ 20 Ω
Maximum Load:	0–750 Ω current mode >2 kΩ voltage mode
Accuracy:	±0.55% of full scale at 25°C
Step Response:	100 ms

Communications

Communications Ports

Standard EIA-232 (2 ports)

Location (fixed):	Front Panel, Rear Panel
Data Speed:	300–38400 bps

Optional Ethernet port:

Single/Dual 10/100BASE-T copper (RJ45 connector)
Single/Dual 100BASE FX Multimode (LC connector)

Optional multimode fiber-optic serial port:

Class 1 LED product
Complies with IEC 60825-1:1993 + A1:1997 + A2:2001

Fiber-Optic Ports Characteristics

Port 1 (or 1A, 1B) Ethernet

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

Port 2 Serial

Wavelength:	820 nm
Optical Connector Type:	ST
Fiber Type:	Multimode
Link Budget:	8 dB
Typical TX Power:	–16 dBm
RX Min. Sensitivity:	–24 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~1 km
Data Rate:	5 Mbps
Typical Fiber Attenuation:	–4 dB/km

Optional Communications Card

Standard EIA-232 or EIA-485 (ordering option)

Data Speed:	300–38400 bps

Maximum Concurrent Connections

Modbus Slave:	1
DNP3 Level 2 Outstation:	3[a]
Ethernet FTP:	2
Telnet:	2
IEC 61850 MMS:	7
IEC 61850 Goose:	64 Incoming 8 Outgoing

[a] Maximum in any combination of serial and/or LAN/WAN links.

Communications Protocols

Modbus RTU slave or Modbus TCP
DNP3 Level 2 Outstation (LAN/WAN and Serial)
IEC 61850 Communications
Ethernet FTP
SNTP
PTP (firmware-based)
RSTP
Telnet
SEL MIRRORED BITS (MBA, MBB, MB8A, MB8B, MBTB)
Ymodem file transfer on the front and rear port
Xmodem file transfer on the front port
SEL ASCII and Compressed ASCII
SEL Fast Meter
SEL Fast Operate
SEL Fast SER
SEL Fast Message unsolicited write
SEL Fast Message read request
SEL Event Messenger Points

AC Metering Accuracies

Current

Phase Current:	±0.5% typical, 25°C, 50/60 Hz, nominal current
Neutral Current:	±0.5% typical, 25°C, 50/60 Hz, nominal current
Negative Sequence (3I2):	±0.5% typical, 25°C, 50/60 Hz, nominal current (calculated)
Residual Ground Current:	±0.5% typical, 25°C, 50/60 Hz, nominal current (calculated)

Voltage

Line-to-Neutral Voltage:	±0.25% typical, 25°C, 60 Hz, operating voltage (4 ACI/3 AVI) ±0.5% typical, 25°C, 60 Hz, nominal voltage (3 ACI/3 AVI and 3AVI card)
Line-to-Line Voltage:	±0.25% typical, 25°C, 60 Hz, operating voltage (4 ACI/3 AVI) ±0.5% typical, 25°C, 60 Hz, nominal voltage (3 ACI/3 AVI and 3 AVI card)
Negative-Sequence (3V2):	±0.25% typical, 25°C, 60 Hz, operating voltage (4 ACI/3 AVI) ±0.5% typical, 25°C, 60 Hz, nominal voltage (3 ACI/3 AVI and 3 AVI card-calculated)

Power

Three-Phase Real Power (kW):	±1% typical, 25°C, 50/60 Hz, nominal voltage and current with 0.10 to 1.00 power factor
Three-Phase Reactive Power (kVAR):	±1% typical, 25°C, 50/60 Hz, nominal voltage and current with 0.00 to 0.90 power factor
Three-Phase Apparent Power (kVA):	±1% typical, 25°C, 50/60 Hz, nominal voltage and current

Power Factor

Three-Phase (wye connected):	±1% typical, 25°C, 50/60 Hz, nominal voltage and current (between 0.97 and 1)

Sampling and Processing Specifications

Without Voltage Card or Current Card

Analog Inputs

Sampling Rate:	Every 4 ms

Digital Inputs

Sampling Rate:	2 kHz

Contact Outputs

Refresh Rate:	2 kHz
Logic Update:	Every 4 ms

Analog Outputs

Refresh Rate:	Every 4 ms
New Value:	Every 100 ms
Timer Accuracy:	±0.5% of settings and ±4 ms

With Either Voltage Card, Current Card, or Both Voltage and Current Cards

Analog Inputs

Sampling Rate:	4 times/cycle

Digital Inputs

Sampling Rate:	32 times/cycle

Contact Outputs

Refresh Rate:	32 times/cycle
Logic Update:	4 times/cycle

Analog Outputs

Refresh Rate:	4 times/cycle
New Value:	Every 100 ms
Timer Accuracy:	±0.5% of settings and ±1/4 cycle

Processing Specifications and Oscillography

AC Voltage and Current Inputs:	16 samples per power system cycle
Frequency Tracking Range:	44–66 Hz
Digital Filtering:	Cycle cosine after low-pass analog filtering. Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.
Control Processing:	Four times per power system cycle or 4 ms if no current or voltage card (except for math variables and analog signals used in logic, which are processed every 100 ms)

Oscillography

Length:	15 or 64 cycles
Sampling Rate:	16 samples per cycle unfiltered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII Binary COMTRADE (16 samples per cycle unfiltered)

Note: Binary COMTRADE format as per IEEE C37.11-1999, IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems.

