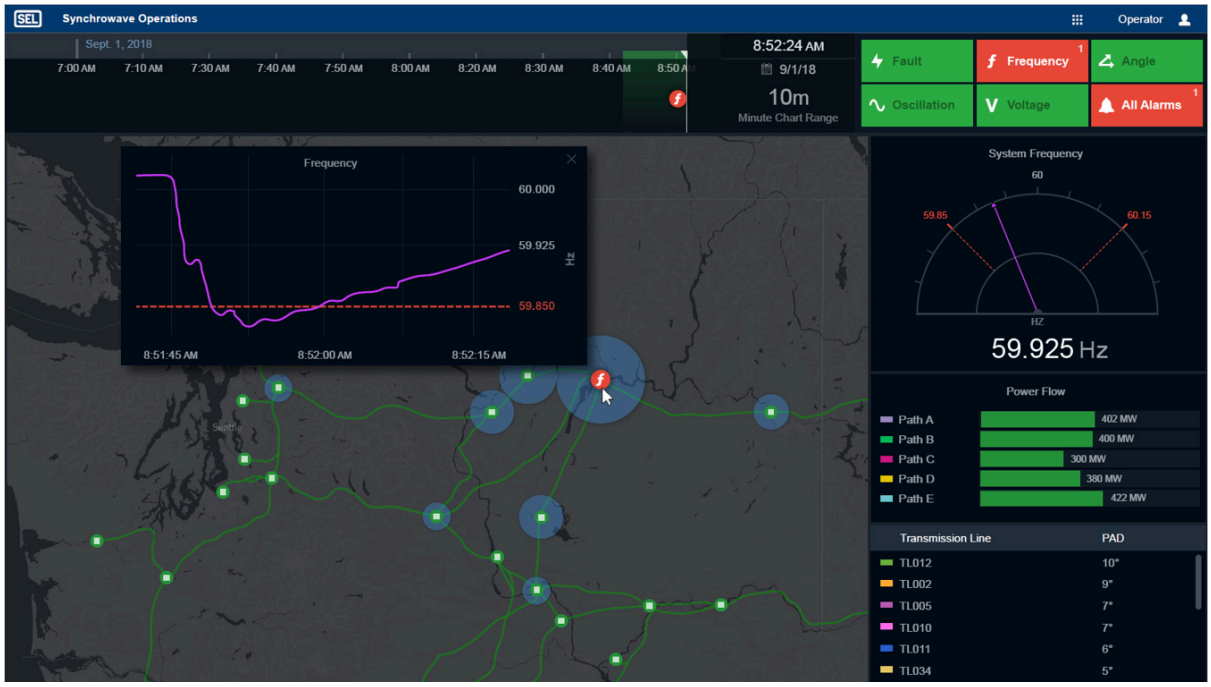
# Synchrowave Operations and Platform

## Instruction Manual




20250221

SEL SCHWEITZER ENGINEERING LABORATORIES

© 2019–2025 Schweitzer Engineering Laboratories, Inc. All rights reserved.

Content subject to change without notice. Unless otherwise agreed in writing, all SEL product sales are subject to SEL's terms and conditions located here: https://selinc.com/company/termsandconditions/.

# Table of Contents

## Section 1: Introduction

Introduction..... 1
Feature Highlights..... 1
Functional Overview..... 2
Applications..... 2

## Section 2: Synchrowave Platform

Introduction..... 5
Application Manager..... 8
Platform Applications..... 15
SEL Signals Application..... 23
System Manager and Resource Monitor..... 26

## Section 3: Synchrowave Operations

Introduction..... 29
Notification Application..... 33
Timeline Application..... 46
Dashboards Application..... 49
Playback Application..... 66

## Section 4: Applications

Introduction..... 69
Power System Applications..... 69
Frequency Monitor Application..... 72
Voltage Monitor Application..... 74
Phase Angle Monitor Application..... 75
Power Monitor Application..... 76
Oscillation Monitor Application..... 78
Disturbance Detector Application..... 81
Signal Monitor Application..... 82
Instrument Transformer Monitor Application..... 83
Modal Analysis Application..... 84
Generation Trip Locator Application..... 88
Synchrowave Vision..... 90
Sequence Calculator Application..... 92
Panel Applications..... 94
Time-Series Trend Panel Application..... 95
Bar Chart Panel Application..... 99
Histogram Panel Application..... 104
Dial Panel Application..... 107
Phasor Scope Panel Application..... 111
XY Panel Application..... 115
Device Events Panel Application..... 116
Notification Table Application..... 119
Notification Inhibit Table..... 123
Table Panel Application..... 124
Numeric Panel Application..... 127
Digital Chart Application..... 129
ESRI Map Panel Application..... 131
One-Line Diagram Panel Application..... 145

Data and Storage Applications....147
Time-Series Historian Application....148
Calculations Application....152
Event Store Application....154
SWave Server Application....154
OSI PI Reader Application....157
IEEE P2664 STTP Reader Application....159
IEEE C37.118 Reader Application....161
Continuous Waveform Streaming Receiver Application....164
Setting Up Meter Calculations....165
Virtual Meters Application....167
Load Profile Application....174
Power System Model Application....176
ACSELERATOR Database Reader Application....180
DMA Receiver Application....183
Synchrowave Event Express....190
Data Export Application....193
One-Line Manager Application....194

## Section 5: Installation and Hardware Requirements

Introduction....199
Deployment Network Architecture....199
Server and Client Requirements and Specifications....201
Data Storage Requirements....205
Linux Software Installation....206
Run the Synchrowave Command Line Interface....210
Allow Installation of Third-Party Applications....213
Synchrowave Platform Backup Procedure....213
Configuring Network Settings....215
Windows Software Installation....215

## Appendix A: Software and Manual Versions

Software....217
Instruction Manual....221

## Appendix B: Troubleshooting SEL Synchrowave Platform and Operations

Introduction....229
Symptoms....229
Solutions....231

## Appendix C: Creating SVG Diagrams

Introduction....235
Creating SVG Diagrams....235
Adding Attributes to SVG Objects....236

## Appendix D: Installation Checklist

## Appendix E: Cybersecurity Features

Introduction and Security Environment....245
Version Information....245
Commissioning and Decommissioning....245
External Interfaces....247
Access Controls....247
Logging....248
Backup and Restore....248
Malware Protection Features....248

Product Updates..... 248
Contact SEL..... 249

This page intentionally left blank

# List of Figures

Figure 1.1 Synchrowave Operations and Platform Functional Diagram.... 2
Figure 2.1 Synchrowave Platform Diagram....5
Figure 2.2 Containers Enable Scalability.... 6
Figure 2.3 Containers Improve Resiliency.... 7
Figure 2.4 Web-Client Based Platform Diagram.... 7
Figure 2.5 PMU Measurements Compared to SCADA....8
Figure 2.6 Application Manager.... 9
Figure 2.7 Application Manager in Platform Navigation Menu....9
Figure 2.8 Add Application....9
Figure 2.9 Application Menu....10
Figure 2.10 Application Status....10
Figure 2.11 Application Management....10
Figure 2.12 Application Configuration.... 11
Figure 2.13 Application Configuration Import Dialog Box....11
Figure 2.14 Application Configuration History.... 12
Figure 2.15 Configuration Query and Download.... 12
Figure 2.16 Alternate Configuration Import and Export....13
Figure 2.17 Diagnostic Logs....14
Figure 2.18 Filtering Diagnostic Log Columns.... 14
Figure 2.19 Export Diagnostic Logs to CSV File.... 15
Figure 2.20 Platform Services Configuration.... 16
Figure 2.21 Web Gateway Overview....17
Figure 2.22 Web Browser Not Secure Warning....18
Figure 2.23 HTTPS Configuration....18
Figure 2.24 CSR Dialog.... 19
Figure 2.25 Web-Client HTTPS Status Indication....19
Figure 2.26 LDAP Server Connection Setup.... 20
Figure 2.27 Adding/Removing Users and User Groups.... 21
Figure 2.28 Synchrowave Platform Login Page.... 22
Figure 2.29 Login Message and Enable Remember Me....23
Figure 2.30 Configuration of Default Application Page.... 23
Figure 2.31 Signal Definition.... 24
Figure 2.32 Signal Bus Overview....24
Figure 2.33 Signals Application.... 25
Figure 2.34 Unit Mappings Configuration File....26
Figure 2.35 Digital Signals Configuration File....26
Figure 2.36 Resource Monitor Information.... 27
Figure 2.37 Resource Monitor Notification Pane....27
Figure 2.38 Monitoring.csv Configuration File.... 27
Figure 3.1 Synchrowave Operations Workflow Overview.... 29
Figure 3.2 Software User Interface—Notification Summary....31
Figure 3.3 Software User Interface—Timeline Application.... 32
Figure 3.4 Software User Interface—Dashboards and Dashboard Navigation....33
Figure 3.5 Notification Architecture....34
Figure 3.6 Notification Summary Display Location.... 34
Figure 3.7 Notification Summary Details....35
Figure 3.8 Disconnected Power System Monitor Indication....35
Figure 3.9 Creating a User Notification....36
Figure 3.10 Edit User Notification....36
Figure 3.11 Notification Analysis Mode.... 37

Figure 3.12 Notification List Details.....38
Figure 3.13 Shelving a Notification.....38
Figure 3.14 Unshelving a Notification.....39
Figure 3.15 Shelve Notification Settings.....39
Figure 3.16 Inhibit Measurement Points Dialog.....40
Figure 3.17 Notification Mode Opening Comment Section.....40
Figure 3.18 Exit Comment Section.....41
Figure 3.19 Comment Section Layout.....42
Figure 3.20 Deleting a Notification Comment.....43
Figure 3.21 Notification Analysis Dashboard.....44
Figure 3.22 Notification State Diagram.....45
Figure 3.23 Notification State Transition Diagram.....45
Figure 3.24 Notifications Application Configuration.....46
Figure 3.25 Changing Notification Audio Volume.....46
Figure 3.26 Timeline Time Range.....47
Figure 3.27 Timeline Chart Time Range.....47
Figure 3.28 Timeline Chart Time Range Default Values.....47
Figure 3.29 Timeline Time-Marker.....47
Figure 3.30 Timeline Real-Time Mode Indication.....48
Figure 3.31 Timeline Historic Mode Indication.....48
Figure 3.32 Timeline Calendar Date Selection.....48
Figure 3.33 Timeline Notification Icons.....48
Figure 3.34 Timeline Replay Controller.....49
Figure 3.35 System Monitoring Dashboard.....50
Figure 3.36 Asset Investigation Dashboard.....51
Figure 3.37 Notification Analysis Dashboard.....51
Figure 3.38 Dashboard Navigation Toolbar.....52
Figure 3.39 Dashboard Navigation Menu.....52
Figure 3.40 Dashboard Navigation Path.....52
Figure 3.41 Navigating to Dashboards in the Same Folder.....52
Figure 3.42 Searching for Dashboards.....53
Figure 3.43 Navigating to the Home Dashboard.....53
Figure 3.44 Setting the Home Dashboard.....53
Figure 3.45 Dashboard Manager in Platform Navigation Menu.....54
Figure 3.46 Importing Dashboard Folder Path.....54
Figure 3.47 Example Dashboard Folder Path File.....55
Figure 3.48 Creating a Dashboard Navigation Folder.....55
Figure 3.49 Importing and Exporting Dashboards.....56
Figure 3.50 Export Select Dashboards.....56
Figure 3.51 Creating a Dashboard.....57
Figure 3.52 Naming a Dashboard.....57
Figure 3.53 Private User Dashboard Indication.....57
Figure 3.54 Dashboard Options Menu.....58
Figure 3.55 Adding Dashboard Panel.....58
Figure 3.56 Rearranging Dashboard Panels.....59
Figure 3.57 Resizing Dashboard Panels.....59
Figure 3.58 Dashboard Panel Options.....59
Figure 3.59 Dashboard Panel Configuration.....59
Figure 3.60 User Dashboard Indication.....60
Figure 3.61 Publishing Dashboards.....60
Figure 3.62 Navigating Published Dashboards.....60
Figure 3.63 Published Dashboard Indication.....60
Figure 3.64 Dashboard Navigation Toolbar for Other Users.....61
Figure 3.65 Minimum Dashboard Folder Path Structure.....61
Figure 3.66 Dashboard Folder Path Example.....62

Figure 3.67 Associating a Dashboard With a Folder Path.... 62
Figure 3.68 Resulting Dashboard Navigation Menu.... 63
Figure 3.69 Adding Context to Dashboard Panels.... 63
Figure 3.70 Changing the Dashboard Display Order.... 65
Figure 3.71 Light Theme Dashboard Display.... 65
Figure 3.72 Theme Toggle Button.... 65
Figure 3.73 Theme Font Size.... 66
Figure 3.74 Playback Mode.... 66
Figure 3.75 Playback Manager.... 67
Figure 4.1 Flow Chart of Condition Generation by the Monitor Applications.... 70
Figure 4.2 TimeSettings.csv Open in a Spreadsheet Application.... 71
Figure 4.3 TimeSettings.csv Open in a Text Editor.... 71
Figure 4.4 Flow Chart of Condition Grouping Algorithm Used by the Monitor Applications.... 72
Figure 4.5 Frequency Monitor Application Configuration, Thresholds.csv Shown in a Spreadsheet Application.... 73
Figure 4.6 Frequency Monitor Application Configuration, Thresholds.csv Shown in a Text Editor.... 73
Figure 4.7 Oscillation Monitor Output Example.... 78
Figure 4.8 Oscillation Monitor Frequency Band Configuration.... 79
Figure 4.9 Oscillation Monitor Signals Configuration.... 79
Figure 4.10 Oscillation Monitor Thresholds Configuration.... 80
Figure 4.11 Oscillation Monitor Time Settings Configuration.... 80
Figure 4.12 Disturbance Detector Frequency Band Configuration.... 81
Figure 4.13 Disturbance Detector Signals Configuration.... 82
Figure 4.14 Signal Monitor Conditions Display Via General or All Notification Tile.... 82
Figure 4.15 Grouping Parameters and Notification Type Configuration.... 82
Figure 4.16 Signal Monitor Application Configuration, Thresholds.csv Shown in a Spreadsheet Application.... 83
Figure 4.17 Instrument Transformer Monitor Configuration, MeasurementPoints.csv.... 84
Figure 4.18 Instrument Transformer Monitor Configuration, MeasurementPoints.csv.... 84
Figure 4.19 Modal Analysis Example.... 85
Figure 4.20 Modal Analysis Signal Group Configuration.... 86
Figure 4.21 Modal Analysis Mode Configuration.... 86
Figure 4.22 Modal Analysis Threshold Configuration.... 87
Figure 4.23 Modal Analysis Time Settings Configuration.... 87
Figure 4.24 Generation Trip Locator Configuration, MeasurementPoints.csv.... 88
Figure 4.25 Generation Trip Map Layer.... 89
Figure 4.26 Generation Trip Map Layer Configuration.... 90
Figure 4.27 Synchrowave Vision Indicator.... 91
Figure 4.28 Enable Synchrowave Vision.... 92
Figure 4.29 Sequence Calculator CSV Setting File Format.... 94
Figure 4.30 Dashboard Panel Overview.... 95
Figure 4.31 Selecting Copy Panel.... 95
Figure 4.32 The Clipboard Icon for Pasting Panel.... 95
Figure 4.33 Time-Series Trend Panel Overview.... 95
Figure 4.34 Selecting the Time-Series Trend Edit Button.... 97
Figure 4.35 Edit Data Type.... 97
Figure 4.36 Add/Remove Measurement Points From Time-Series Trend.... 98
Figure 4.37 Setting Up Default Time-Series Trend.... 99
Figure 4.38 Bar Chart Panel Overview.... 99
Figure 4.39 Bar Chart Panel With No Thresholds.... 100
Figure 4.40 Bar Chart Panel Toggle Scale Button.... 100
Figure 4.41 Bar Chart Panel Threshold Scale.... 100
Figure 4.42 Bar Chart Panel Fixed Scale.... 101
Figure 4.43 Edit Bar Chart Panel Data Type.... 101
Figure 4.44 Add/Remove Measurement Points From Bar Chart Panel.... 102
Figure 4.45 Configure the Bar Chart Panel Default View Range.... 103

Figure 4.46 Configure the Bar Chart Panel Sort Order....103
Figure 4.47 Bar Chart Panel With Limits Shown....104
Figure 4.48 Bar Chart Panel With Vertical Bar Orientation....104
Figure 4.49 Histogram Panel Overview....105
Figure 4.50 Selecting the Histogram Edit Button....105
Figure 4.51 Adding Measurement Point to Histogram Panel....106
Figure 4.52 Configuring Histogram Panel....107
Figure 4.53 Dial Panel Overview....107
Figure 4.54 Edit Dial Panel Data Type....109
Figure 4.55 Add/Remove Measurement Points From Dial Panel....110
Figure 4.56 Configure the Dial Range....110
Figure 4.57 Phasor Scope Panel Overview....111
Figure 4.58 Selecting the Phasor Scope Edit Button....112
Figure 4.59 Edit Phasor Scope Panel Data Type....112
Figure 4.60 Add/Remove Measurement Points From Phasor Scope Panel....113
Figure 4.61 Configuring the Reference Measurement Point....113
Figure 4.62 Phasor Scope With Custom Angle Range....114
Figure 4.63 Phasor Scope With Zero Position at Top....114
Figure 4.64 Phasor Scope Show Magnitudes Configuration....115
Figure 4.65 XY Panel Overview....115
Figure 4.66 Configure the XY Chart Signals....116
Figure 4.67 Configure the XY Chart Default View Range....116
Figure 4.68 Device Events Panel Overview....117
Figure 4.69 MeasurementPointA.Device1 Summary Example....118
Figure 4.70 Selecting the Device Events Panel Edit Button....118
Figure 4.71 Edit Event Type....118
Figure 4.72 Add/Remove Measurement Point Devices From Device Events Panel....119
Figure 4.73 Notification Table Panel Overview....119
Figure 4.74 Notification Table Show or Hide Columns....120
Figure 4.75 Notification Table Filtering....120
Figure 4.76 Notification Table Column Sorting....120
Figure 4.77 Notification Table Change Column Width....121
Figure 4.78 Notification Table Selecting Notification....122
Figure 4.79 Notification Table Selecting Row....122
Figure 4.80 Notification Inhibit Table Overview....123
Figure 4.81 Table Panel Overview....124
Figure 4.82 Temporary Table Column Sorting....124
Figure 4.83 Table Measurement Point Selection....125
Figure 4.84 Add/Remove Measurement Points From the Table....126
Figure 4.85 Table Data Columns Options Menu....127
Figure 4.86 Numeric Panel Overview....127
Figure 4.87 Selecting the Numeric Edit Button....128
Figure 4.88 Edit Numeric Panel Data Type....128
Figure 4.89 Add/Remove Measurement Points From Numeric Panel....129
Figure 4.90 Digital Chart....129
Figure 4.91 Digital Chart Configuration Dialog....130
Figure 4.92 Digital Chart Insufficient Resolution....131
Figure 4.93 ESRI GIS Map Overview....132
Figure 4.94 Set the GIS Map Panel Default Zoom....132
Figure 4.95 Switching to Satellite Basemap....133
Figure 4.96 Connecting to ESRI GIS Server....133
Figure 4.97 Changing the GIS Map Base Map....134
Figure 4.98 Add/Remove Map Layers....135
Figure 4.99 Example of Lines and Stations Map Layers....135
Figure 4.100 Notification Map Layer....136

Figure 4.101 Indication of Multiple Notifications at One Location....137
Figure 4.102 Power Flow Direction Map Layer.... 137
Figure 4.103 Change Layer Visibility.... 137
Figure 4.104 Edit Layer Properties.... 138
Figure 4.105 Adding Layers By Using the Search Portal.... 139
Figure 4.106 Adding Layer With URL.... 139
Figure 4.107 Display Map Layer Information.... 140
Figure 4.108 Removing Map Layers.... 140
Figure 4.109 Finding Layer Title.... 141
Figure 4.110 Example Asset Mapping Configuration File.... 142
Figure 4.111 Contour Map Layer....142
Figure 4.112 Example Renamed Contour Layer Configuration Files....143
Figure 4.113 Example Information.csv Files.... 143
Figure 4.114 Example MeasurementPoints.csv Files....144
Figure 4.115 Example Color.csv Files.... 144
Figure 4.116 One-Line Diagram Panel Overview....145
Figure 4.117 Set the One-Line Diagram Panel Default Zoom....146
Figure 4.118 Selecting SVG Diagram for One-Line Diagram Panel.... 147
Figure 4.119 Data and Storage Architecture....147
Figure 4.120 Synchrowave Historian System Notification.... 149
Figure 4.121 Synchrowave Historian Data Retention Configuration.... 151
Figure 4.122 Synchrowave Historian Deletion Exemption Configuration.... 152
Figure 4.123 Calculations Overview....152
Figure 4.124 Accessing Calculations Help Menu....152
Figure 4.125 Calculations Help Menu.... 153
Figure 4.126 Calculations Libraries....153
Figure 4.127 Example SWave Server CSV Mapping File....155
Figure 4.128 SWave Server Initially Functioning Correctly.... 156
Figure 4.129 Incorrectly Configured SWave Server....156
Figure 4.130 Correctly Configured SWave Server....156
Figure 4.131 Disable SWave Server After Set Time....157
Figure 4.132 OSI PI Reader Configuration....157
Figure 4.133 Example OSI PI Signal Mapping....158
Figure 4.134 Example OSI PI Unit Mapping.... 159
Figure 4.135 Connecting to an STTP Source.... 160
Figure 4.136 IEEE P2664 STTP Reader CSV Mapping File Format.... 160
Figure 4.137 Completed IEEE P2664 STTP Reader CSV Mapping File....160
Figure 4.138 Connecting to an IEEE C37.118 Source....162
Figure 4.139 IEEE C37.118 Reader CSV Mapping File Format.... 163
Figure 4.140 Completed IEEE C37.118 Reader CSV Mapping File.... 163
Figure 4.141 Meter Calculations With No Configurations.... 166
Figure 4.142 Meter Calculations Configuration.... 166
Figure 4.143 Meter Calculations Assign Measurement Points.... 167
Figure 4.144 Configured Templates File.... 169
Figure 4.145 Configured MeasurementPointMappings File....170
Figure 4.146 Configured Templates File.... 176
Figure 4.147 Configured Mappings File....176
Figure 4.148 stations.csv File Format.... 177
Figure 4.149 buses.csv File Format....178
Figure 4.150 lines.csv File Format....178
Figure 4.151 poles.csv File Format.... 179
Figure 4.152 segments.csv File Format....179
Figure 4.153 Example Line.... 180
Figure 4.154 acSELerator Database Reader Overview....180
Figure 4.155 acSELerator Database Manager.... 181

Figure 4.156 acSELerator Database Connection Key Password Prompt..... 181
Figure 4.157 acSELerator Database Reader Configuration..... 182
Figure 4.158 acSELerator Database Device CSV Mapping File Format..... 183
Figure 4.159 DMA Receiver Overview..... 183
Figure 4.160 Resource Management..... 184
Figure 4.161 Create a New Web Server Resource..... 184
Figure 4.162 Add a Connection to the Web Server..... 185
Figure 4.163 Create a New Direct Resource Access..... 186
Figure 4.164 Add a Connection to the Direct Resource Access..... 187
Figure 4.165 Create a Collection Plan..... 188
Figure 4.166 Create a New Publishing Plan..... 189
Figure 4.167 Synchrowave Event Express Overview..... 190
Figure 4.168 Opening an Event in Synchrowave Event Express..... 190
Figure 4.169 Event Details Information..... 191
Figure 4.170 Relay Settings From Event Report..... 191
Figure 4.171 Default Analog Charts Displaying Current and Voltage Oscillography..... 192
Figure 4.172 Default Digital Chart Displaying Relay Word Bits..... 192
Figure 4.173 Toggle Between Zoom and Pan..... 192
Figure 4.174 One-Line Manager Application Overview..... 195
Figure 4.175 Line Object Configuration Example..... 196
Figure 4.176 Text Object Configuration Example..... 197
Figure 5.1 Secure Network Deployment Architecture..... 199
Figure 5.2 Corporate Network Deployment Architecture..... 200
Figure 5.3 Review and Accept K3s License Agreement..... 207
Figure 5.4 Join Cluster..... 208
Figure 5.5 Enter Output String Into Installer Prompt..... 208
Figure 5.6 Application Directory Path..... 209
Figure 5.7 Synchrowave Command Line Interface Directory..... 210
Figure 5.8 Remove Node From List..... 212
Figure 5.9 Restore to Previous Application Version..... 212
Figure 5.10 Configuration of Application Data Directory..... 216
Figure C.1 One-Line Diagram Panel Overview..... 235
Figure C.2 Adding an Attribute to an SVG Object..... 236
Figure C.3 JSON for Changing Color of Feeder Object..... 237
Figure C.4 JSON for Changing Color of Breaker Object..... 238
Figure C.5 JSON for Right Power Flow Arrow..... 239
Figure C.6 JSON for Left Power Flow Arrow..... 239
Figure C.7 JSON for Signal Values and Threshold State (Alarm State)..... 240
Figure C.8 JSON for Selection State—Top and Bottom Bar..... 240
Figure C.9 JSON for Selection State—Threshold Region for Selection State..... 241

# List of Tables

Table 1.1 Synchrowave Operations Application Highlights.....2
Table 1.2 Synchrowave Platform Application Highlights.....3
Table 1.3 Power System Monitoring Application Highlights.....3
Table 1.4 Panel Application Highlights.....3
Table 1.5 Data Application Highlights.....4
Table 2.1 Synchrowave Standard Quantities.....24
Table 4.1 CWS Receiver Quantities.....165
Table 4.2 Meter Quantities.....170
Table 4.3 Load Profile Functions.....174
Table 5.1 Single-Node System.....204
Table 5.2 Cluster.....204
Table 5.3 Operations Applications.....204
Table A.1 Synchrowave Operations WASA Package Revision History.....217
Table A.2 Synchrowave Linux Platform Software Revision History.....219
Table A.3 Synchrowave Windows Platform Software Revision History.....220
Table A.4 Manual Revision History.....221
Table B.1 Symptoms.....229

This page intentionally left blank

SECTION 1

# Introduction

## Introduction

Synchrowave® Operations is situational awareness for power system operations. It delivers detection, notification, and visualization of power system conditions to operators for greater situational awareness. It helps operators make the right decision every time. Synchrowave Operations is comprised of a suite of applications running on the Synchrowave Platform.

The Synchrowave Platform incorporates the latest in software technology to deliver the following benefits:

- Fast application development, integration, and customization platform that enables you to quickly prototype new functionality based on emerging needs.
- Containerized applications for reliability and scalability. Leveraging technology that makes cloud services secure and powerful and your private servers are both more secure and more accessible.
- System data aggregation for situational awareness. Collecting, organizing, and presenting high-resolution time-series sensor data with classical system information provides a holistic picture that improves operator understanding of the system state.
- Context-sensitive displays customize the data presentation. They show you the information you need, when you need it, and minimizes distractions.

## Feature Highlights

**Situational Awareness.** Flexible dashboards make workflow customization easy, ensuring display of the right information at the right time. Dashboards enable bringing together a collection of applicable power system data and information in a single display.

**Time-Domain Values and Synchrophasors.** Synchrowave Platform supports streaming time-domain point-on-wave data and synchrophasors. Direct point-on-wave measurements can be streamed from devices such as the SEL Axion Wave Server. Data rates as fast as 10,000/second are supported.

**Real-Time Analytics.** Real-time analytics applications continuously analyze numerous sources of data in real-time to detect and characterize anomalous power system conditions. Upon detecting a condition, the application then notifies operators and engineers, providing information about what, when, where, and why.

**High-Performance Platform.** The Synchrowave Platform brings state of the art data center technology to your secure private network. The platform is designed from the ground up with micro-service and container technology giving utilities a robust and scalable platform.

**Flexible Platform.** Defined interfaces simplify integrating applications, enabling engineers to quickly create, integrate, and deploy new applications and algorithms.

# Functional Overview

*Figure 1.1* provides an overview of Synchrowave Operations and Synchrowave Platform from an application perspective. In this manual, each application is discussed in detail.

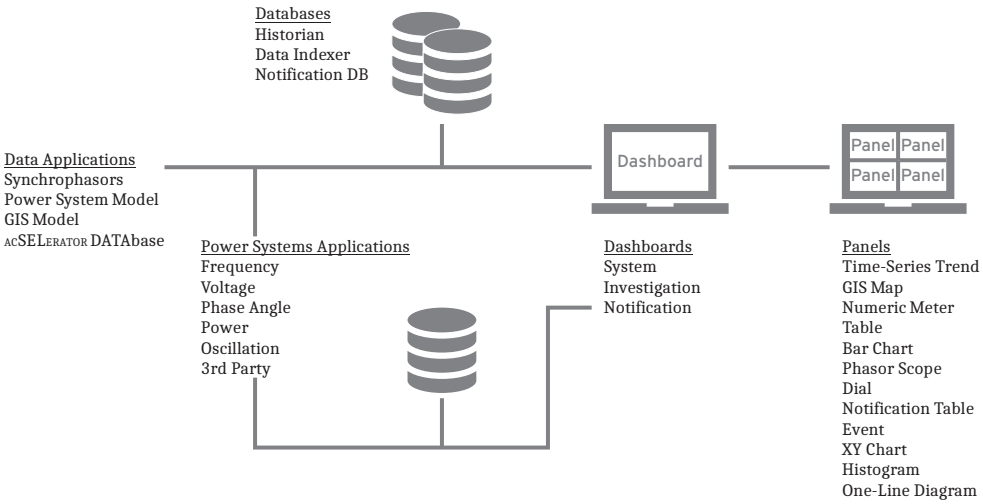



**Figure 1.1 Synchrowave Operations and Platform Functional Diagram**

# Applications

Synchrowave Operations and Synchrowave Platform support a variety of power system operations and analytics applications. Applications will be continuously developed and released.

*Table 1.1* through *Table 1.5* list the available applications and key features in the initial software release. With the Synchrowave Platform, every unit of functionality is deployed as an application. Therefore, while some applications in *Table 1.1* through *Table 1.5* are part of the software infrastructure, they are all visible and listed.

**Table 1.1 Synchrowave Operations Application Highlights**

| Applications | Key Features |
|---|---|
| Timeline | Navigation and synchronization of time for dashboards. |
| Dashboards | The primary visualization of power system data.<br>Customizable and built from a collection of panel applications. |
| Notifications | Alert operators of power system conditions detected by power system applications.<br>Provide operators with impact and location information of power system conditions. |

**Table 1.2 Synchrowave Platform Application Highlights**

| Applications | Key Features |
|---|---|
| Application Manager | Interface to manage and configure applications installed on the platform. |
| Web-Gateway | Provides secure access to applications and data on the platform. |
| Signals | Collects, consolidates, and publishes signals to applications. |

**Table 1.3 Power System Monitoring Application Highlights**

| Applications | Key Features |
|---|---|
| Frequency Monitor | Detects frequency and rate-of-change frequency power system conditions. |
| Phase Angle Monitor | Calculates phase angle difference between substations.<br>Detects phase angle difference based on present power system conditions. |
| Power Monitor | Calculates real, reactive, and apparent power, and power factor.<br>Detects real, reactive, and apparent power conditions. |
| Voltage Monitor | Calculates line-to-line voltage and Dv/Dt.<br>Detects voltage and rate-of-change-of-voltage power system conditions. |
| Modal Analysis Monitor | Calculates oscillation frequency, damping, amplitude, and angle.<br>Detects oscillation power system conditions. |
| Disturbance Detector | Identifies unusual disturbances on the power system. |
| Signal Monitor | Detects general power system conditions for any type of signal. |

**Table 1.4 Panel Application Highlights**

| Applications | Key Features |
|---|---|
| ESRI GIS Map Panel | Provides geospatial location display information for operators.<br>Displays substation and transmission line locations.<br>Displays location information for power system conditions.<br>Displays voltage and frequency contour layers. |
| Numeric Panel | Provides a display of numeric values in dashboards. |
| One-Line Diagram Panel | Provides a display of scalable vector graphics (SVG) diagrams in dashboards. |
| Table Panel | Provides a display of tabular value in dashboards. |
| Time-Series Trend Panel | Provides a display of time-series data in dashboards. |
| Bar Chart Panel | Provides a bar chart display of values in dashboards. |
| Dial Panel | Provides a dial display of values in dashboards. |
| Phasor Scope Panel | Provides a display of phase angle values in dashboards. |
| Event Panel | Provides a display of event report information in dashboards. |
| Notification Table | Provides a tabular display of notifications in dashboards. |
| XY Chart | Provides an XY chart display of values in dashboards. |
| Histogram Panel | Provides a histogram display of values in dashboards. |

**Table 1.5 Data Application Highlights**

| Applications | Key Features |
|---|---|
| Historian | Archives all time-series data for storage, analytics, and display. Creates indexes of historian data to provide fast data access performance. |
| Calculations | Processes custom calculations in real-time and publishes results as signals. |
| IEEE P2664 STTP Reader | The Streaming Telemetry Transport Protocol (STTP) reads synchrophasor streams and publishes signals to the platform for visualization, analytics, and archiving. |
| IEEE C37.118 Reader | Reads from IEEE C37.118 synchrophasor streams and publishes signals to the platform for visualization and archiving. |
| Power System Model | Associates signals with physical power system equipment. |
| ACSELERATOR Database Reader | Reads event reports from ACSELERATOR Database and publishes event reports to the platform for visualization and analysis. |
| Synchrowave Event Express | Provides web-client based oscillography analysis for event reports in the Device Events panel. |
| OSI PI Reader | Reads from OSI PI Database for visualization of data stored in OSI PI database. |
| One-Line Manager | Provides user interface to associate signals, measurement points, and assets with SVG objects in diagrams. |
| Data Export | Downloads selected data directly from web-client display in CSV and COMTRADE format. |

SECTION 2

# Synchrowave Platform

## Introduction

The Synchrowave Platform incorporates the latest in software technology to deliver the following benefits:

- Fast application development, integration, and customization through an open platform.
- High reliability and scalability through offline cloud technology called containers.
- Power system insight through real-time analytics of high-resolution time-series sensor data.

## Open Application Platform Technology

### Application Oriented

The Synchrowave Platform is modularized into small server and user-interface applications. Applications can be removed, replaced, or customized to provide the flexibility needed to meet the unique requirements of each utility.

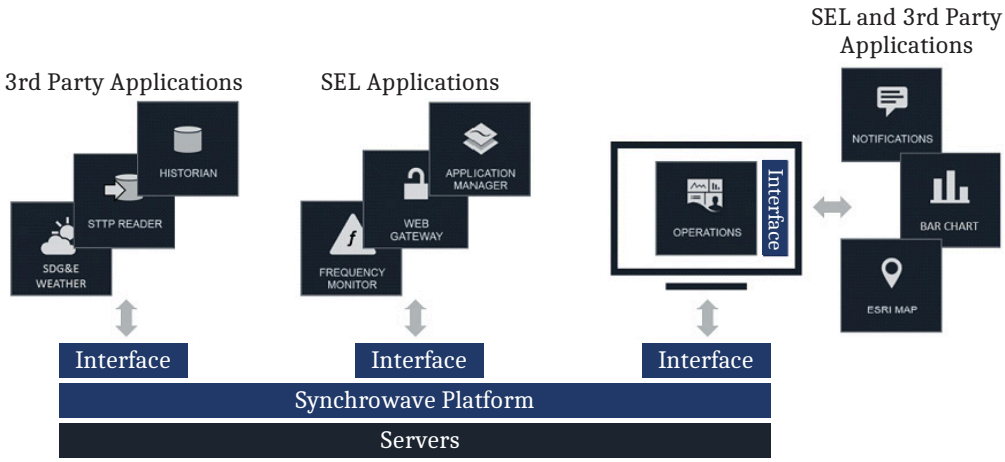



**Figure 2.1 Synchrowave Platform Diagram**

## Offline Software Infrastructure Technology

The software industry has been transformed by software technology called containers. Containers enable applications to be packaged into independent modules that each run in their own user space. This allows a software suite composed of multiple containers to be scalable, resilient, and secure.

## Simple and Fast Deployment

The container technology in the Synchrowave Platform eliminates operating environment inconsistencies that often cause time-consuming challenges during testing and deployment. Containers include all dependencies necessary to run the applications within the container, meaning the software functions consistently independent of the operating environment.

## Scalable Platform

As new applications, algorithms, or devices are added to the platform, you can add the additional hardware to the cluster to handle the new processing burden. The platform automatically distributes the required processing across CPUs when new hardware is added. Because the processing is distributed across hardware, the need for expensive server hardware is reduced.

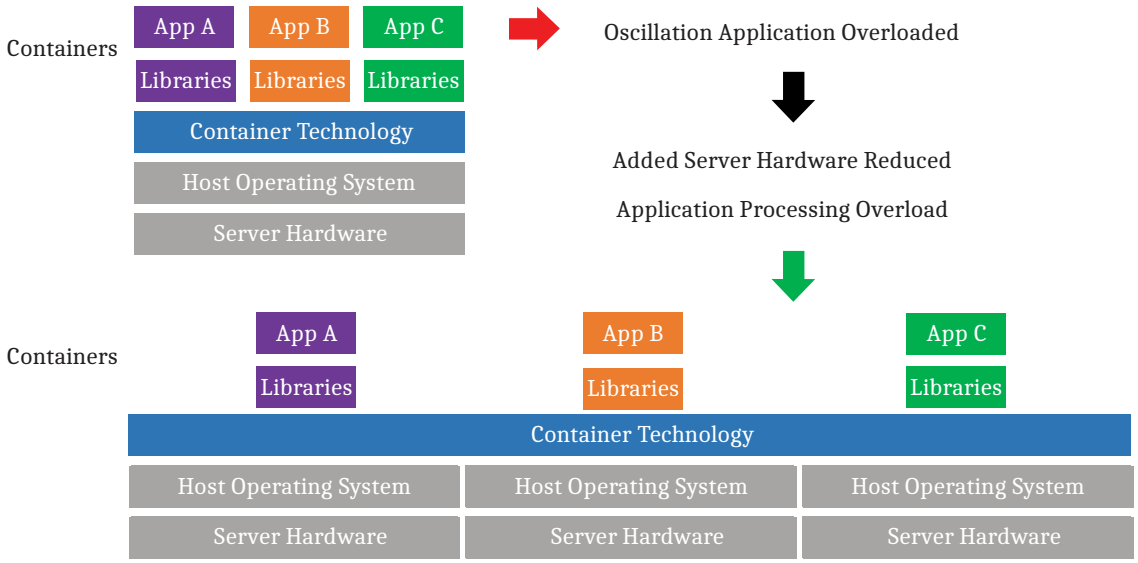



**Figure 2.2 Containers Enable Scalability**

## High Availability

During hardware failure or maintenance, applications automatically rebalance and move to healthy servers in the platform hardware cluster ensuring the applications that are needed by power system operators are always operational.

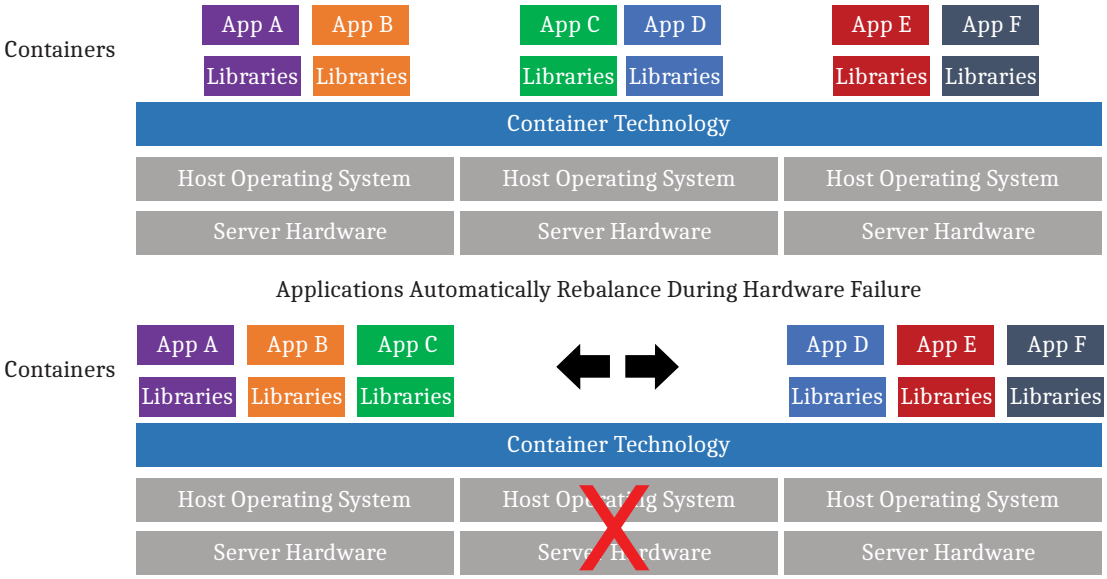



**Figure 2.3 Containers Improve Resiliency**

## Security and Isolation

Each application runs in its own dedicated containers and interacts with other applications via well-defined and testable interfaces. Even though multiple containers run on common hardware, they cannot interfere with each other. If one application fails, the other applications will continue to run. This isolation also reduces security risks.

## Web-Based

The Synchrowave Platform is built on modern web standards (HTML5). Web-client visualization provides fast access to data and applications to end users without software installed on the client computers. Visualization clients include desktops, laptops, tablets, and phones. Web-clients reduce total cost of software ownership by keeping software version and installation management at the server.

**Figure 2.4 Web-Client Based Platform Diagram**

## High-Resolution Time-Series Technology

The Synchrowave Platform delivers power system insight that SCADA does not provide, with support for synchrophasor, event report, and time-domain data sources. High-resolution time-synchronized data improves wide-area situational awareness by correlating data across the system together for advanced event detection and enhanced visualization.

*Figure 2.5* shows a growing oscillation captured from a PMU at a wind farm, which went undetected by traditional SCADA measurements.

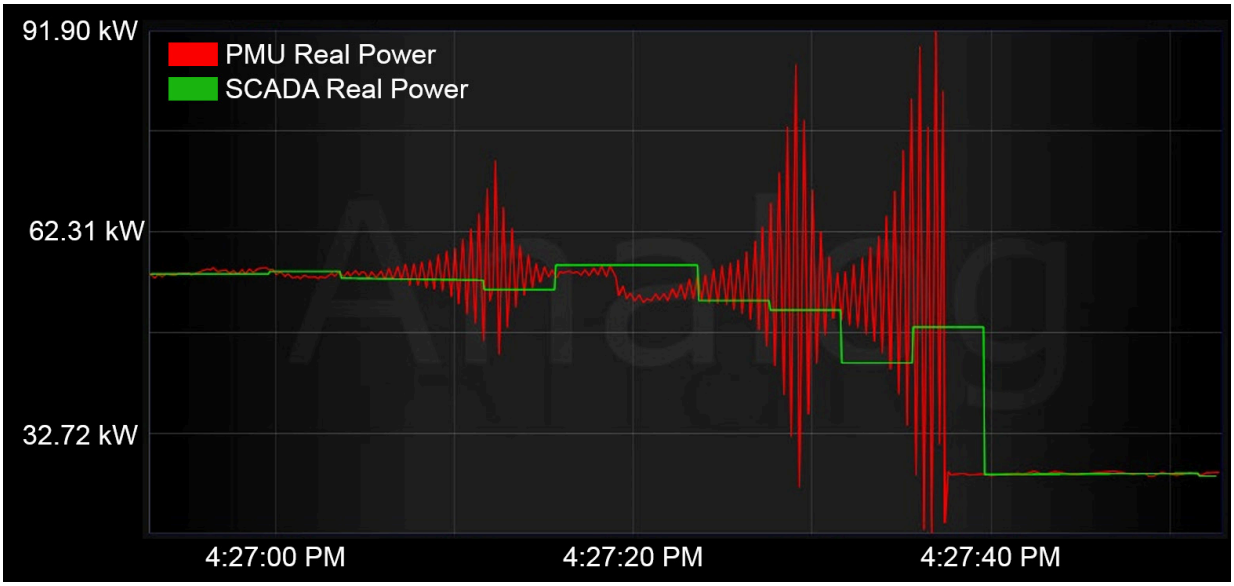



**Figure 2.5 PMU Measurements Compared to SCADA**

# Application Manager

The Synchrowave Platform was developed to support modular applications. As a result, the platform includes well-defined interfaces by which applications communicate with each other. Applications are added, configured, and managed through the Application Manager.

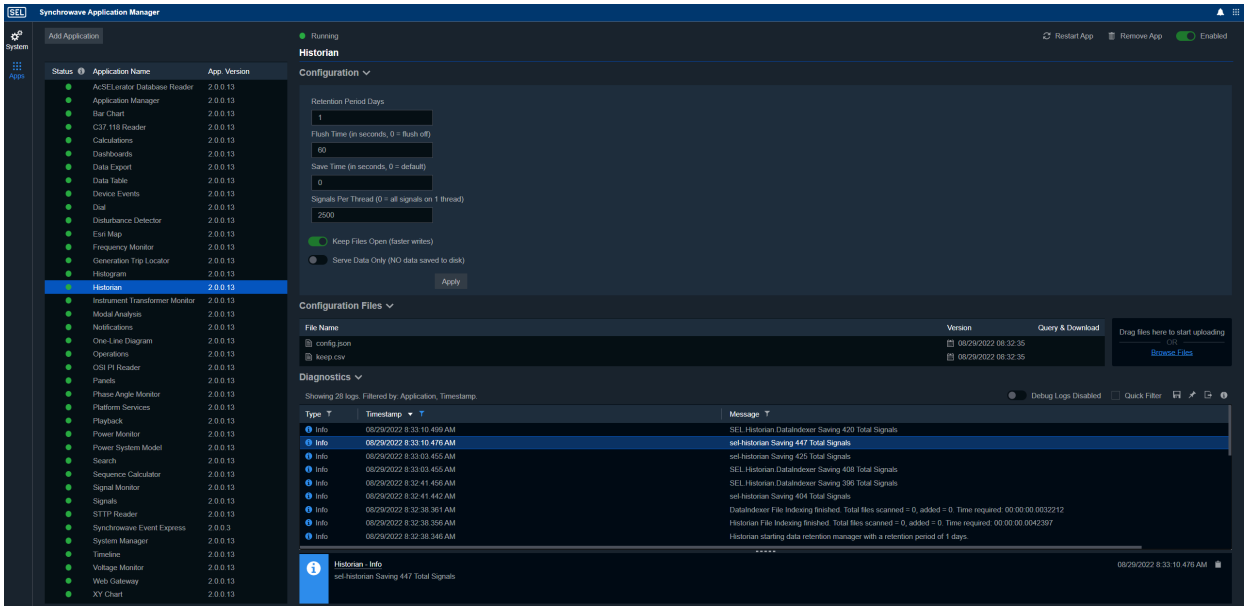



**Figure 2.6 Application Manager**

The Application Manager is accessed through the platform navigation menu.