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (with respect to Time Source):	±1 ms

Type Tests

Environmental Tests

Enclosure Protection:	IEC 60529:2001 + CRDG:2003 IP65 enclosed in panel (2-line display models) IP54 enclosed in panel (touchscreen models) IP50 for terminals enclosed in the dust-protection assembly (protection against solid foreign objects only) (SEL Part #915900170). The 10°C temperature derating applies to the temperature specifications of the relay. IP10 for terminals and the relay rear panel
Vibration Resistance:	IEC 60255-21-1:1988, Class 1 IEC 60255-27:2013, Section 10.6.2.1 Endurance: Class 2 Response: Class 2
Shock Resistance:	IEC 60255-21-2:1988, Class 1 IEC 60255-27:2013, Section 10.6.2.2 IEC 60255-27:2013, Section 10.6.2.3 Withstand: Class 1 Response: Class 2 Bump: Class 1
Seismic (Quake Response):	IEC 60255-21-3:1993 IEC 60255-27:2013, Section 10.6.2.4 Response: Class 2
Cold:	IEC 60068-2-1:2007 IEC 60255-27:2013, Section 10.6.1.2 IEC 60255-27:2013, Section 10.6.1.4 –40°C, 16 hours
Dry Heat:	IEC 60068-2-2:2007 IEC 60255-27:2013, Section 10.6.1.1 IEC 60255-27:2013, Section 10.6.1.3 85°C, 16 hours
Damp Heat, Steady State:	IEC 60068-2-78:2013 IEC 60255-27:2013, Section 10.6.1.5 40°C, 93% relative humidity, 10 days
Damp Heat, Cyclic:	IEC 60068-2-30:2005 IEC 60255-27:2013, Section 10.6.1.6 25° to 55°C, 95% relative humidity, 6 cycles
Change of Temperature:	IEC 60068-2-14:2009 IEC 60255-1:2010, Section 6.12.3.5 –40° to +85°C, ramp rate 1°C/min, 5 cycles

Dielectric Strength and Impulse Tests

Dielectric (HiPot):	IEC 60255-27:2013, Section 10.6.4.3 IEEE C37.90-2005 1.0 kVac on analog outputs, Ethernet ports, Port 3, IRIG 2.0 kVac on analog inputs 2.5 kVac on contact I/O 3.6 kVdc on power supply, current, and voltage inputs
Impulse:	IEC 60255-27:2013, Section 10.6.4.2 0.5 J, 5 kV on power supply, contact I/O, ac current, and voltage inputs 0.5 J, 1 kV on Port 3, RTD, and IRIG ports 0.5 J, 530 V on analog outputs IEEE C37.90:2005 0.5 J, 5 kV 0.5 J, 530 V on analog outputs

RFI and Interference Tests

Front-port serial cable (non-fiber) lengths are assumed to be <3 m.

EMC Immunity

Electrostatic Discharge Immunity:	IEC 61000-4-2:2008 IEC 60255-26:2013; Section 7.2.3 IEEE C37.90.3:2001 Severity Level 4 8 kV contact discharge 15 kV air discharge
Radiated RF Immunity:	IEC 61000-4-3:2010 IEC 60255-26:2013; Section 7.2.4 10 V/m IEEE C37.90.2-2004 20 V/m

Surge Withstand Capability Immunity:	EN 61000-4-18:2010 IEC 60255-26:2013; Section 7.2.6 2.5 kV common mode 1 kV differential mode 1 kV common mode on comm. ports IEEE C37.90.1-2002 2.5 kV oscillatory 4 kV fast transient Comm. ports, IRIG, and PTC ports Zone B, 2 kV line-to-earth LEA ports compliant with IEC 61869-13 tested to 1 kV, 1 MHz common mode
Surge Immunity:	IEC 61000-4-5:2005 IEC 60255-26:2013; Section 7.2.7 2 kV line-to-line 4 kV line-to-earth
Fast Transient, Burst Immunity:	IEC 61000-4-4:2011 IEC 60255-26:2013; Section 7.2.5 4 kV @ 5.0 kHz 2 kV @ 5.0 kHz for comm. ports
Conducted RF Immunity:	IEC 61000-4-6:2008, IEC 60255-26:2013; Section 7.2.8 10 Vrms
Magnetic Field Immunity:	IEC 61000-4-8:2009 IEC 60255-26:2013, Section 7.2.10 Severity Level: 1000 A/m for 3 seconds, 100 A/m for 1 minute; 50/60 Hz IEC 61000-4-9: 2001 Severity Level: 1000 A/m IEC 61000-4-10:2001 Severity Level: 100 A/m (100 kHz and 1 MHz)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999 IEC 61000-4-29:2000 IEC 60255-26:2013, Section 7.2.11 IEC 60255-26:2013, Section 7.2.12 IEC 60255-26:2013, Section 7.2.13

EMC Emissions

Conducted Emissions:	IEC 60255-26:2013, Class A FCC 47 CFR Part 15.107, Class A Canada ICES-001 (A) / NMB-001 (A) EN 55011:2009 + A1:2010, Class A EN 55022:2010 + AC:2011, Class A EN 55032:2012 + AC:2013, Class A CISPR 11:2009 + A1:2010, Class A CISPR 22:2008, Class A CISPR 32:2015, Class A
Radiated Emissions:	IEC 60255-26:2013, Class A FCC 47 CFR Part 15.109, Class A Canada ICES-001 (A) / NMB-001 (A) EN 55011:2009 + A1:2010, Class A EN 55022:2010 + AC:2011, Class A EN 55032:2012 + AC:2013, Class A CISPR 11:2009 + A1:2010, Class A CISPR 22:2008, Class A CISPR 32:2015, Class A

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