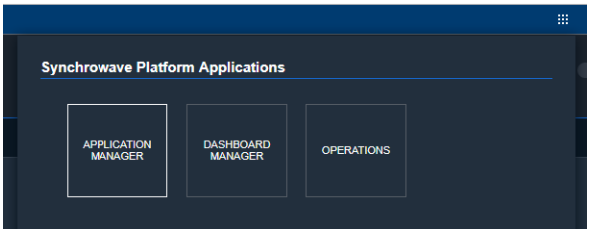



**Figure 2.7 Application Manager in Platform Navigation Menu**

# Adding Applications

Applications and application packages are added to the Synchrowave Platform by using the **Add Application** button in the top left corner of the Application Manager.

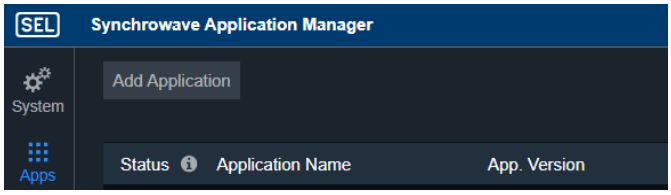
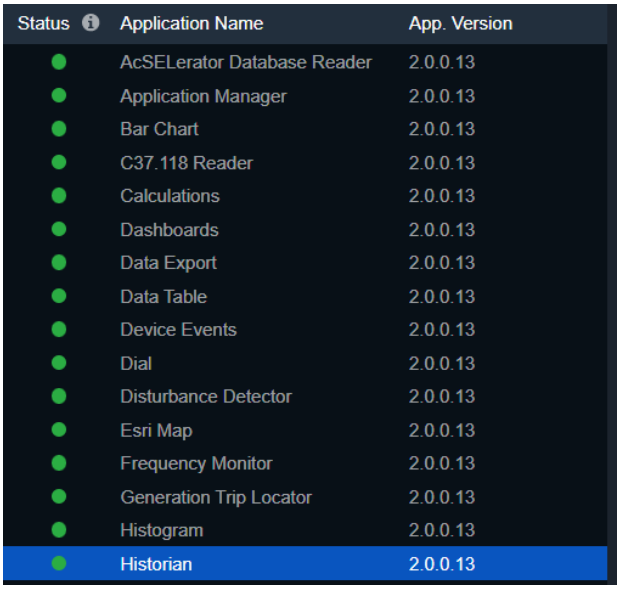



**Figure 2.8 Add Application**

Select **Add Application** to launch Windows Explorer. Use Windows Explorer to navigate to the zipped Application or Application Package folder. Applications will appear in the Application menu as they are loaded onto the platform.

# Application Menu

The Application menu lists the applications installed on the platform. It also provides application status and version information.



| Status | Application Name | App. Version |
|---|---|---|
| ● | AcSELerator Database Reader | 2.0.0.13 |
| ● | Application Manager | 2.0.0.13 |
| ● | Bar Chart | 2.0.0.13 |
| ● | C37.118 Reader | 2.0.0.13 |
| ● | Calculations | 2.0.0.13 |
| ● | Dashboards | 2.0.0.13 |
| ● | Data Export | 2.0.0.13 |
| ● | Data Table | 2.0.0.13 |
| ● | Device Events | 2.0.0.13 |
| ● | Dial | 2.0.0.13 |
| ● | Disturbance Detector | 2.0.0.13 |
| ● | Esri Map | 2.0.0.13 |
| ● | Frequency Monitor | 2.0.0.13 |
| ● | Generation Trip Locator | 2.0.0.13 |
| ● | Histogram | 2.0.0.13 |
| ● | Historian | 2.0.0.13 |

**Figure 2.9 Application Menu**

Access the status definitions shown in *Figure 2.10* by hovering over the Status Information Icon. Additional information regarding the reason for the status may be found in the Application Diagnostic logs.

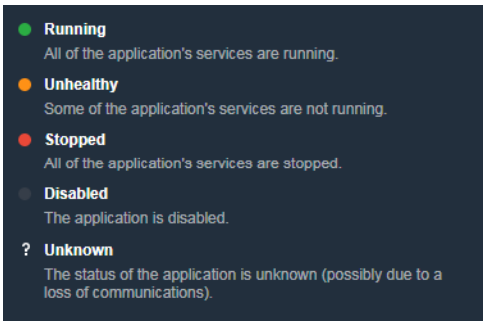



**Figure 2.10 Application Status**

Selecting an application in the Application menu also gives users the ability to restart, remove, or disable an application.

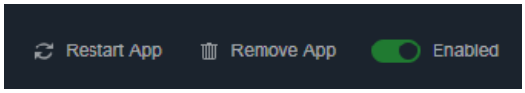



**Figure 2.11 Application Management**

# Application Configuration

Application Configuration is accessed for each application by selecting the desired application from the Application Menu. Configuration consists of a Configuration section where settings are entered directly into the user interface and a Configuration Files section where settings are imported and exported via .csv and .json files. Applications can have either or both of these configuration sections.

The standard procedure for using configuration files is to export, edit, and then import the file. Files can be exported by selecting the file name, which causes the browser to download it.

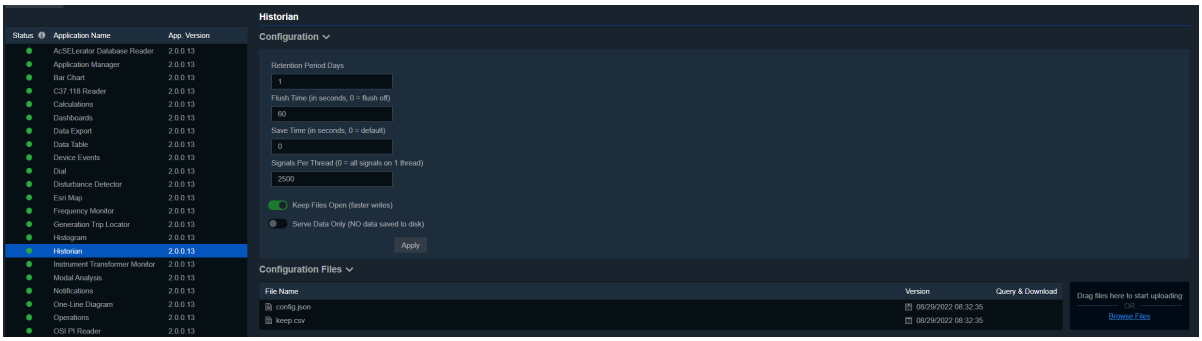



**Figure 2.12 Application Configuration**

Once edited, the file can be imported by either dragging and dropping the file anywhere on the Application Manager screen or selecting the **Browse Files** button. In either case, the file name will be validated and a dialog window appears that allows the user to discard or apply the files. Multiple files (including from multiple applications) can be imported at the same time. Only files with the correct Application Name and file name can be imported. Files with correct names are most easily created by first exporting the file.

Users can optionally associate a comment with a configuration change from the Import dialog box. The comment stored for a specific file is a combination of the Configuration Comment from the upper left combined with the app-specific comment (they are both included, separated by a space).

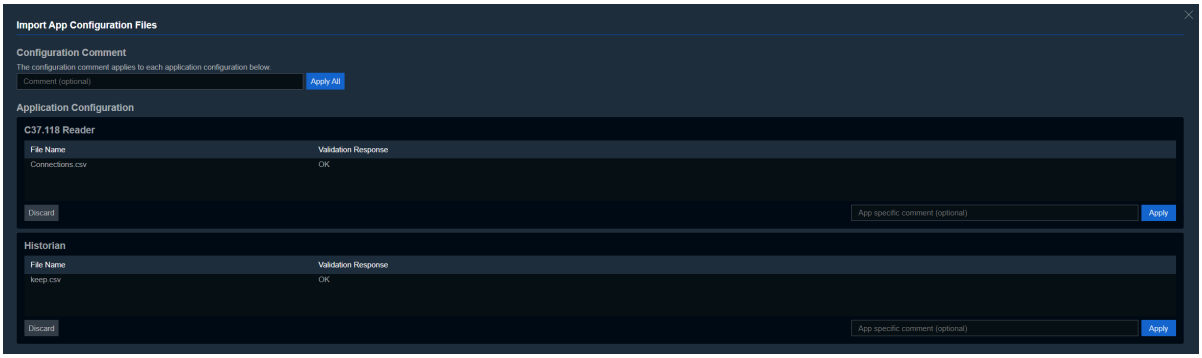



**Figure 2.13 Application Configuration Import Dialog Box**

Users are *not* required to edit .json configuration files. They are made available for advanced users or for copying a configuration from one system to another.

A history of each configuration change is stored in the shared file system. The history displays the version date/time, the name of the user that made the change, and the comment associated with the version. Users can download and restore an application configuration to a previous version by selecting the row associated with the desired application and selecting the **Download** or **Load** button.

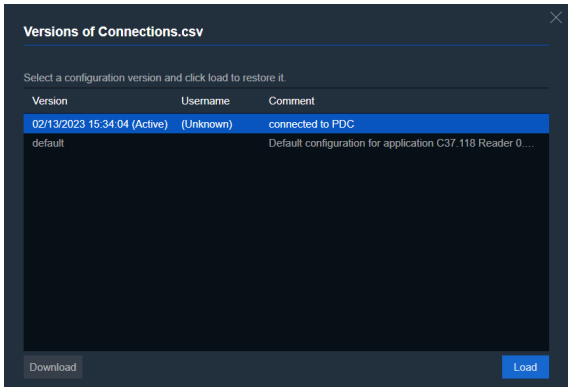



**Figure 2.14 Application Configuration History**

Some applications have the ability to auto-populate some of the information in configuration files. To export an auto-populated file, select the icon in the **Query & Download** column of the Configuration Files section, as shown in *Figure 2.15*.

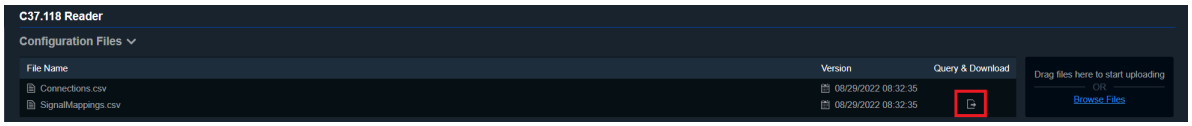



**Figure 2.15 Configuration Query and Download**

Users can alternatively import and export configuration files in bulk as .zip files by selecting the **System** tab in the upper left of the Manager and using the Import/Export Configuration buttons at the bottom of the screen. Selecting **Export Configuration** displays a dialog box allowing the user to customize which application configurations to be exported.

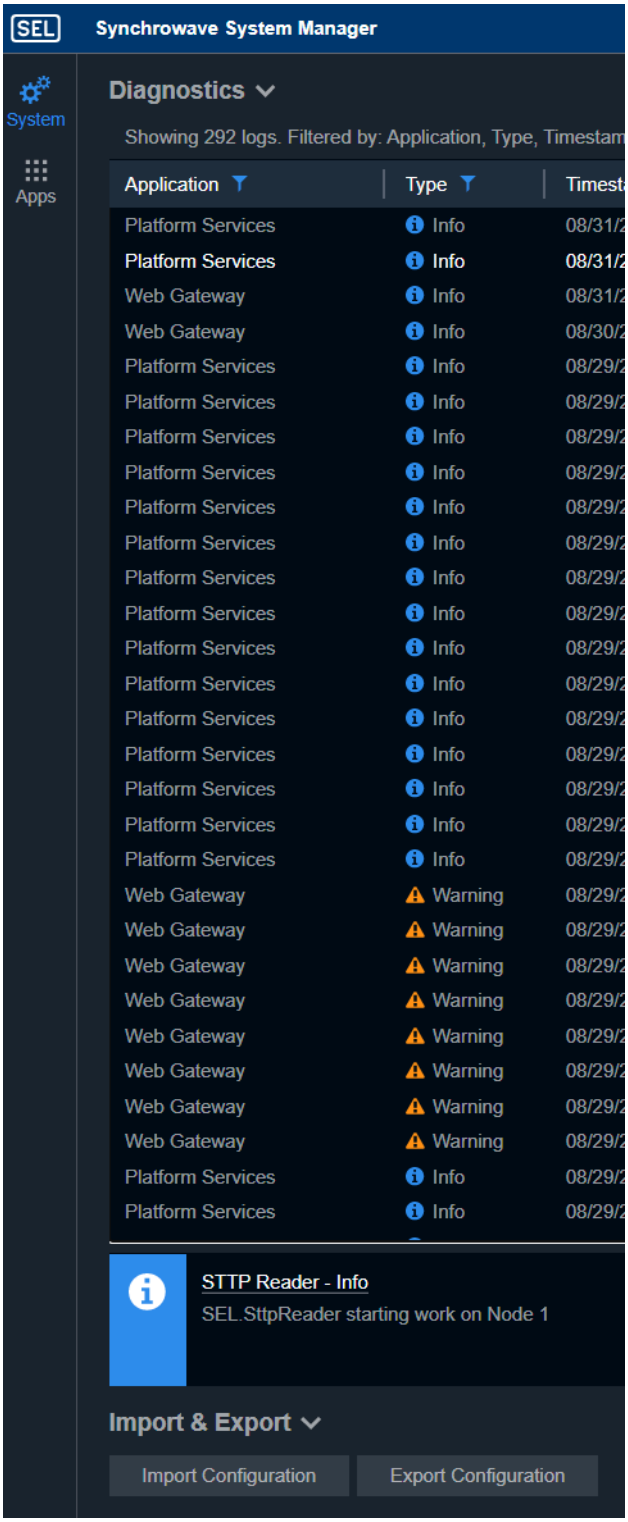



**Figure 2.16 Alternate Configuration Import and Export**

# Application Diagnostics

Diagnostic information for each application is displayed in the Diagnostics section of the Application Manager (beneath the Configuration sections). Diagnostic information helps system administrators understand an application's status and determine any corrective action that may be necessary. Selecting a log row shows the full message at the bottom of the screen.

While investigating an application error, it may also be helpful to see diagnostic log messages across all applications installed on the platform. Logs for all applications can be viewed by selecting the System button in the upper left of the Manager.

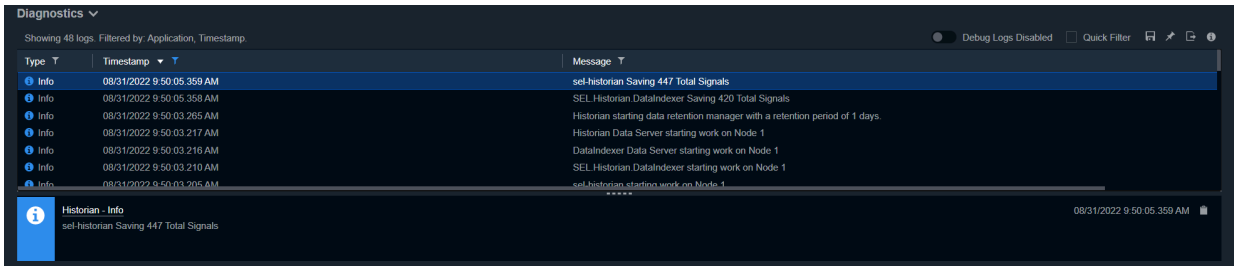



**Figure 2.17 Diagnostic Logs**

Each column in the Diagnostic Logs can be sorted in ascending or descending order by selecting the column name. Additionally, each column can be filtered by selecting the funnel icon next to the column name. The current log view can be frozen by selecting the pin icon. Unneeded logs can be quickly filtered out either by selecting the Quick Filter check box and then highlighting text in the log or by holding **<Ctrl>** and highlighting the text.

By default, the Timestamp column is filtered to only include logs from the previous seven days. To show logs for all time, select the funnel icon in the Timestamp column and select the **X** to clear the filter start date.

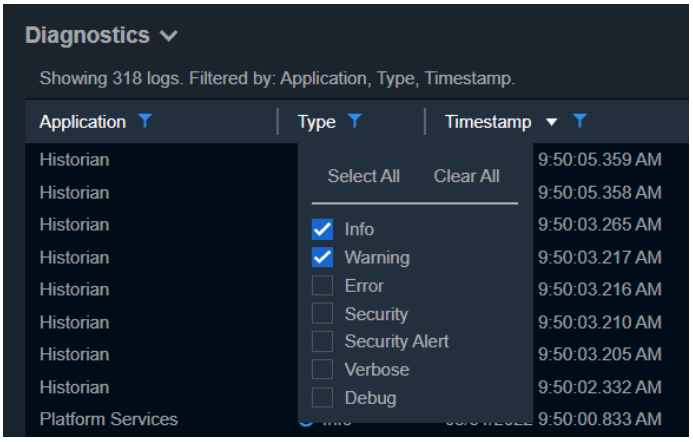



**Figure 2.18 Filtering Diagnostic Log Columns**

For advanced diagnostic log analysis, you can export the logs for an individual application or for all applications by selecting **Export Logs** in the Diagnostic Settings menu. More detailed logs can also be collected by toggling the Debug Logs Disabled button (toggling restarts the application). A significant number of logs are generated when debug logs are enabled, which may consume system resources such as disk space and CPU. Therefore, debug logs should be disabled once the problem has been solved.

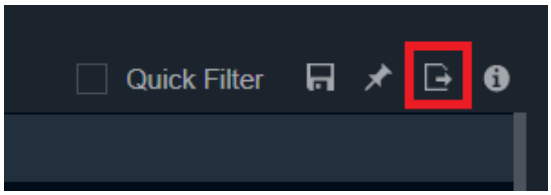



**Figure 2.19 Export Diagnostic Logs to CSV File**

# Platform Applications

The following applications are included with the platform. It is not possible for a user to add or remove these applications. They are visible because of the unique software architecture, treating all functionality as applications. The following section describes the features and configuration of platform applications.

## Platform Services Application

The Platform Services application handles interaction with the operating system and containerization environment.

The Platform Services configuration is accessible from the Application Manager by selecting Platform Services in the application list, and then selecting the Configuration tab, as shown in *Figure 2.20*.

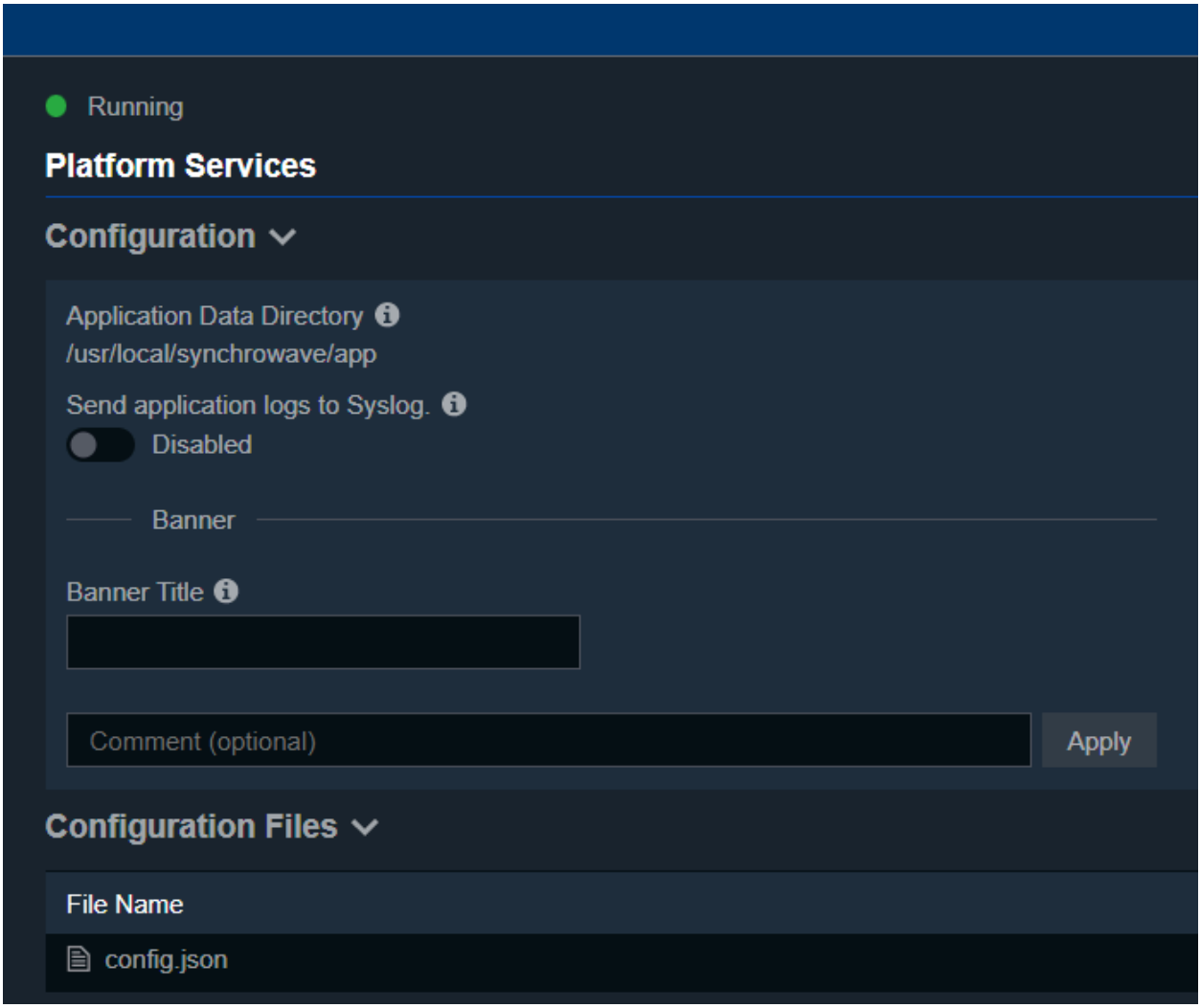



**Figure 2.20 Platform Services Configuration**

The Application Data Directory is the folder where Synchrowave stores all application data (such as dashboards and historian data). Synchrowave creates a subfolder for each application under the Application Data Directory.

This Application Data Directory is set using the Synchrowave CLI. See *View and Set the Application Data Directory on page 210* for details.

A Banner Title can also be configured. It appears at the top center of any Synchrowave Operations page. Once the desired banner is entered, select **Apply**. An optional text box next to the Apply button allows you to enter comments describing the changes. Once **Apply** has been selected, the comment will be stored in the configuration history of the config.json file.

Synchrowave logs can optionally be also routed to syslog. This allows system administrators to use external tools to monitor the logs. To enable this feature, select the setting **Send application logs to Syslog**.

# Web Gateway Application

The Synchrowave Platform uses a server/web-client software architecture. All users interact with the software through a web-client user interface. The Web Gateway application ensures secure access to applications and data on the Synchrowave Platform.

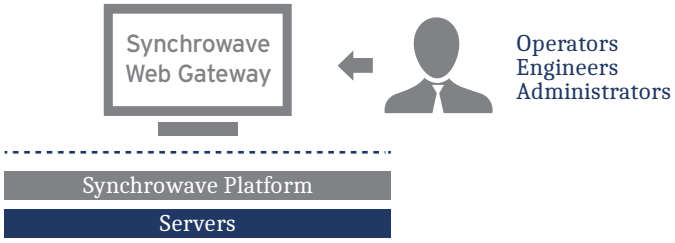



**Figure 2.21 Web Gateway Overview**

## Configuration of HTTPS

The Synchrowave Platform requires HTTPS communication between the web browser and the Synchrowave Platform. HTTPS is a secure version of HTTP employing transport layer security (TLS) and certificates to encrypt the communication.

The Synchrowave Platform includes a self-signed HTTPS certificate automatically created at installation. As a result, when accessing Synchrowave Monitoring or the Application Manager for the first time, the user will receive a message stating the connection is not private because the certificate signing authority is not trusted by the computer operating system. Select **Advanced Options** and then **Proceed to IP Address** to configure the web gateway in the Application Manager.

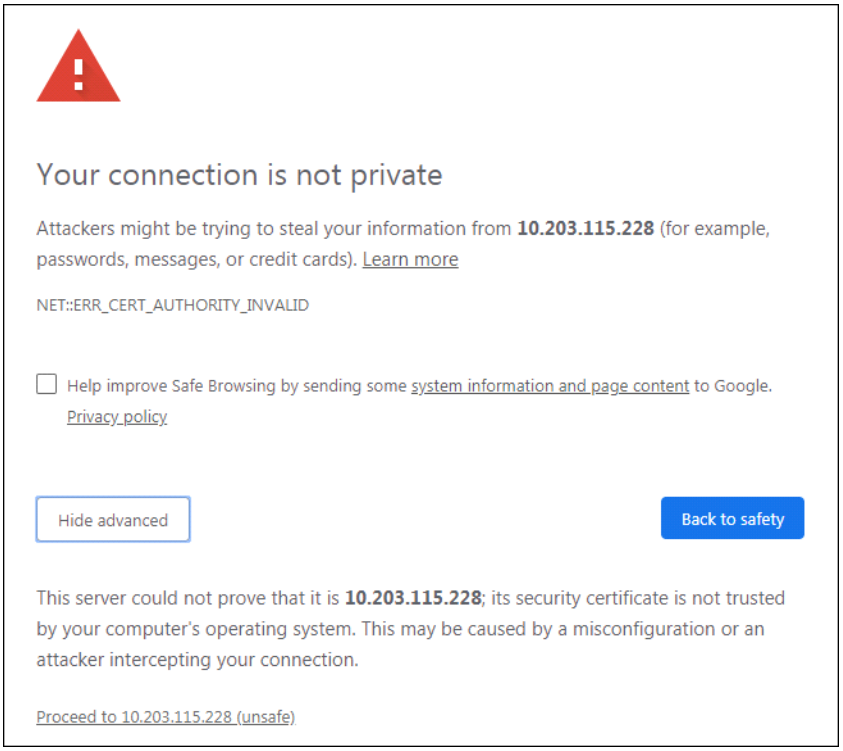



**Figure 2.22 Web Browser Not Secure Warning**

The configuration for the Web Gateway application provides two methods for uploading a signed HTTPS certificate, as shown in *Figure 2.23*. First, the **Select Certificate** button allows for loading a password-protected HTTPS personal information exchange (PFX) format certificate. The PFX certificate can usually be generated by personnel in your IT/IS organization.

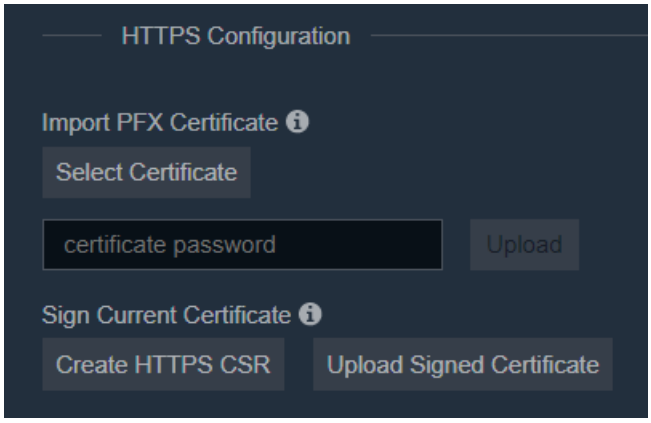



**Figure 2.23 HTTPS Configuration**

Alternatively, the **Create HTTPS CSR** button opens a dialog (as shown in *Figure 2.24*) that allows you to provide information for creating a Certificate Signing Request (CSR) for the certificate that Synchrowave created on initial install. Only the Common Name field is required to be filled. Contact your IT department for organization-specific requirements. Once the CSR is obtained, a Certificate Authority can sign it. Select **Upload Signed Certificate** to load the signed certificate.

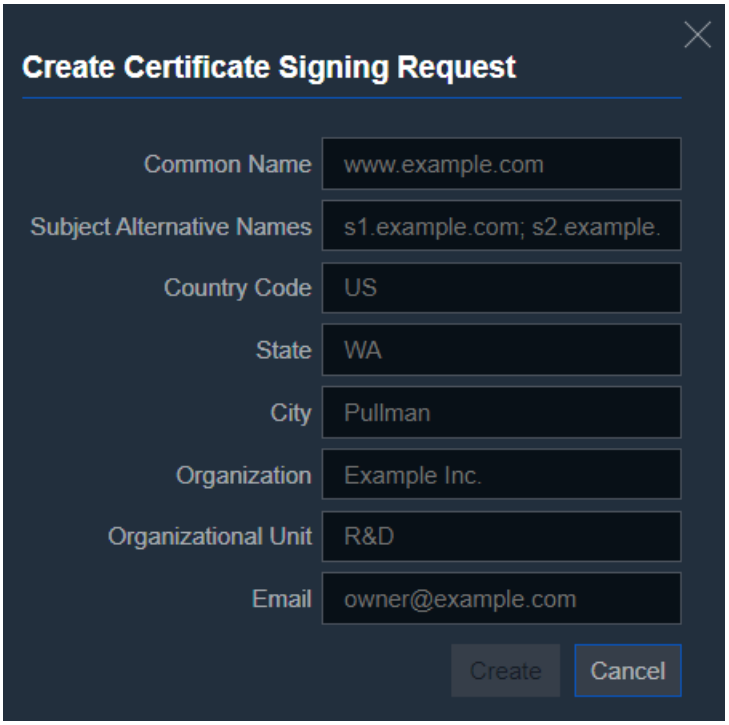



**Figure 2.24 CSR Dialog**

Upon loading a valid HTTPS certificate from your organization, the web browser shows a secure indication in the web address bar.

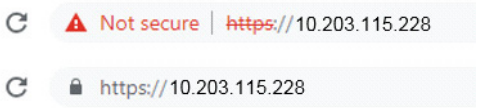



**Figure 2.25 Web-Client HTTPS Status Indication**

# Configuration of Authentication

## Connecting to an LDAP Server

The Synchrowave Platform supports Lightweight Directory Access Protocol (LDAP) user authentication to ensure only authenticated users have access to applications and data on the Synchrowave Platform.

By default, authentication on the Synchrowave Platform is disabled. System administrators configure authentication by accessing the Web Gateway application Configuration in the Application Manager. Work with IT/IS personnel from your organization to enter the required information regarding the LDAP server of your organization. Before Synchrowave will allow a TLS connection to the LDAP server, an LDAP certificate must be uploaded using the **Upload LDAP Certificate** button. Supported file formats are .cer, .der, and .crt. On a Windows server, the certificate must be configured using Windows' certificate management tools and this step is unnecessary. IT/IS personnel will likely already have this done before Synchrowave is installed.

**NOTE**
To launch a page with detailed help, select the information tooltip at the top of the Authentication Configuration section.

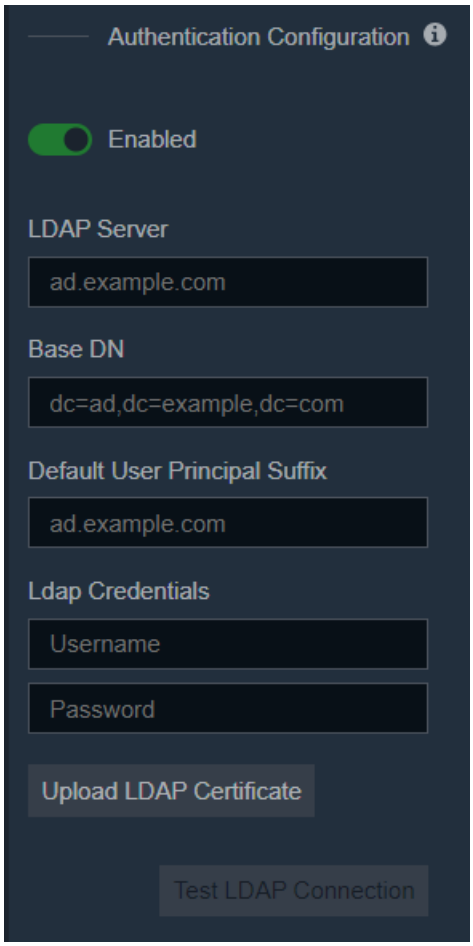



**Figure 2.26 LDAP Server Connection Setup**

Once any desired changes are made to the authentication configuration, select **Apply**. An optional text box next to the Apply button allows you to enter a comment describing the changes. Once **Apply** has been selected, the comment will be stored in the configuration history of the config.json file.

## Adding/Removing Users

Upon establishing a successful connection to an LDAP server, users and user groups can be added to the allowed users/groups list. A user or user group can be assigned to the following roles:

- **System Admin.** Access to all Synchrowave Platform applications.
- **Operator.** Access to Synchrowave Operations/Monitoring.
- **Operations Support.** All the access of the Operator role, plus access to Dashboard Manager. Not allowed to acknowledge alarms.
- **Operations Admin.** All the access of the Operations Support role, plus access to Calculations and permission to acknowledge alarms.

- **Engineer.** All the access of the Operator role, plus access to Calculations and without permission to acknowledge alarms.
- **View Only.** Access to Synchrowave Operations/Monitoring, but without permission to make any changes seen by other users. Cannot export data.

**NOTE**
If a user is added to a group on the LDAP server, it may take as long as 10 minutes before the user can login. The Web Gateway application checks LDAP user groups for changes every 10 minutes and upon restart.

If a user group is added, the selected role is applied to all users in the group.

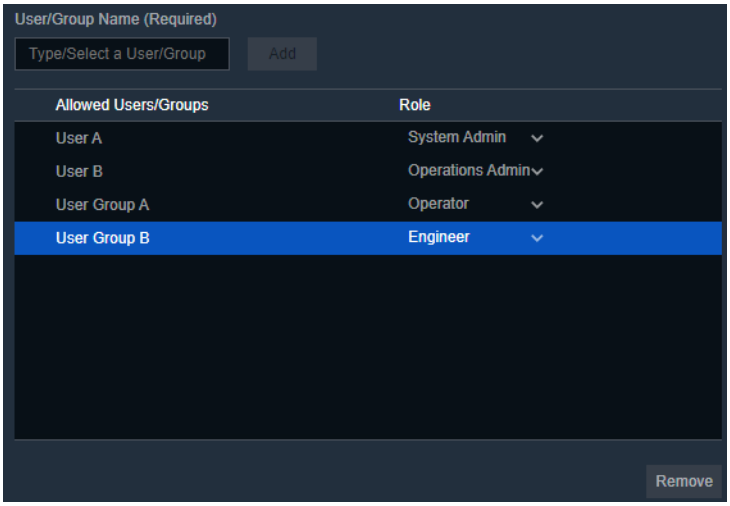



**Figure 2.27 Adding/Removing Users and User Groups**

If the web gateway is configured incorrectly or is unable to start, all users are locked out of the platform.

### For a Synchrowave Platform Installed on a Windows Server:

The "sel-webgateway" section of the C:/ProgramData/SEL/Synchrowave/platform.settings or the Web Gateway configuration file at C:\ProgramData\SEL\Synchrowave\config\sel-webgateway\config can be edited in a text editor to manually adjust the Web Gateway configuration. Alternatively, these files may be backed-up and deleted to reset the configuration. Following changes to either of these configuration files, restart the SEL Synchrowave application in Services tab in Windows Task Manager.

### For a Synchrowave Platform Installed on a Linux Server:

In this case, an administrator logs in to the server and uses the Synchrowave command line interface (CLI) tool to restore access.

## Logging Into Synchrowave Platform

When authentication is enabled, the Synchrowave Platform login screen requires a user to enter their username and password before being allowed access to Synchrowave applications. Some web browsers will store login credentials and therefore bypass this login page automatically.

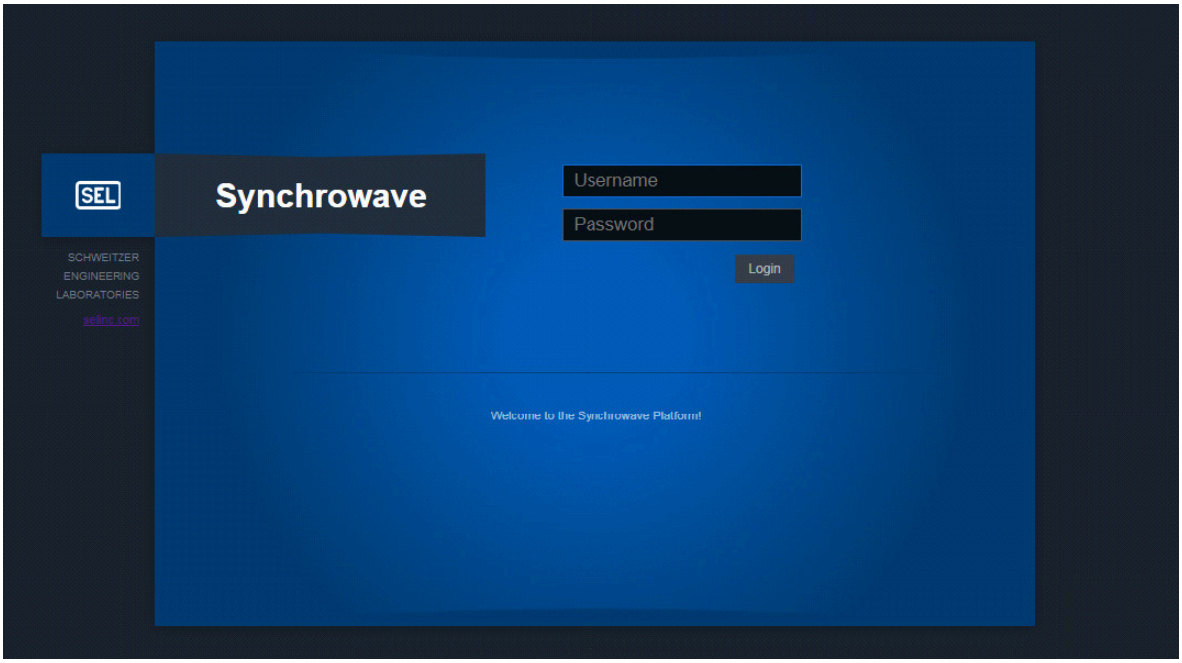



**Figure 2.28 Synchrowave Platform Login Page**

The default login page message is configurable in the Web Gateway application configuration. By default, the login message states "Welcome to the Synchrowave Platform!"

## Login Message and Remember Me Duration

Remember Me allows users to quickly return to the Synchrowave Platform for a set duration after closing the browser window without having to re-enter their login credentials. Users can opt into this feature by checking the **Remember Me** box on the login screen while Remember Me is enabled in the Application Manager. To enable Remember Me, select the toggle switch and enter a duration greater than one hour. Select **Apply** to save the changes. Note that users will not automatically be signed back in if they manually log out of the platform.

The Login Message is displayed for all users on the login page when authentication is enabled.

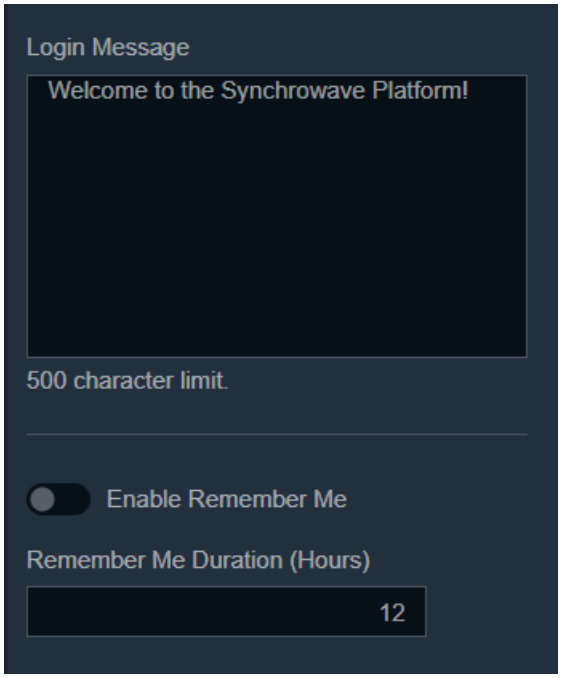



**Figure 2.29 Login Message and Enable Remember Me**

## Default Login Application Page

By default, upon entering the IP address or server name of the Synchrowave Platform into a web browser, the Application Manager (https://*ipaddress*/sel.applicationmanager) page is displayed. This is because during configuration and initial setup, it is helpful to have quick access to the Application Manager. As the software transitions to the deployment stag e, it is possible to change the default application to Synchrowave Monitoring (https://*ipaddress*/sel.monitoring). The default login page is set from the Configuration tab for the Web Gateway.

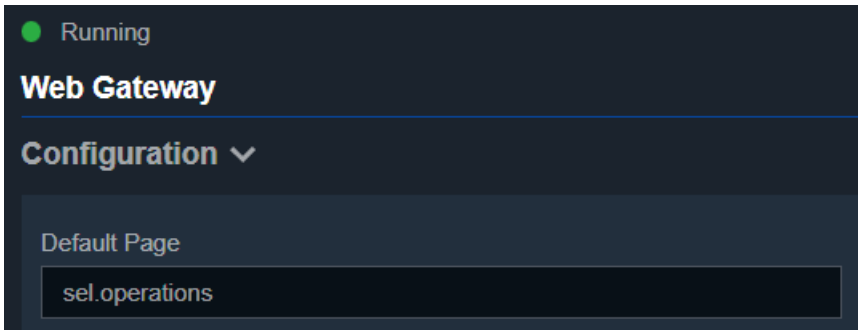



**Figure 2.30 Configuration of Default Application Page**

# SEL Signals Application

## SEL Signals Features

The SEL Signals application collects, consolidates, and publishes signals to applications on the Synchrowave Platform via the signal bus.

Signals in the Synchrowave Platform are composed of two parts:

- **Measurement Point.** Represents the physical location at which the signal was measured.
- **Data Type (or Quantity).** Represents the type of signal measured.

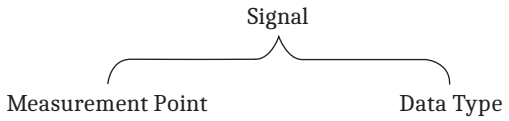



**Figure 2.31 Signal Definition**

Signals are published to the signal bus, through well-defined interfaces, by data reader applications and applications that generate signals. Power system applications and panel applications then request signal data through interfaces for analytics and monitoring.

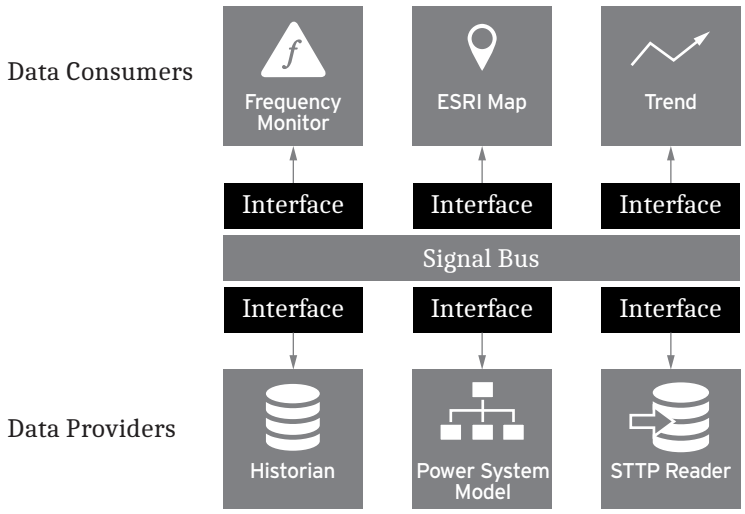



**Figure 2.32 Signal Bus Overview**

## Standard Quantities

Certain interdependencies in the software require using a set of standard quantity names for common power system signals. Recommended quantities are shown in the following table where the phase modifier can take on the values P=[A, B, C, 0, 1, 2]. Values of 0, 1, and 2 correspond to zero-, positive-, and negative-sequence components, respectively, and do not apply to power signals.

**Table 2.1 Synchrowave Standard Quantities**

| Description | Units | Quantity Name |
|---|---|---|
| Frequency | Hz | Frequency |
| Rate of change of frequency | Hz/s | Frequency.DxDt |
| Line-neutral complex voltage phasor | V | Phase[P].Voltage |
| Line-neutral voltage magnitude | V | Phase[P].Voltage.Magnitude |
| Line-neutral voltage angle | ° | Phase[P].Voltage.Angle |

| Description | Units | Quantity Name |
|---|---|---|
| Line-line voltage magnitude | V | LL.Voltage.Magnitude |
| Rate of change of voltage | V/s | LL.Voltage.DxDt |
| Complex current phasor | A | Phase[P].Current |
| Current magnitude | A | Phase[P].Current.Magnitude |
| Current angle | ° | Phase[P].Current.Angle |
| Phase angle difference (PAD) | ° | PAD |
| Single-phase apparent power | VA | Phase[P].Power.Apparent |
| Single-phase real power | W | Phase[P].Power.Real |
| Single-phase reactive power | Var | Phase[P].Power.Reactive |
| Single-phase power factor | None | Phase[P].Power.Factor |
| Three-phase apparent power | VA | ThreePhase.Power.Apparent |
| Three-phase real power | W | ThreePhase.Power.Real |
| Three-phase reactive power | Var | ThreePhase.Power.Reactive |
| Three-phase power factor | None | ThreePhase.Power.Factor |
| Percentage of samples valid | % | Availability |

# SEL Signals Diagnostics Menu and Configuration

The Signals application provides a list of all signals present in the system for diagnostic purposes. Selecting the Multiple Producers check box filters the list to signals for which multiple applications are attempting to publish. This is an undesirable situation that should be addressed. The list can also be filtered using the Search box. You can enter multiple keywords separated by spaces to include certain signals or precede a string with a minus sign to exclude certain signals.

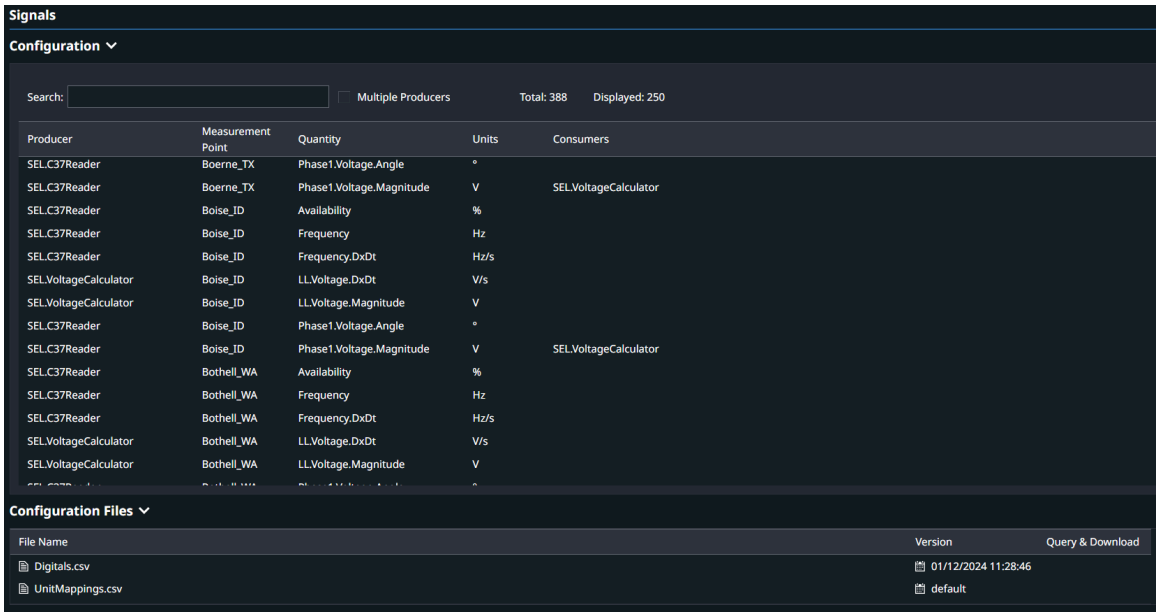



**Figure 2.33 Signals Application**

Units for Data Types beyond the standard types are specified in the UnitMappings.csv configuration file for the Signals application. Select the file name to download the current configuration. Fill out the desired Quantity and associated Unit information.

For example, a generator's temperature and oil pressure are mapped as analogs in a C37.118 stream and mapped to the Temperature and OilPressure quantities, respectively. Units of F for temperature and psi for OilPressure are mapped as shown by adding the units to the CSV file as shown in *Figure 2.34*.

| | A | B |
|---|---|---|
| 1 | Quantity | Unit |
| 2 | Temperature | F |
| 3 | OilPressure | psi |

**Figure 2.34 Unit Mappings Configuration File**

Digital signals are configured in the Digitals.csv file. Any signal quantities that should be treated by Synchrowave as digital should be added to this file. The Digital Chart, Data Table, and Numeric Panel applications have specialized functionality reserved for digital signals. If the state label fields of the Digitals.csv file are filled out, these applications will display the state labels corresponding to the signal values instead of the raw signal values. For the example configuration below, if a signal with a Quantity of Breaker1Status had a value of 0, "Closed" would be displayed instead of 0. If the state label fields are empty, the values of the signals are displayed instead. Up to 16 state labels can be configured.

| | A | B | C | D | E | F | G | |
|---|---|---|---|---|---|---|---|---|
| 1 | Quantity | State0Label | State1Label | State2Label | State3Label | State4Label | State5Label | State |
| 2 | Modes | Manual | Auto | Cascade | Program | Prog_Auto | | |
| 3 | Breaker1Status | Closed | Open | Alarm | | | | |
| 4 | Breaker2Status | Closed | Open | Alarm | | | | |
| 5 | Breaker3Status | Closed | Open | Alarm | | | | |

**Figure 2.35 Digital Signals Configuration File**

# System Manager and Resource Monitor

The System Manager contains system performance and other information provided by the Resource Monitor as well as diagnostic logs for all applications. Selecting a node in the Resources section displays a pane with detailed information about CPU usage, memory, the file system, disk I/O, and network traffic. Hovering over names of metrics brings up details.

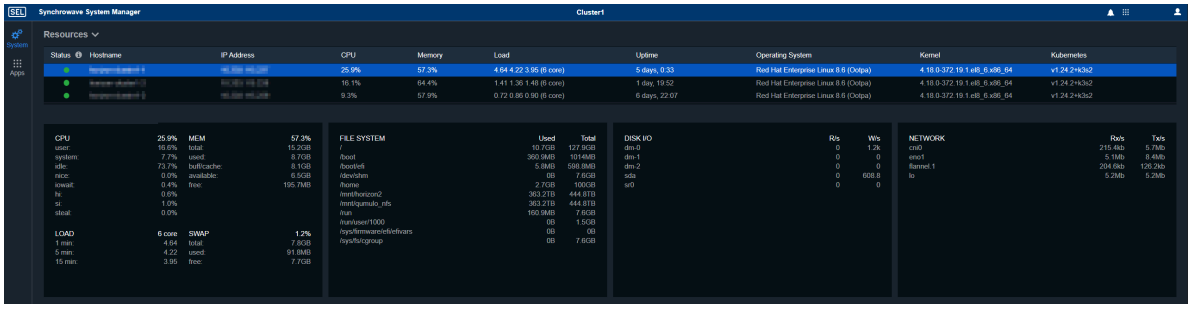



**Figure 2.36 Resource Monitor Information**

The Resource Monitor application monitors metrics such as CPU usage and file system size and automatically notifies users if the monitored metrics exceed configurable thresholds. It compares metrics to thresholds every 10 seconds. When there is an active notification, the bell icon in the upper right pulses. Selecting the bell icon toggles a Notifications pane on the right side of the screen that shows a description of all active notifications.

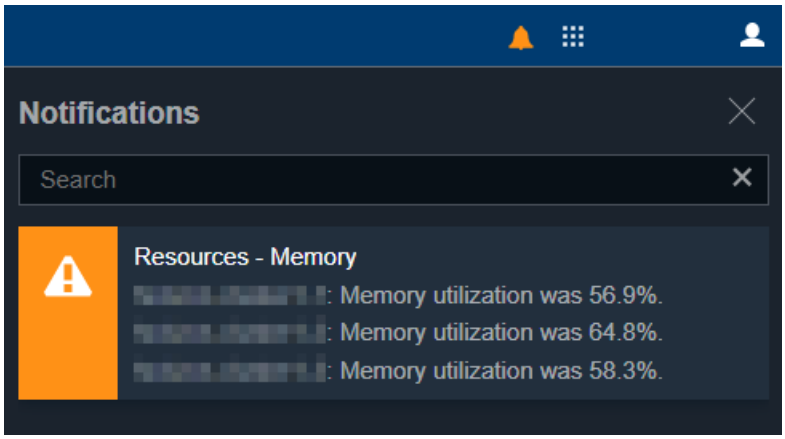



**Figure 2.37 Resource Monitor Notification Pane**

# Resource Monitor Configuration

The Resource Monitor is configured from the Application Manager with two files. The Monitoring.csv file configures the quantities to be monitored (the limits that, if crossed, will trigger a notification) and whether or not each is enabled. The SampleCount column specifies a window length over which the metric will be averaged before being compared to the threshold. Samples are taken every 10 seconds, so, for example, with SampleCount set to 30, the CPU notification would assert if the average usage over 300 seconds exceeded the threshold.

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | ResourceId | Limit | SampleCount | Enabled | Description |
| 2 | CPU | 75 | 30 | TRUE | CPU utilization. Limit is an upper bound percentage. |
| 3 | Memory | 90 | 30 | TRUE | Memory utilization. Limit is an upper bound percentage. |
| 4 | IO Wait | 20 | 6 | TRUE | Time waiting for IO. Limit is an upper bound percentage. |
| 5 | File System Size | 90 | 1 | TRUE | Space used on file system. Limit is an upper bound percentage. |
| 6 | Network Errors | 3 | 30 | TRUE | Network errors. Limit is an upper bound percentage. |

**Figure 2.38 Monitoring.csv Configuration File**

The FilesystemIgnore.txt file allows the user to list file systems to be skipped for the monitoring of the file system size. Each line is a separate entry to be ignored. The entries can be plain strings or regex patterns and should match the file system mount point.

SECTION 3

# Synchrowave Operations

## Introduction

Synchrowave Operations delivers detection, notification, real-time analytics, and visualization of power system conditions to operators for situational awareness, helping operators make the right decision every time. The applications listed in this section provide the base functionality for Synchrowave Operations. It is possible to customize the operations system by adding individual applications available from Schweitzer Engineering Laboratories. The instruction manuals for these additional applications are provided separately.

## Software Workflow

The Synchrowave Operations user interface is designed to provide power system operators situational awareness as they perform the following workflows:

- System Monitoring
- Notification Analysis
- Asset Investigation

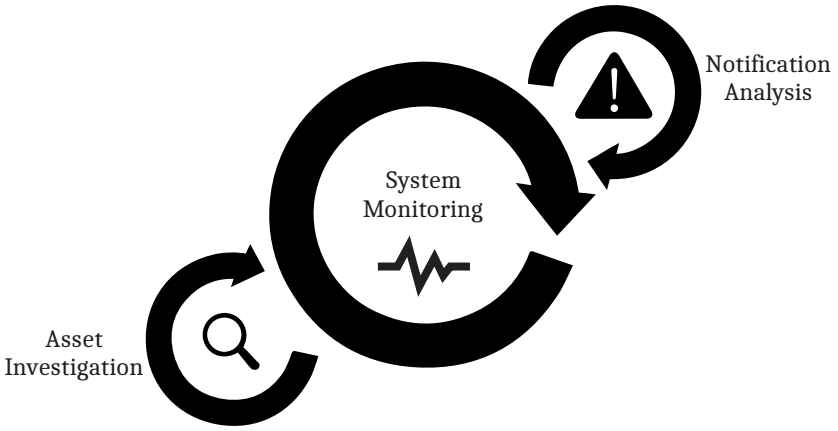



**Figure 3.1 Synchrowave Operations Workflow Overview**

### System Monitoring

The System Monitoring mode provides operators high-level visibility into the state of the power system. This mode supports operators during typical conditions by providing continuous monitoring of potential issues relating to the following:

- Frequency
- Power flow
- Phase angle
- Voltage stability

## Notification Analysis

The Notification Analysis mode provides operators visibility into active and historic power system conditions. During normal system monitoring, a power system condition is detected and presented to the operator in the form of a notification. Selecting the notification icon transitions Synchrowave Operations into Notification Analysis mode where additional information related to the associated condition is presented. After analyzing the condition, the operator returns to System Monitoring mode. Notification Analysis helps operators answer the following questions:

- What happened?
- When did it happen?
- Why did it happen?
- Is the power system currently in a safe and secure state?
- What can be done to return the system to a safe and secure state?

## Asset Investigation

At any time, an operator may select an asset to receive additional information from the software. This transitions Synchrowave Operations into Asset Investigation mode. The user can now assess any power system asset and view the current state of that asset. Asset investigation use cases include the following power system asset examples:

- Transmission lines
- Substation buses
- Generators
- Transformers
- Feeders

# Summary of Software User Interface Applications

Synchrowave Operations provides users the following three key user interface applications for situational awareness:

- Notifications Application
- Timeline Application
- Dashboards Application

## Notification Application Overview

The notification summary always displays the real-time state of the power system. It notifies operators when Synchrowave Operations identifies a new condition on the power system. The notification summary is always displayed, regardless of the currently open dashboard, so that a new notification is never missed. The notification summary is in the top right corner of the software display to place it near the most recent measurements.

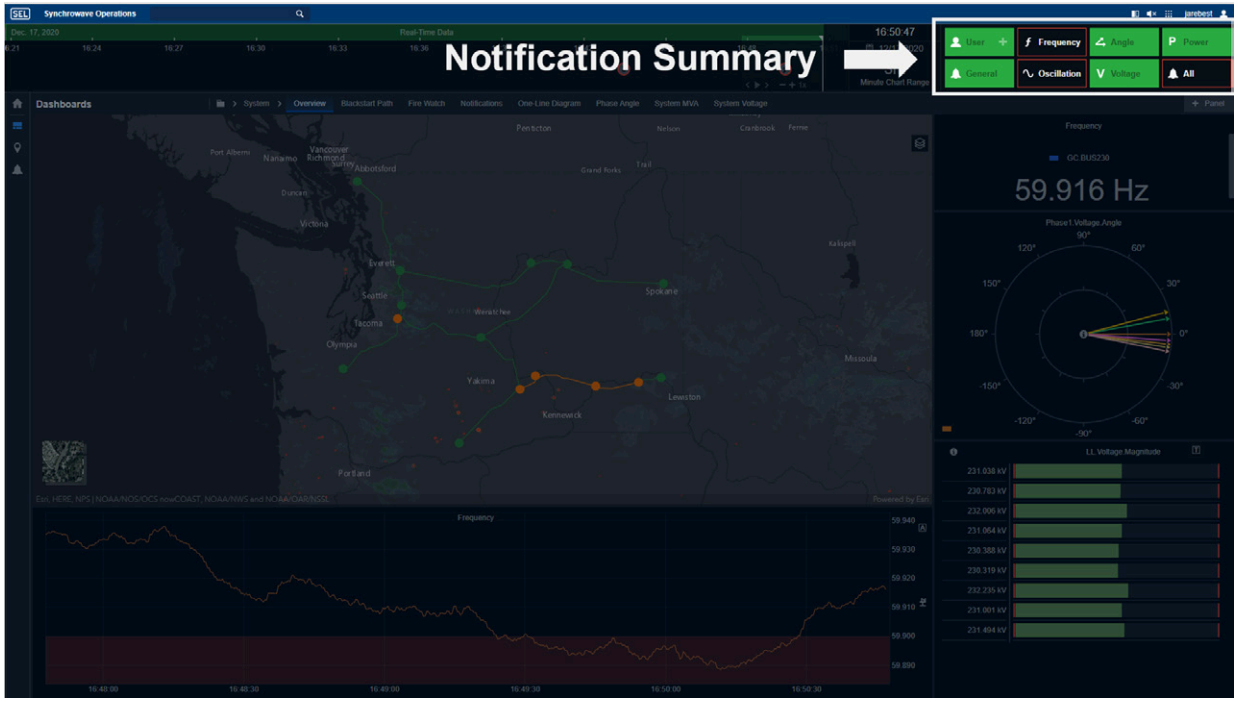



**Figure 3.2 Software User Interface—Notification Summary**

## Timeline Application Overview

The timeline provides both visualization and control of historic event information presentation. Notification icons are displayed on the timeline to indicate when notifications are generated. Selecting a date/time on the timeline synchronizes all dashboards and panels to that time. Operators can transition between real-time and historic data via the timeline. The timeline also allows choosing the range of data displayed in synchronized display panels.

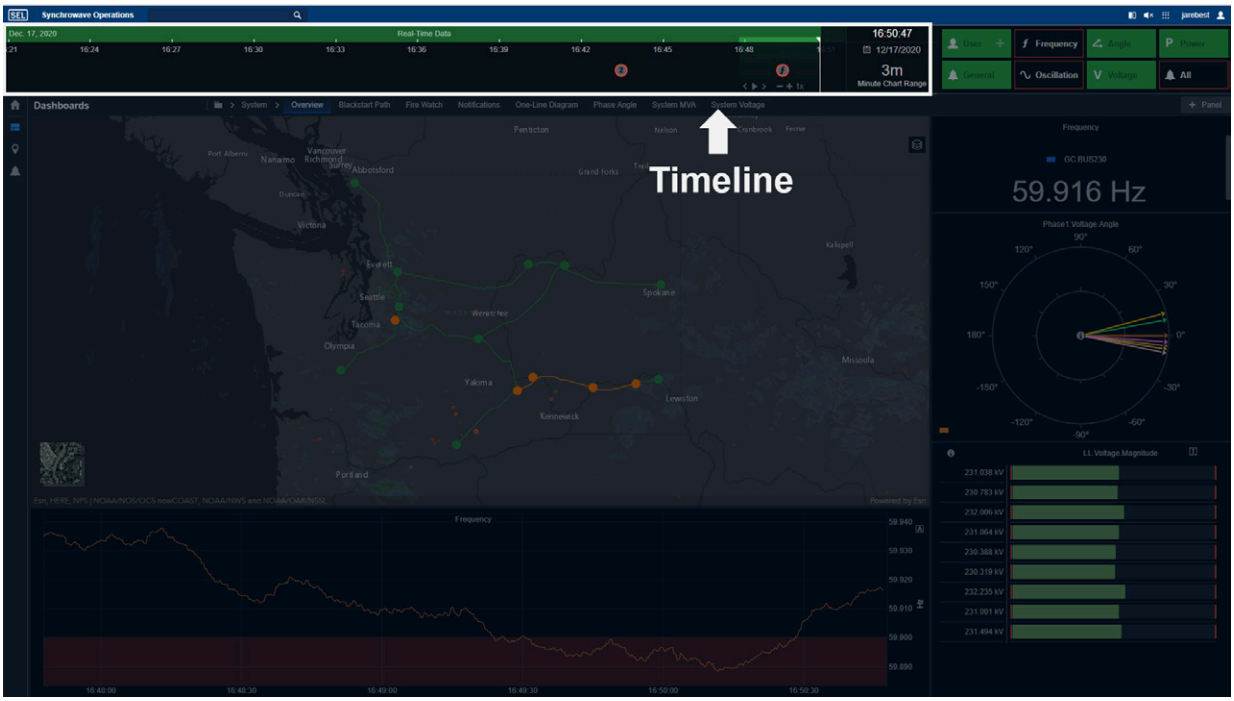



**Figure 3.3 Software User Interface—Timeline Application**

## Dashboard Application Overview

Dashboards provide the primary visualization of power system data and information in Synchrowave Operations. Dashboards are composed of a collection of panel applications. Dashboards are dynamic and customizable, ensuring convenient and quick access to the actionable information needed for efficient analysis of the power system. There are three primary use cases for dashboards:

- System Monitoring
- Asset Investigation
- Notification Analysis

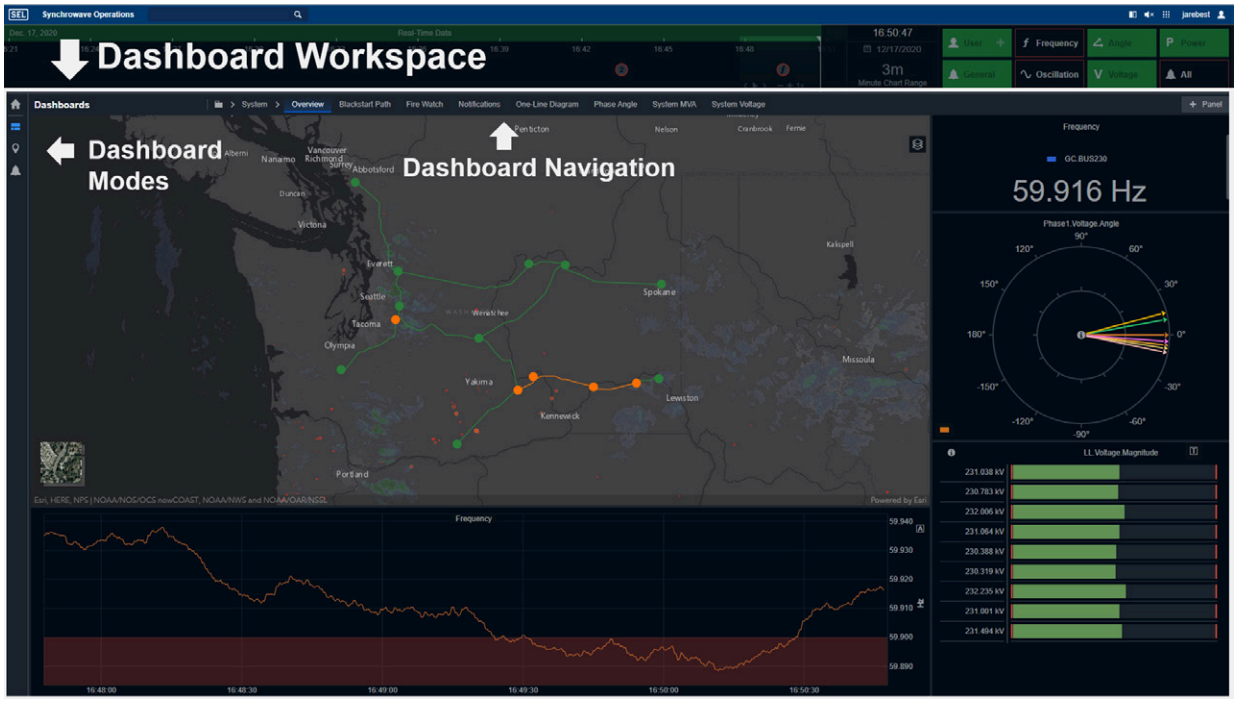



**Figure 3.4 Software User Interface—Dashboards and Dashboard Navigation**

# Notification Application

Notifications provide visibility into active and historic power system conditions. During normal system monitoring, a power system condition is detected and presented in the form of a notification. After analysis of the notification, the operator returns to System Monitoring mode. Notification Analysis helps operators answer the following questions:

- What happened?
- When did it happen?
- Why did it happen?
- What needs to happen next to return the system to a secure state?

## Notification Creation and Content

As systems and deployments grow, constant monitoring of high-resolution streaming data from hundreds of locations becomes impractical. Intelligent monitoring applications ease that burden by mining the high-resolution streaming data for power system conditions. The algorithms employed by these monitors can be as simple as a threshold limit or as complex as a contingency analysis engine. The Notification application receives condition updates from monitors and provides operators with an indication of the detected power system conditions.

### NOTE

If the node that the Notification application is running on fails, new notifications will be created for conditions present on the system at the time of the failure after the Notification application restarts on a new node in the cluster.

See *Power System Applications on page 69* for details regarding the applications that generate notifications.

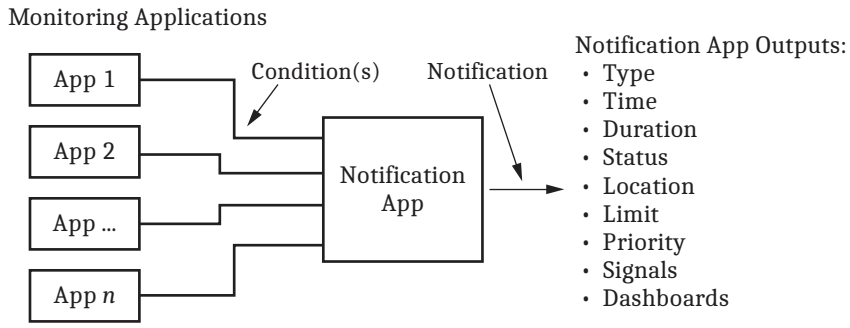



**Figure 3.5 Notification Architecture**

# Notification Summary

New notifications are displayed by notification type to the operator via the Notification Summary. The Notification Summary is always displayed in the top right corner of Synchrowave Operations regardless of the dashboard being viewed. Access active and historic notifications for the selected type of notification by selecting a Notification Type tile in the Notification Summary.

**Figure 3.6 Notification Summary Display Location**

There are six default notification types:

- Frequency
- Angle
- Voltage
- Power
- User-Created
- All

The **All** Notification Type displays all active notifications, including notifications that do not fall under one of the default Notification Types.

Each Notification Type in the Notification Summary provides an indication of the most severe notification state for the displayed notification type. When there are no active or self-corrected notifications for a notification type, the notification type tile is shown in green, indicating that the system is healthy for the given type of power system conditions. The notification tile background indicates the active state and the outline indicates any unacknowledged states. For example, if both an active frequency warning and a no longer active frequency alert are present, the Frequency Notification tile is an orange background for the warning with a red border for the unacknowledged, but no longer active, alert. See *Notification States on page 44* for additional details on notification states.

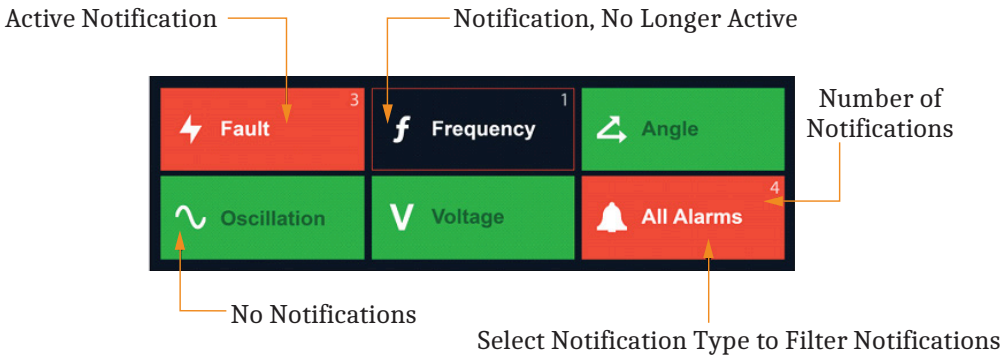



**Figure 3.7 Notification Summary Details**

If a Power System Monitor application is disconnected, disabled, or receives invalid data, the Notification Summary displays the disconnected state to the user.

**Figure 3.8 Disconnected Power System Monitor Indication**

# User-Created Notifications

For power system conditions that are not detected by power system applications, operators and engineers can generate user-created notifications.

## Creating a User Notification

To create a user notification, set the time-marker to the time of the power system condition, and select the + button on the User tile in the Notification Summary.

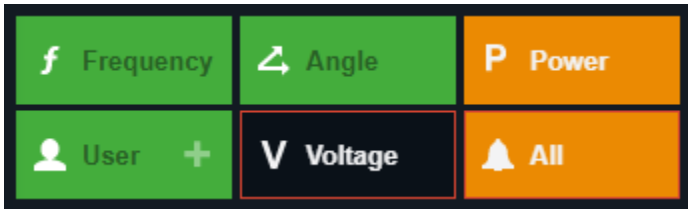



**Figure 3.9 Creating a User Notification**

In the Edit Notification menu, enter a name for the power system condition. The Duration is automatically populated with the chart range.

Add a measurement point(s) to include the location information for the condition. The measurement point listed at the top of the selected measurement point list is used as the primary location of the condition.

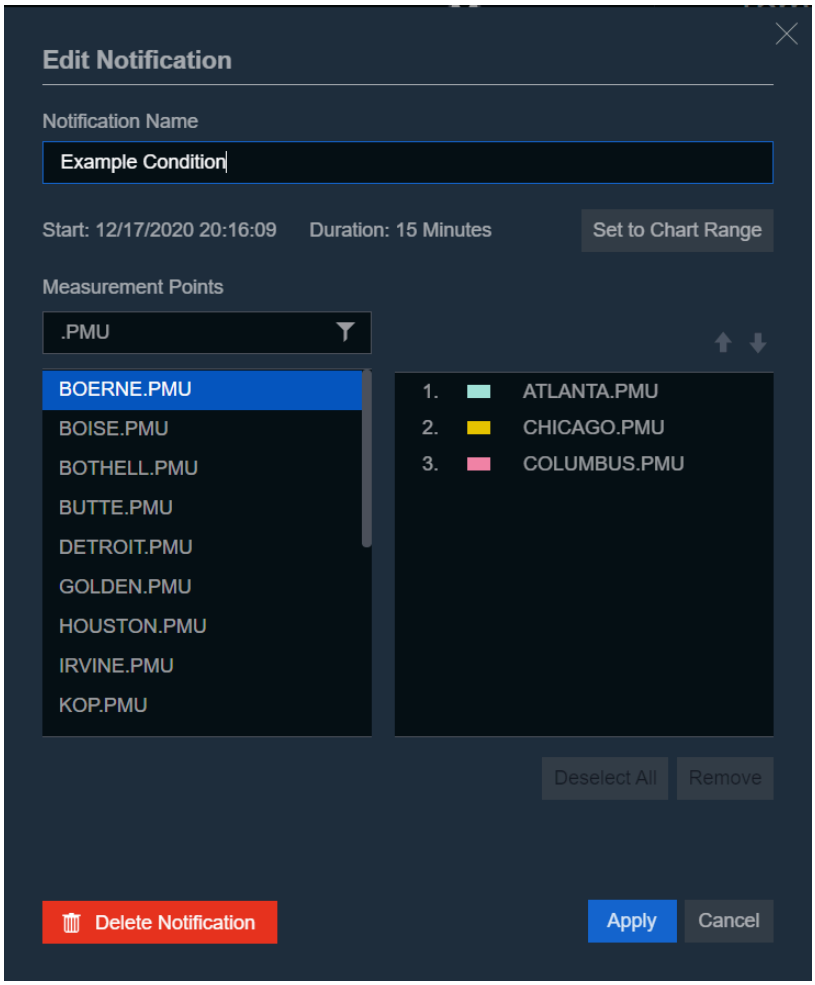



**Figure 3.10 Edit User Notification**

## Viewing User Notifications

Selecting the User tile, in the Notification Summary, opens Notification Mode with a list of previously created user notifications. User notifications created by other users are also displayed.

# Notification Analysis Mode

Upon selecting a Notification Type tile in the Notification Summary, Synchrowave Operations enters Notification Analysis mode. In Notification Analysis mode, a list of notifications appear on the left side of the software display in the Notification List.

When a Notification Type tile is selected, the first Notification (i.e., most severe) in the list is selected automatically to provide context to its associated dashboard. Details regarding the content and management of Notifications are explained in *Notification List on page 37*.

**Figure 3.11 Notification Analysis Mode**

# Notification List

## Notification Display

Use the Notification List to manage notifications. The notifications in the list contain information regarding type, location, time, current state, limit, and duration for each notification.

Notifications are displayed in the Notification List Focused tab if any of the following are true:

- Notification is in Active state.
- Notification is in Unacknowledged state.

➤ Notification is in Timeline time range.

➤ Notification is selected.

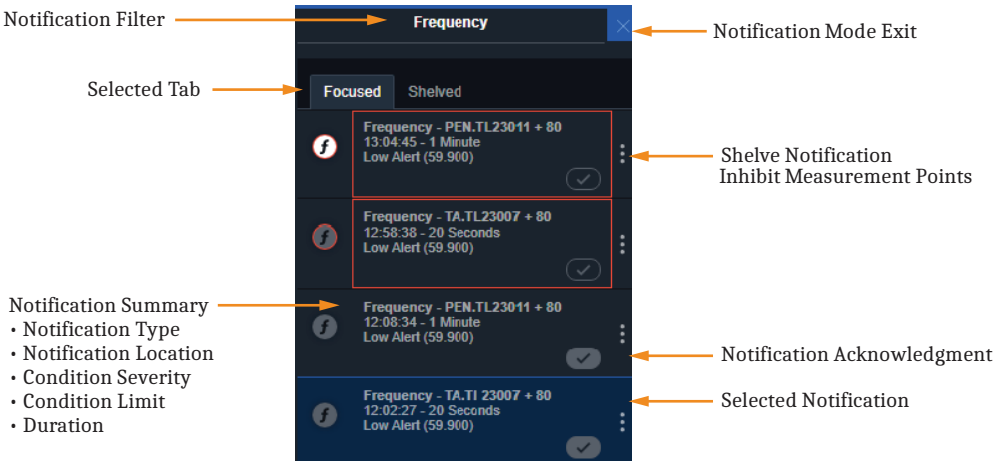



**Figure 3.12 Notification List Details**

## Notification Acknowledgment

Notifications are acknowledged from the Notification List by selecting the Acknowledge Notification toggle check box. When a notification is acknowledged, a log is generated, recording the user and time of the acknowledgment. The notification is acknowledged for all users.

Notifications can be configured to auto-acknowledge after a specified time-out. This feature is configured in the Notification application settings in the Application Manager. Set the TimeoutSeconds to the auto-acknowledge time-out in seconds. Setting Timeout Seconds to –1 disables this feature.

Notifications can also be unacknowledged by selecting the Acknowledge Notification toggle check box again. A pop-up window will appear confirming this operation.

## Shelving Notification

Notifications can be shelved for a given duration. After the configured time elapses, the notification will be moved from the Shelved tab back to the Focused tab. Any shelved notification can be unshelved manually at any time. Optionally, shelved notifications can be figured to automatically unshelve if configurable operating conditions are met.

Select the ⋮ button and then **Shelve** to bring up the Shelving settings menu.

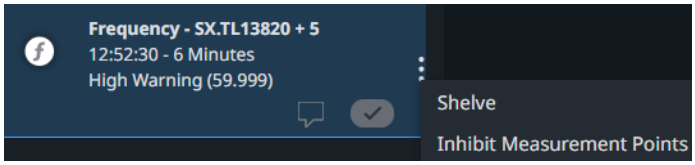



**Figure 3.13 Shelving a Notification**

Manually unshelve a notification by selecting the ⋮ button and selecting **Unshelve**.

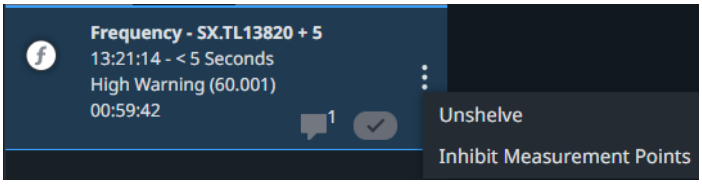



**Figure 3.14 Unshelving a Notification**

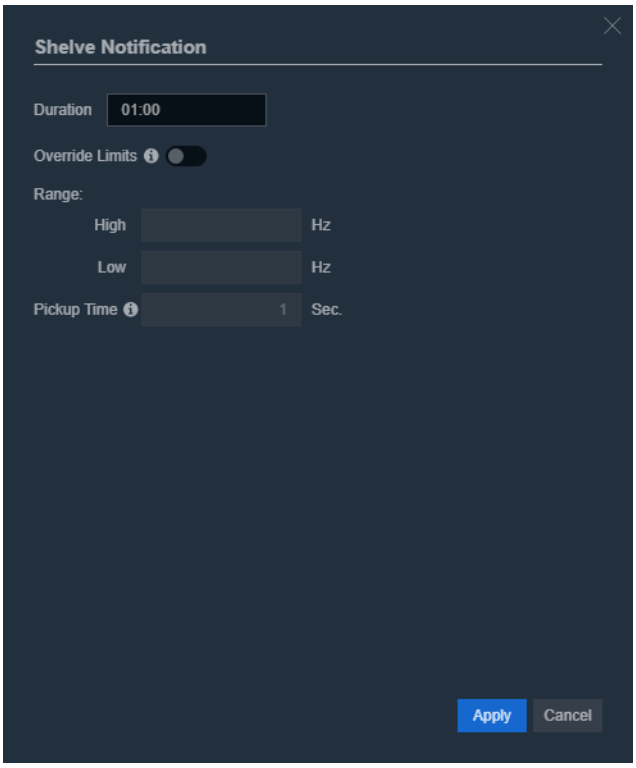



**Figure 3.15 Shelve Notification Settings**

Whenever a notification is shelved or unshelved either by a user or automatically by the system, a comment is created on that notification. The comment shows what user performed the shelve/unshelve operation as well as a description of the change. (If the change was automatic, the user is listed as System.)

## Inhibiting Measurement Points

Manually inhibit one or more measurement points from producing further notifications by selecting the ⋮ button and then selecting **Inhibit Measurement Points** (see *Figure 3.13*). Select the measurement points to inhibit and then select **Ok**. See *Notification Inhibit Table on page 123* for more details.

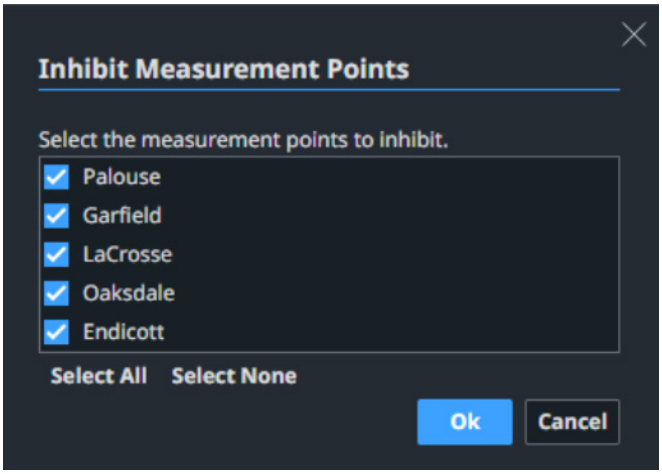



**Figure 3.16 Inhibit Measurement Points Dialog**

# Notification Comments

Notification comments allow users to provide additional information about a specific notification. You can modify comments to be private or shared with others and associated with a specific point in time. This allows users to collaborate and organize their analysis on each notification to better understand what happened, why it happened, and how to mitigate the problem in the future.

## Viewing Comments

In the Notification mode, select the comment icon to open the comment section (see *Figure 3.17*).

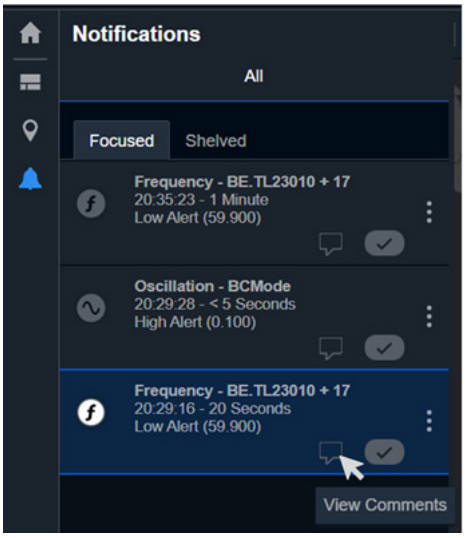



**Figure 3.17 Notification Mode Opening Comment Section**

The comment section shows all visible comments for the selected notification. It also enables users to create additional comments, edit comments, or delete comments. Comments are organized chronologically by the time stamp with which they are associated and by when they were created.

Return to the notification list by selecting the back arrows in comment section header (see *Figure 3.18*).

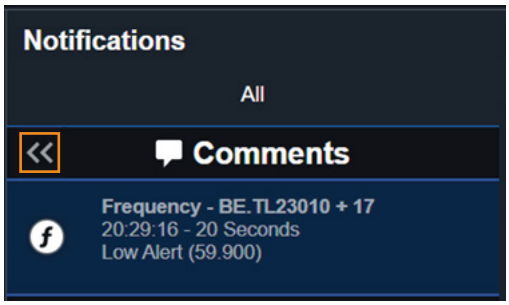



**Figure 3.18 Exit Comment Section**

## Comment Section Layout

*Figure 3.19* shows the comment section layout.

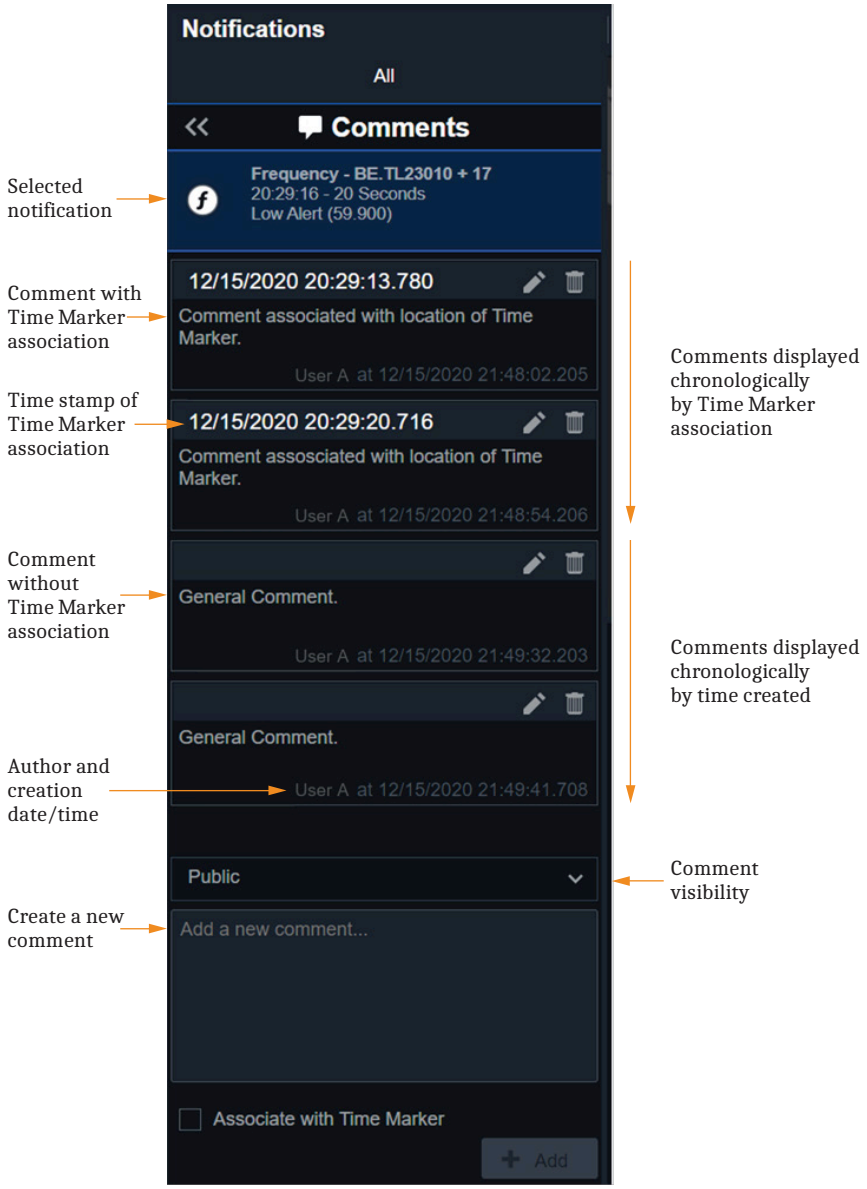



**Figure 3.19 Comment Section Layout**

## Making a New Comment

In the Notification mode, select the comment icon to open the comment section. At the bottom of the screen, enter the comment in the text box. Comments must be less than 500 characters.

Change the comment visibility by selecting the dropdown menu above the comment text box and selecting a corresponding visibility. By default, the visibility is set to Private. Associate the comment with the time cursor position in the timeseries trend chart by checking the **Associate with Time Marker** check box. Select **Add** to finish creating the comment.

### Comment Visibility

You can assign any of the following visibilities to comments when they are created:

- **Public.** The comment is visible to everyone.
- **Private.** The comment is only visible to its author and to users or user groups with the System Admin role.
- **Engineer.** The comment is visible to users or user groups with the Engineer or the System Admin role.
- **Operator.** The comment is visible to users or user groups with the Operator, the Operations Admin, or the System Admin role.

Any user can see their own comments regardless of the selected visibility.

## Editing a Comment

Only the comment author can edit a comment.

In the Notification mode, select the comment icon to open the comment section. Select the pencil icon to edit a comment. You can only modify the comment text; you cannot edit the visibility or the associated time stamp. Select the check mark to finish editing the comment. The comment will update to display the username of the comment author and corresponding edit time.

## Delete a Comment

Only the comment author or System Admin can delete a comment.

In the Notification mode, select the comment icon to open the comment section. Select the trash icon to delete the comment. Select **Ok** in the window that appears to confirm this operation (see *Figure 3.20*).

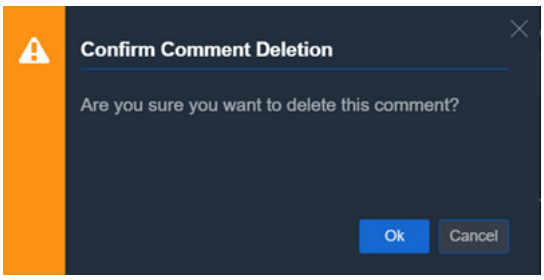



**Figure 3.20 Deleting a Notification Comment**

# Notification Selection and Dashboards

When Notification tile is selected from the Notification List, a Notification Dashboard is displayed. This Dashboard shows the information and data needed to analyze the power system condition that triggered the notification. In addition to the default notification dashboard, secondary dashboards can be selected to analyze how the power system condition might have impacted other aspects of the system such as frequency, voltage, current, power, etc.

**Figure 3.21 Notification Analysis Dashboard**

## Modification of Notification Dashboards

When viewing the Notification Dashboard, it is possible to modify that dashboard to investigate additional information. You can move, resize, delete, and add new panels. These dashboard modifications remain associated with the notification and are automatically saved.

This modified dashboard is only available for its associated notification. In this initial release, the modified dashboard is not available for publication as a notification dashboard template. See *Dashboards Application on page 49* for detailed information on how to design a notification dashboard template.

# Notification States

For each notification, a Notification tile is displayed in the Notification List describing the present state of the power system condition. *Figure 3.22* shows the states of the notifications.

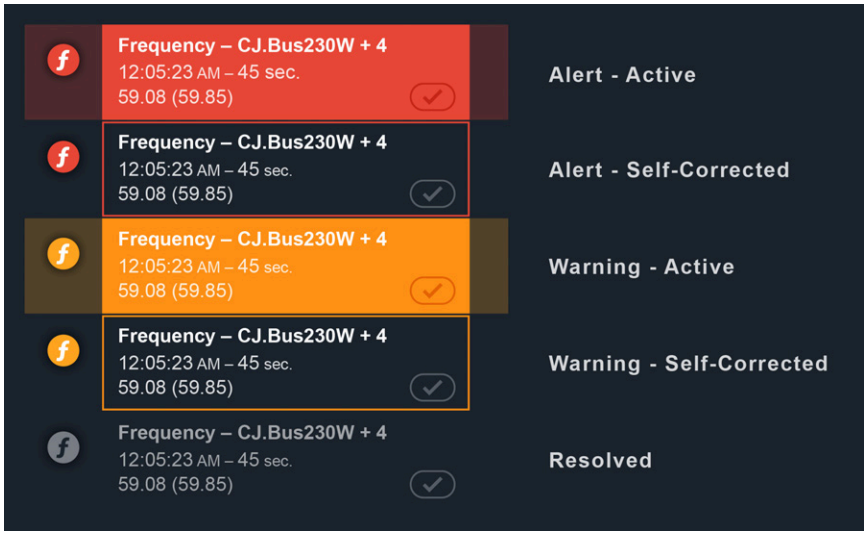



**Figure 3.22 Notification State Diagram**

*Figure 3.23* shows the transition diagram for alert state; warning state functions identically. A notification acknowledged while in a warning state stays acknowledged if the notification elevates to alert. An unacknowledged notification remains in the notification list even after it moves beyond the presently displayed timeline range.

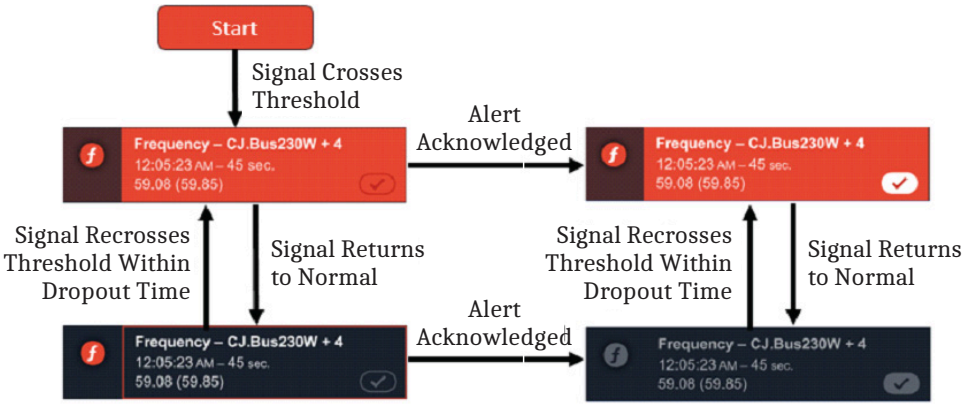



**Figure 3.23 Notification State Transition Diagram**

# Audible Notifications

A notification can play a configurable sound when a notification occurs. In the Application Manager, select **Notifications** > **Configuration** > **Import** to upload an .mp3 file. Audio clips are limited to 250 KB.

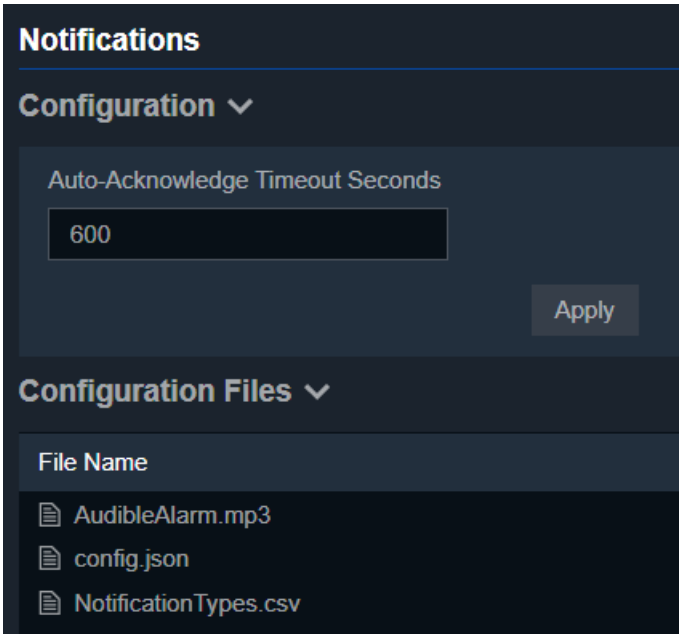



**Figure 3.24 Notifications Application Configuration**

The time the Notifications application waits to auto-acknowledge an alarm is configurable. Set the desired time and select **Apply**. An optional text box next to the Apply button allows you to enter a comment describing the changes. Once **Apply** has been selected, the comment will be stored in the configuration history of the config.json file.

You can adjust the playback volume in Operations. Select the audio icon near the top right corner to cycle through the Muted, Low, Medium, and High volume settings.

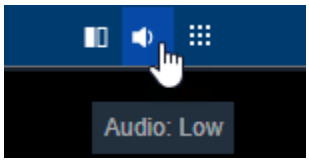



**Figure 3.25 Changing Notification Audio Volume**

**NOTE**
You must have the local computer system audio on to hear an alarm.

Users can configure which types of notifications produce audible alarms with the NotificationTypes.csv file. Each row should be a notification type that will produce an audible alarm. If empty (the default), all notification types produce audible alarms.

# Timeline Application

Synchrowave software provides time synchronization and time control through a timeline located along the top of the user interface.

The Timeline Time Range provides context for where the operator is in time within the software.

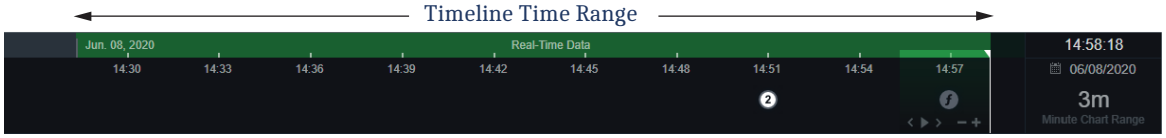



**Figure 3.26 Timeline Time Range**

The shaded region on the Timeline Time Range is the Chart Time Range. The Chart Time Range represents the time range for the data that is displayed in trend chart(s) for any dashboard. Any notification icons within the time range is displayed in the Notification List, even if acknowledged.

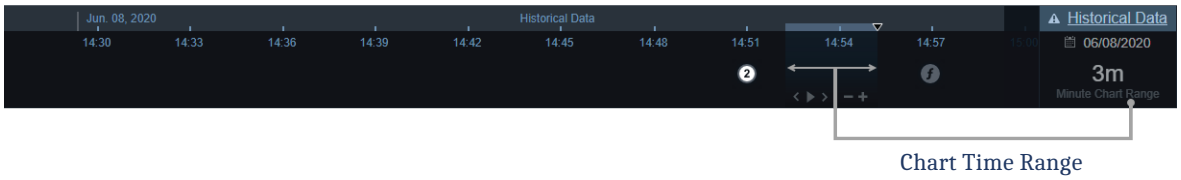



**Figure 3.27 Timeline Chart Time Range**

Modify the selected Chart Time Range value to one of the default values by selecting the Chart Time Range control. All trend charts automatically update to display the new range of data. The Chart Time Range can also be modified by scrolling the mouse wheel while hovering the mouse over the Chart Time Range indicator on the timeline.

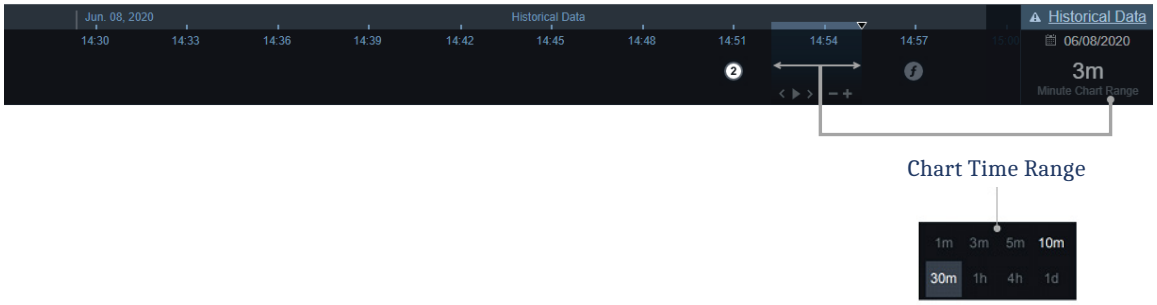



**Figure 3.28 Timeline Chart Time Range Default Values**

For chart panels that display an instantaneous value (Numeric Display, Table, Bar Chart, Phasor Scope, etc.), the time-marker shows the point in time that the instantaneous value chart panels are using to display data. In *Figure 3.29*, the cursor is at the right edge of the chart time range and indicates the most recent data within that range.

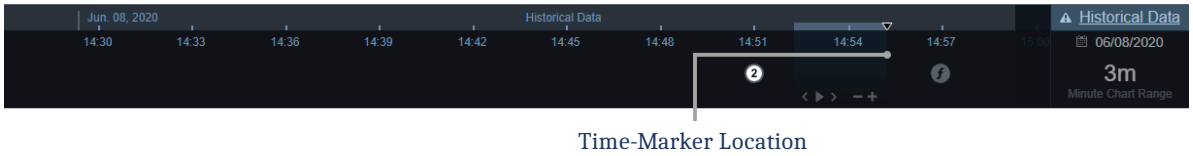



**Figure 3.29 Timeline Time-Marker**

Real-time mode is the default for Synchrowave software. Real-time mode is indicated by the green shading in the chart time range, the scrolling data on any trend chart, and the continuously updating time display. Synchrowave software offers a seamless transition to historical analysis mode by allowing the user to

simply drag the Chart Time Range back in history on the timeline or selecting a historical notification. Historical mode is indicated by the gray shading in the chart time range, the shaded chart time range at a location other than the right side, and the time display is replaced by "Historical Data."

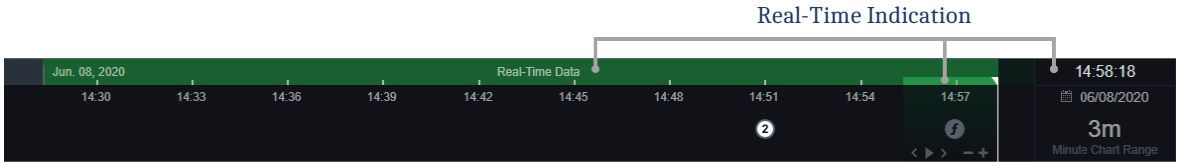



**Figure 3.30 Timeline Real-Time Mode Indication**

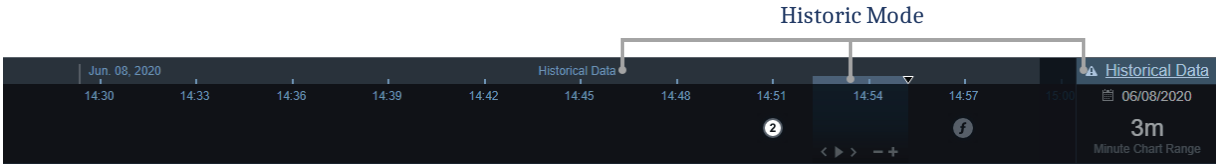



**Figure 3.31 Timeline Historic Mode Indication**

The calendar icon (see *Figure 3.32*) in the time control provides the ability to navigate the software to any date in history for analysis of historic conditions.

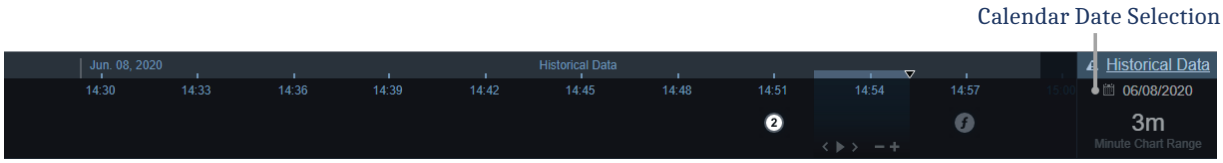



**Figure 3.32 Timeline Calendar Date Selection**

Operators can quickly begin analysis of any notification by simply selecting the Notification icon on the timeline. The Notification icon location on the timeline represents the start time of the condition.

**NOTE**
Monitor-generated notifications are only available in Synchrowave Operations.

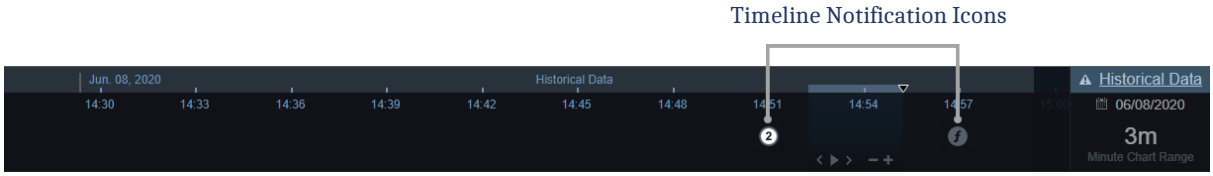



**Figure 3.33 Timeline Notification Icons**

# Replay

Replay enables operators to visualize how the power system state changed over time. The replay controller features several buttons:

- The play button starts replay mode.
- The pause button pauses replay.

- The plus button increases the replay speed.
- The minus button decreases the replay speed.
- The step-forwards button moves the time cursor forward one data point in time.
- The step-backwards button moves the time cursor backwards one data point in time.

All instantaneous data panels—such as trend lines and bar charts—automatically update to display data at the time of the cursor during replay. Synchrowave Operations automatically enters Historical Data mode when you start replay mode.

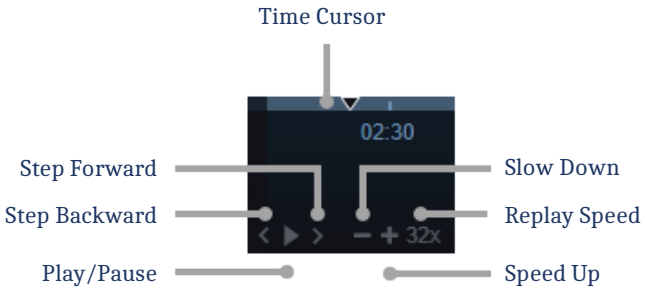



**Figure 3.34 Timeline Replay Controller**

# Dashboards Application

Dashboards provide visualization of power system data and information through a collection of panels. Dashboards are dynamic and customizable, ensuring the actionable information operators need to efficiently analyze the power system is always available. There are three primary types of dashboard use cases available to operators.

## System Monitoring

System Monitoring dashboards provide operators visibility across the entire power system for operators use cases such as path flow, phase angle stress, and voltage monitoring.

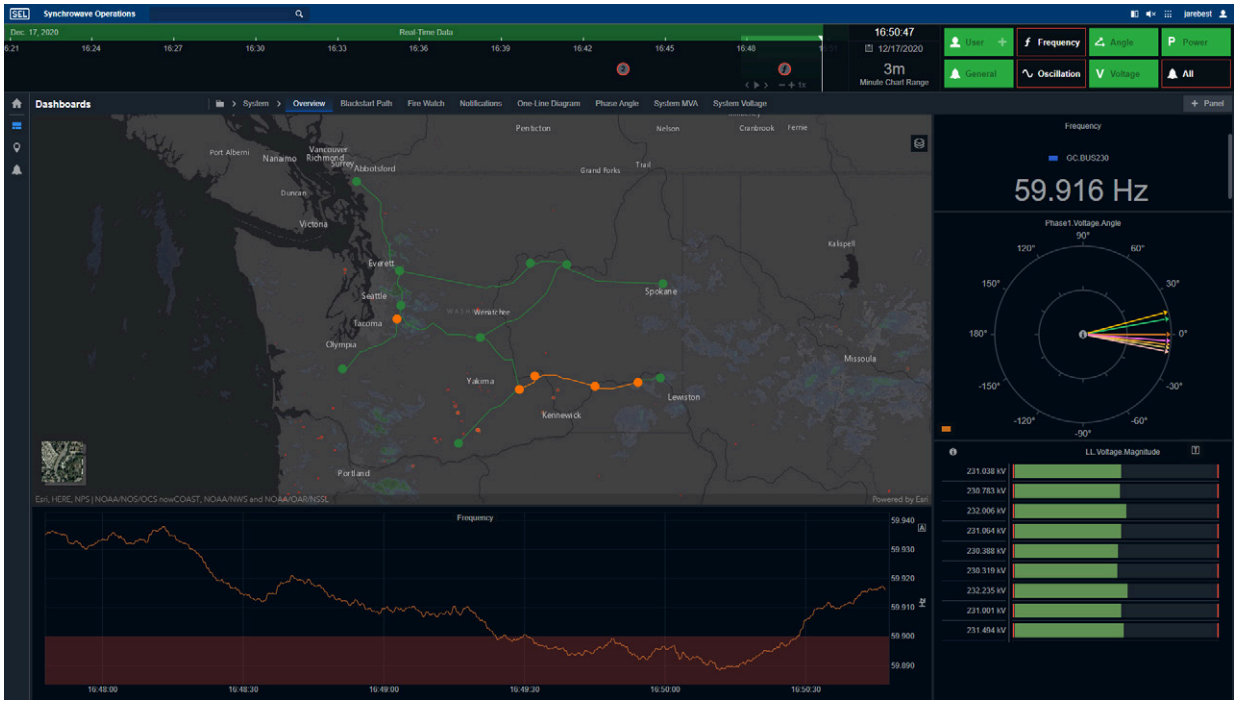



**Figure 3.35 System Monitoring Dashboard**

# Asset Investigation

Asset Investigation dashboards provide operators and engineers the ability to assess any power system asset (transmission line, substation bus, transformer, generator, feeder, etc.) and see the current state of the asset. When an energy management system (EMS) or SCADA alarm does not provide all the information needed, Asset Investigation dashboards provide high-resolution information.

**Figure 3.36 Asset Investigation Dashboard**

# Notification Analysis

Notification Analysis dashboards provide visibility into active and historic power system conditions by dynamically displaying the applicable information, data, limits, location, and time of the condition on a dashboard with one click.

**Figure 3.37 Notification Analysis Dashboard**

# Dashboard Navigation

## Navigating Dashboards

Synchrowave software provides dashboards to visualize the state of the power system. You can access the Dashboards from the Dashboards Navigation toolbar below the timeline in the software.

**Figure 3.38 Dashboard Navigation Toolbar**

From the Dashboards Navigation menu, select a dashboards folder and then select the desired dashboard from the list of available dashboards.

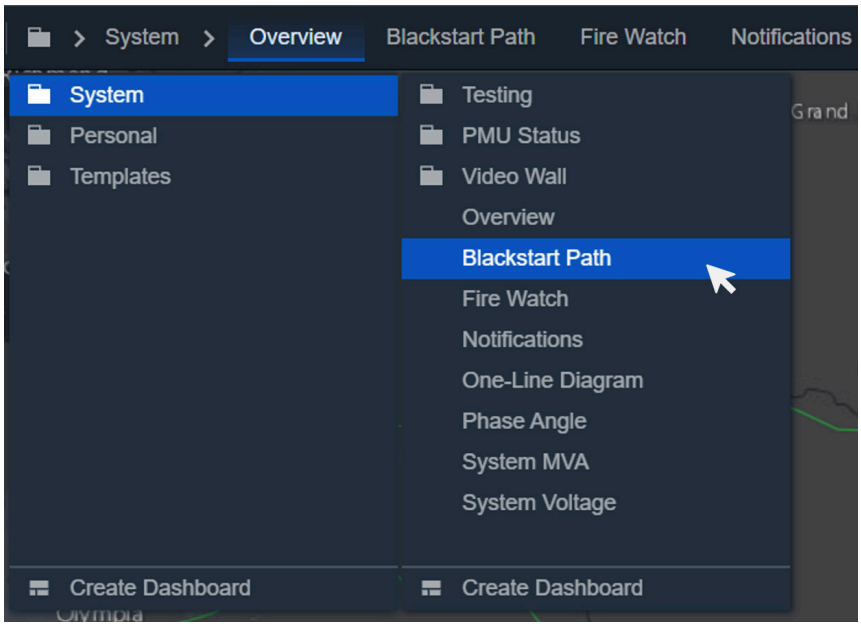



**Figure 3.39 Dashboard Navigation Menu**

The Dashboard Navigation toolbar updates the dashboard path and shows the selected dashboard. The dashboard path is shown to provide the operator context as to which dashboard is being displayed. The dashboard path follows the same concept that Microsoft Windows uses for folder navigation.

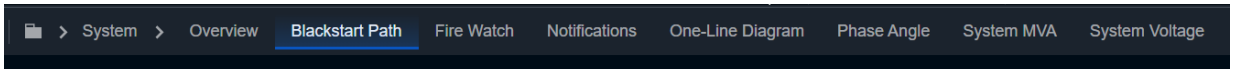



**Figure 3.40 Dashboard Navigation Path**

The Dashboard Navigation toolbar also shows other dashboards that exist in the selected dashboards folder. This allows the operator to switch between related dashboards quickly.

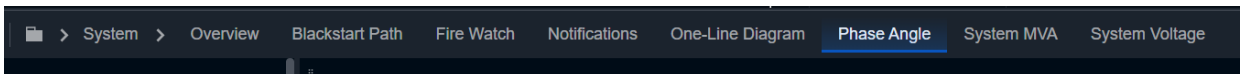



**Figure 3.41 Navigating to Dashboards in the Same Folder**

## Searching for Dashboards

In addition to using the Dashboard Navigation Menu, operators and engineers can search for dashboards. In the Synchrowave Operations search bar, begin typing the name of a published dashboard or power system model asset. Matching dashboards will appear below the search bar.

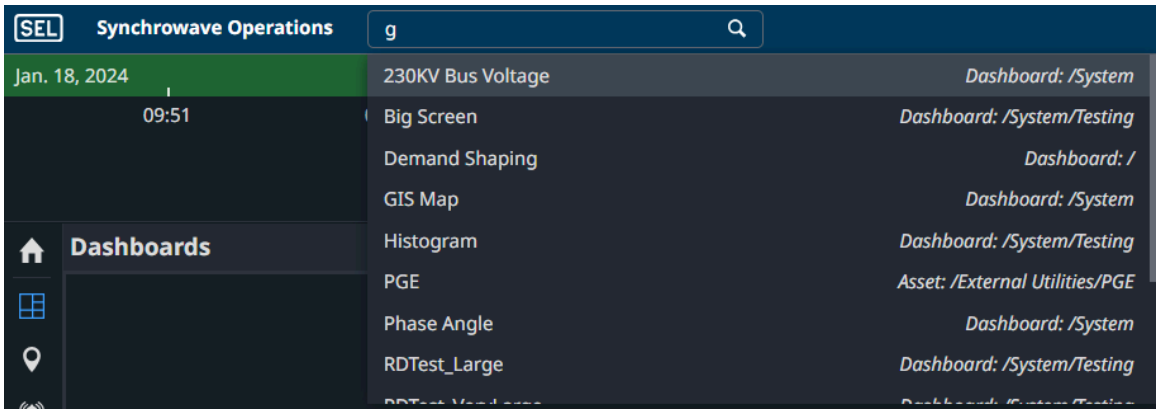



**Figure 3.42 Searching for Dashboards**

## Configuring a Home Dashboard

The Home Dashboard serves as a reference dashboard that is frequently viewed. Each operator or engineer can configure their own Home Dashboard. The Home Dashboard is displayed when first logging into Synchrowave software or by selecting the **Home** icon in the Dashboard Path toolbar.

**Figure 3.43 Navigating to the Home Dashboard**

To set the Home Dashboard, right-click the Home icon in the top left corner. Select **Set Selected Dashboard and Chart Range as Home**. The current Timeline Chart Range is also saved so that when the user selects the Home icon, the Timeline Chart Range also returns to the saved value.

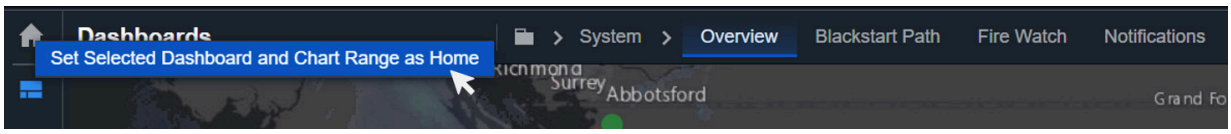



**Figure 3.44 Setting the Home Dashboard**

# Configuring Dashboard Navigation Folders

The dashboard folder path is configured from the Dashboard Manager application. The Dashboard Manager application can be accessed from the Synchrowave Platform Navigation Menu, accessible via the icon in the upper right corner.

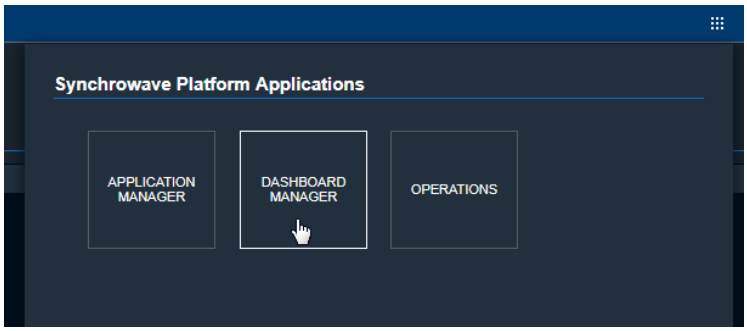



**Figure 3.45 Dashboard Manager in Platform Navigation Menu**

Import the dashboard folder by selecting the Import Dashboard Menu button. To export a copy of the existing dashboard folder path, select the **Export Dashboards** button.

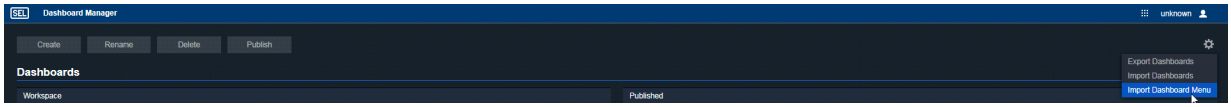



**Figure 3.46 Importing Dashboard Folder Path**

The dashboard folder path can be created or modified using a text editor. The folder structure is built by using forward slashes. For example, lines 6–8 in *Figure 3.47* create a Templates folder with subfolders called Assets and 230 KV Lines. Inside the 230 KV Lines folder, there are three additional folders for each transmission line (TL23001, TL23002, and TL23003). Upon importing the Dashboard Menu text file, users create dashboards for each folder through the Synchrowave Operations user interface.

## NOTE

By using names of assets defined in the Power System Model Application on page 176 (e.g., TL23001, Sub1, or Gen1) in the folder path, dashboards created for the folder will automatically display signals for the appropriate asset when the dashboard is selected and the panels in the dashboard have "Context" enabled. See Creating Dashboard Templates on page 61 for additional information.

dash-menu.txt

```
/
/System/Overview
/System/PMU Status
/System/Video Wall
/Personal
/Templates/Assets/230KV Lines/TL23001
/Templates/Assets/230KV Lines/TL23002
/Templates/Assets/230KV Lines/TL23003
/Templates/Assets/500KV Lines/TL50001
/Templates/Assets/500KV Lines/TL50002
/Templates/Assets/500KV Lines/TL50003
/Templates/Assets/Substations/Sub1
/Templates/Assets/Substations/Sub2
/Templates/Assets/Substations/Sub3
/Templates/Assets/Generation
/Templates/Assets/Generation/Gen1
/Templates/Assets/Generation/Gen2
/Templates/Notifications/Frequency
/Templates/Notifications/Voltage
/Templates/Notifications/Angle
/Templates/Notifications/Power
/Templates/Notifications/Oscillation
/Templates/Notifications/General
/Templates/Notifications/User
```

**Figure 3.47 Example Dashboard Folder Path File**

Folders can also be created and deleted directly from the Dashboard Navigation menu. To create a folder, navigate to the desired location in the folder tree and select **Create Folder**. Enter a name for the folder and select **OK**. To delete a folder, right-click the desired folder, choose Delete, and then select **OK**. The folder and all its subfolders will be deleted. Any dashboards in that folder or its subfolders, however, will persist. To delete a dashboard, either right-click it and select Delete *prior* to deleting the folder or use the Dashboard Manager.

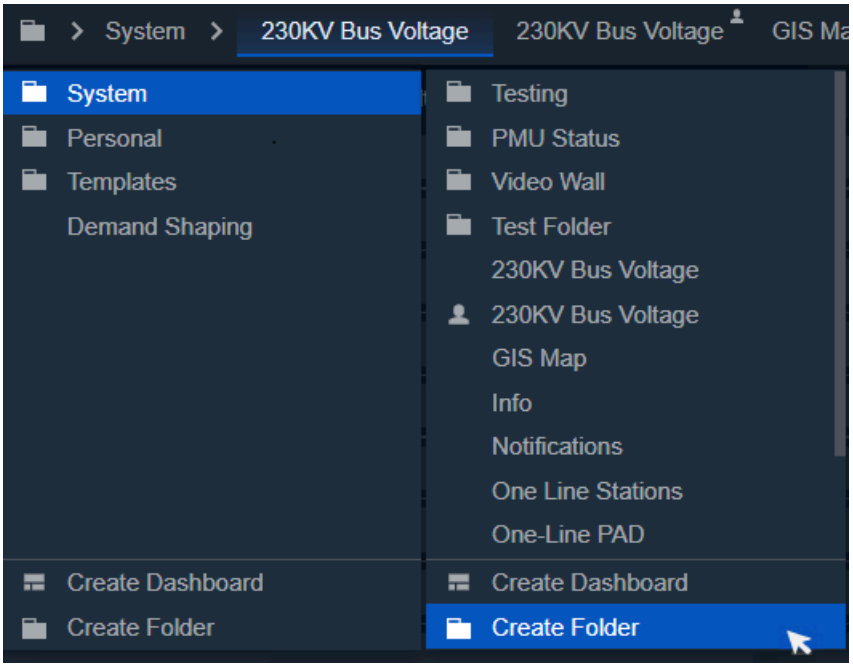



**Figure 3.48 Creating a Dashboard Navigation Folder**

## Importing and Exporting Dashboards

Dashboards can be imported and exported using the **Import Dashboards**, **Export All Dashboards**, and **Export Select Dashboards** buttons in the Dashboard Manager.

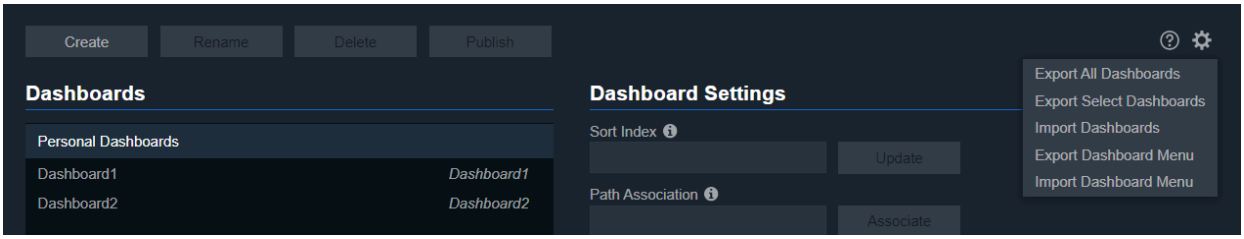



**Figure 3.49 Importing and Exporting Dashboards**

Selecting the **Export All Dashboards** button downloads a .zip file with all dashboards in the system, including published dashboards, all user dashboards, and all dashboard history. The dashboard folder structure is also included.

Selecting the **Export Select Dashboards** button opens a dialog that displays all published dashboards and all dashboards in the current user's workspace. Select the check boxes for the desired dashboards and select the **Export** button. A .zip folder will be downloaded with the current version (no history) of the selected dashboards and a dashboard menu file with folders associated with the dashboards. Folders are only included if the dashboard is associated with exactly one folder. If a dashboard is associated with more than one folder, no folders for that dashboard are included in the export. If they do not exist on the target system, they will need to be created manually.

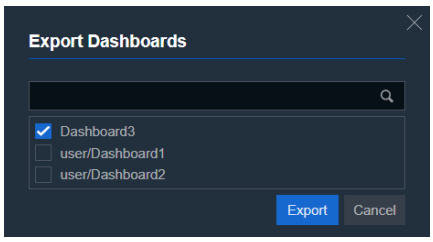



**Figure 3.50 Export Select Dashboards**

The behavior of the **Import Dashboards** button depends on whether the file to be imported was created using the **Export All Dashboards** button or the **Export Select Dashboards** button. If the .zip file was created with the **Export All Dashboards** button, the dashboard file structure currently on the system is overwritten by the structure contained in the imported dashboard menu file. If the file was created with the **Export Select Dashboards** button, the dashboard file structure in the imported dashboard menu file is merged with the existing file structure on the system. Logs for the Dashboard application will call out any conflicts. In both cases, dashboards are imported and any existing dashboards that have the same name as a new dashboard are overwritten.

# Dashboard Creation

To create a Dashboard, navigate to the desired dashboard folder in the Synchrowave software and select the **Create Dashboard** button.

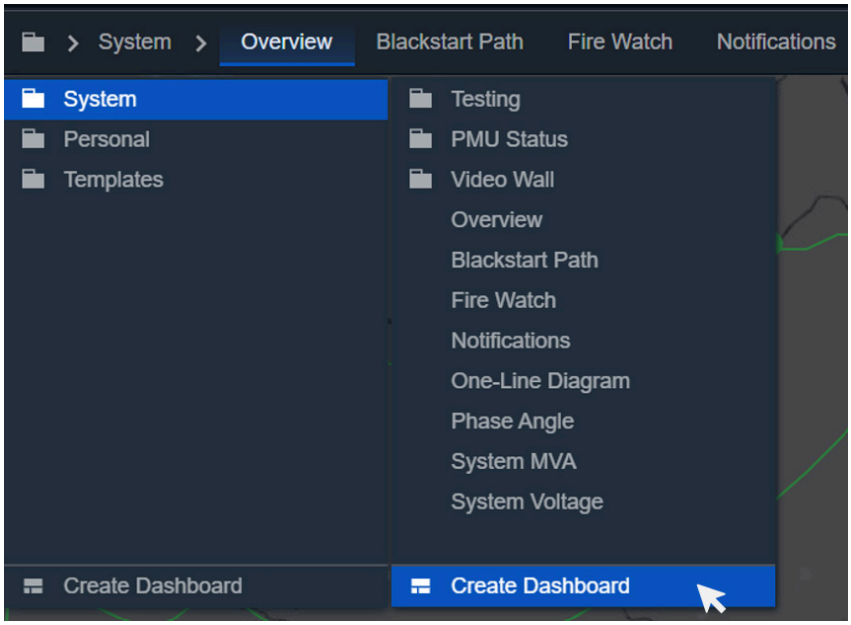



**Figure 3.51 Creating a Dashboard**

Enter a display name for the Dashboard.

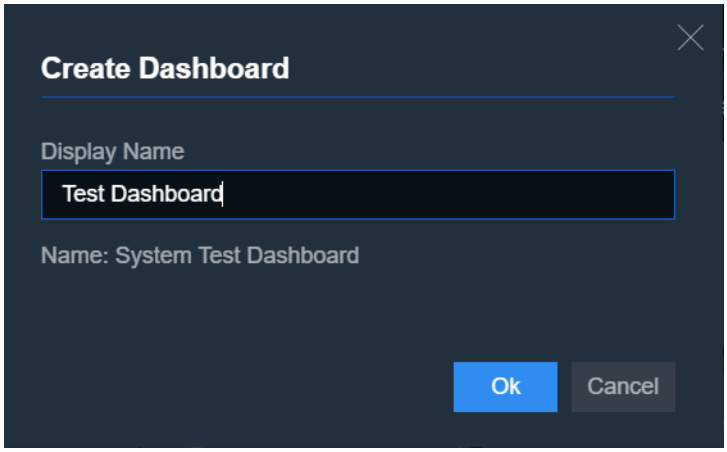



**Figure 3.52 Naming a Dashboard**

The Dashboard is now listed in the Dashboard Navigation toolbar. The (human figure icon) indication next to the Dashboard Name indicates that the dashboard is a private user dashboard. See *Publishing Dashboards on page 59* for information regarding sharing dashboards.

Any change to a dashboard is automatically saved as part of the private user dashboard for efficient ad-hoc analysis and to ensure changes are not lost.

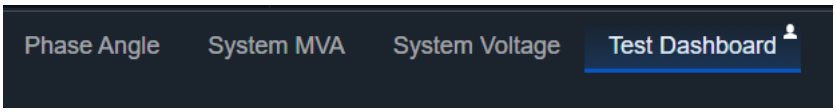



**Figure 3.53 Private User Dashboard Indication**

Right-click on any dashboard to access the Dashboard Option menu. From this menu the following options are available:

- **Delete** dashboard. (Private user dashboard only. Published dashboards can only be deleted from Dashboard Manager.) See *Publishing Dashboards on page 59*.
- **Rename** dashboard. (Private user dashboard only. Published dashboards can only be renamed from Dashboard Manager.) See *Publishing Dashboards on page 59*.
- Copy and paste dashboard content from one dashboard to another. This is a useful feature for efficient dashboard creation.
- Open dashboard in a new tab for analysis on multiple computer monitors.
- **Publish Dashboard.** See *Publishing Dashboards on page 59*.

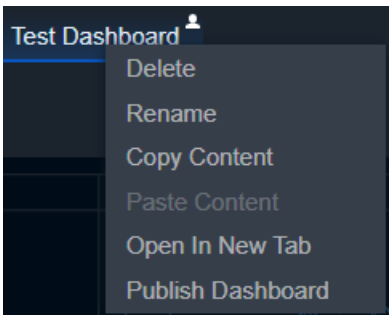



**Figure 3.54 Dashboard Options Menu**

# Adding Dashboard Panels

Panel applications can be added to new or existing dashboards. Select **Add Panel** to add a panel to the selected dashboard. The dashboard panel is added to the center of the dashboard automatically. Select the type of panel application for each panel that is added to the dashboard. **Undo** and **Redo** buttons are available for reverting changes to dashboards.

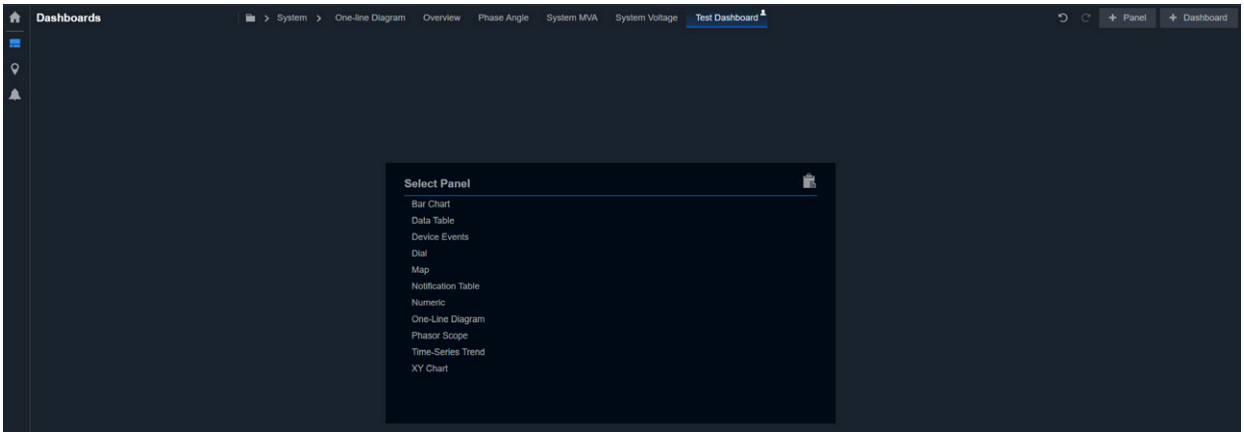



**Figure 3.55 Adding Dashboard Panel**

Panels can be arranged on the selected dashboard by selecting the grip icon in the top center of the panel and dragging the panel to the desired location. The grip icon is displayed when the mouse cursor hovers over a panel.

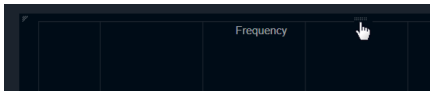



**Figure 3.56 Rearranging Dashboard Panels**

Resize a panel to take up the desired amount of space in a dashboard by selecting a resize arrow icon and dragging the mouse until the desired panel size is selected. Resize arrow icons are displayed in all corners when the mouse cursor hovers over a panel. The dashboard display area is divided into an 18x24 grid. The panels automatically snap to this grid when resized or moved.

**Figure 3.57 Resizing Dashboard Panels**

Remove panels from a dashboard by selecting the **Panel Options** menu in the top right corner of each panel.

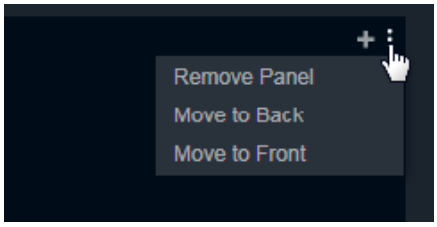



**Figure 3.58 Dashboard Panel Options**

Configure panels by selecting **Edit Panel** in the top right corner of each panel. See *Dashboards Application on page 49* for details regarding configuration for each panel type.

**Figure 3.59 Dashboard Panel Configuration**

# Publishing Dashboards

Dashboards are only viewable to the user that creates the dashboard. This is a private user dashboard. A private dashboard can be published to make it available to other users. When deploying a system with many users, it can be helpful to have a set of published dashboards that are visible to all users.

**NOTE**
If user authentication is not enabled, all user dashboards and published dashboards are shared across all users.

New dashboards and modified versions of published dashboards are marked with a (human figure icon).

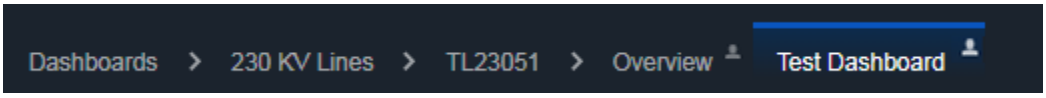



**Figure 3.60 User Dashboard Indication**

Private user dashboards can be published from the Dashboard Manager. Select the private user Dashboard from the list of available dashboards, then select **Publish**. The Dashboard is automatically copied to the Published dashboard list in the Dashboard Manager. Dashboards can also be published from the Dashboard Option menu (right-click a dashboard to open the menu).

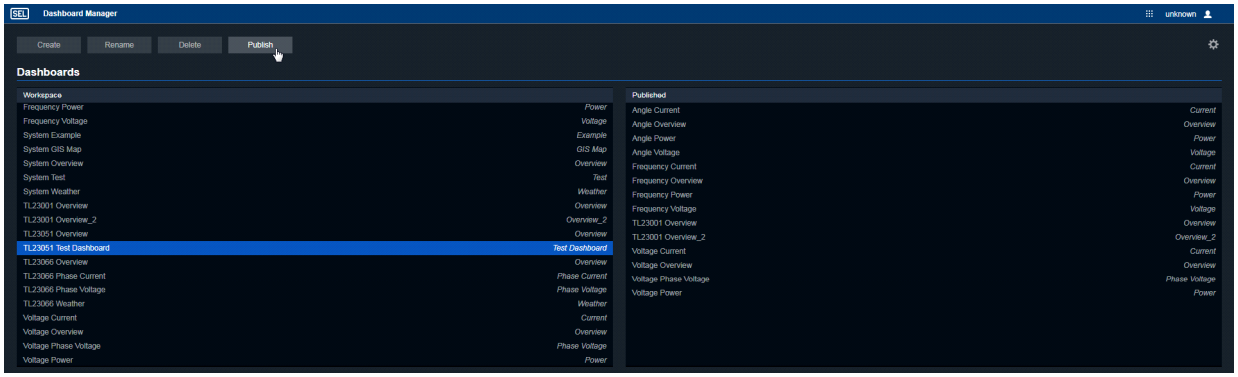



**Figure 3.61 Publishing Dashboards**

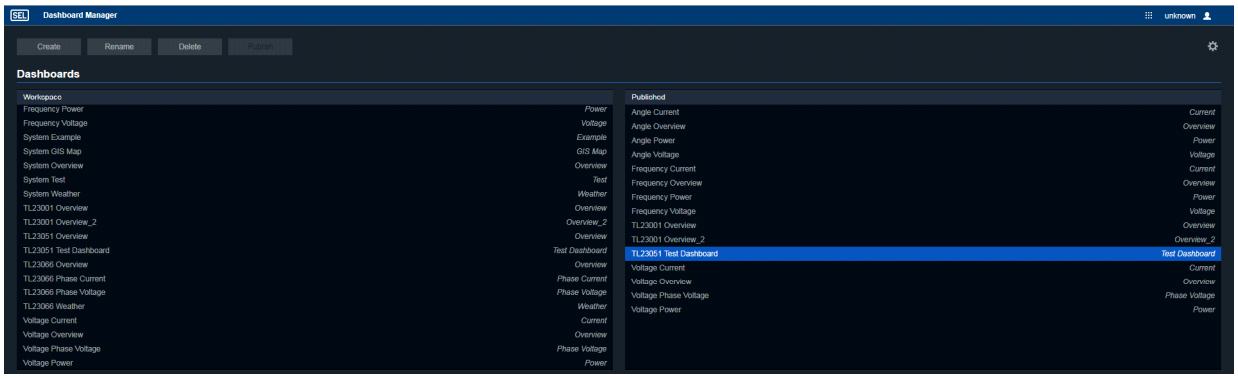



**Figure 3.62 Navigating Published Dashboards**

A published version of the dashboard is now available for all users to view. For the user that created the dashboard that was published, the private user version is automatically deleted.

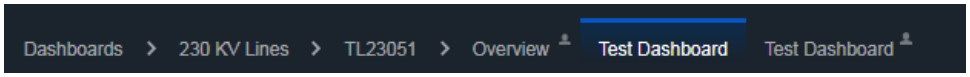



**Figure 3.63 Published Dashboard Indication**

*Figure 3.64* shows the published dashboards visible to other users for the TL23051 Asset in the Dashboard Navigation toolbar.

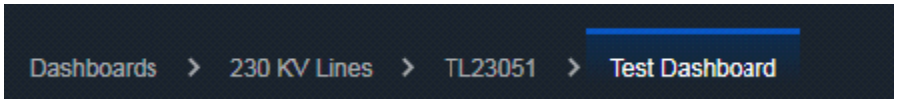



**Figure 3.64 Dashboard Navigation Toolbar for Other Users**

Any new changes made to a published dashboard are automatically saved in a private user copy of the published dashboard. If it is desired for the new changes to be published to all users, the publish process can be repeated for the new changes.

# Creating Dashboard Templates

When analyzing and monitoring dashboards for power system assets such as substations, transmission lines, buses, and generators, it is important to view information for each asset in a consistent format.

Synchrowave Operations simplifies creating consistent dashboards through the concept of Dashboard Templates. Templates enable the creation of dashboards for a specific power system asset (such as a transmission line), the global application of it to all assets, or the regional application to a subset of assets in the power system. Any updates to the dashboard in the future are made once and then re-applied to all power system assets.

For large systems, this feature reduces the number of dashboards managed by orders of magnitude.

## Associating Assets and Dashboard Folder Paths

The first step is to create and upload a dashboard folder path for viewing dashboards that uses actual power system asset names as defined in the Power System Model application (see *Power System Model Application on page 176* for more information). This provides an organized structure to which templates can be assigned. At a minimum, the Dashboard Folder Paths must contain the seven lines shown in *Figure 3.65* to enable the minimum dashboard association capability, where the **/System** section can be expanded to reflect specific network configurations.

```
/
/System
/Personal
/Templates/Assets
/Templates/Notifications/Frequency
/Templates/Notifications/Voltage
/Templates/Notifications/Angle
/Templates/Notifications/Power
/Templates/Notifications/Oscillation
/Templates/Notifications/General
/Templates/Notifications/User
```

**Figure 3.65 Minimum Dashboard Folder Path Structure**

For example, a utility intends to apply templates for their three 230 kV lines (TL23001, TL23002, and Tl23003), their three 500 kV lines (TL50001, TL50002, and TL50003), their two 230 kV stations (Sub 1 and Sub 2), their one 500 kV station (Sub 3), and their two generators (Gen 1 and Gen2). The Folder Path file might look like the example in *Figure 3.66*.

```
/Templates/Assets/230 KV Lines/TL23001
/Templates/Assets/230 KV Lines/TL23002
/Templates/Assets/230 KV Lines/TL23003
/Templates/Assets/500 KV Lines/TL50001
/Templates/Assets/500 KV Lines/TL50002
/Templates/Assets/500 KV Lines/TL50003
/Templates/Assets/Substations/Sub1
/Templates/Assets/Substations/Sub2
/Templates/Assets/Substations/Sub3
/Templates/Assets/Generation
/Templates/Assets/Generation/Gen1
/Templates/Assets/Generation/Gen2
```

Power System Asset Name = TL23001

**Figure 3.66 Dashboard Folder Path Example**

Now associate a dashboard with one or more paths. For example, a dashboard named **230 KV Voltages** might be associated with the following paths:

/Templates/Assets/230 KV Lines/TL23001

/Templates/Assets/230 KV Lines/TL23002

/Templates/Assets/230 KV Lines/TL23003

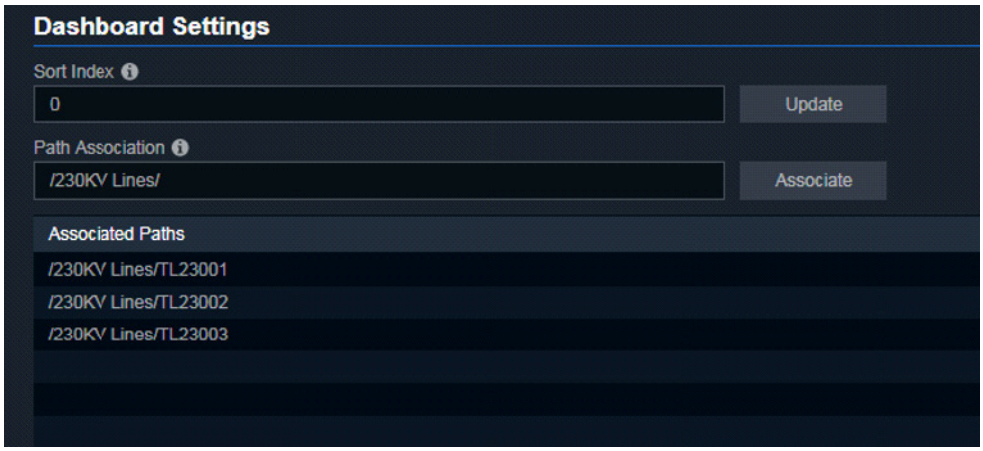



**Figure 3.67 Associating a Dashboard With a Folder Path**

This causes the 230 KV Voltages dashboards to be selectable from these paths. When selecting this dashboard, Synchrowave Operations automatically includes the associated assets in the context. Synchrowave Operations then further looks at the power system model to add the associated Measurement Points (signal locations) for those assets to display on the dashboard.

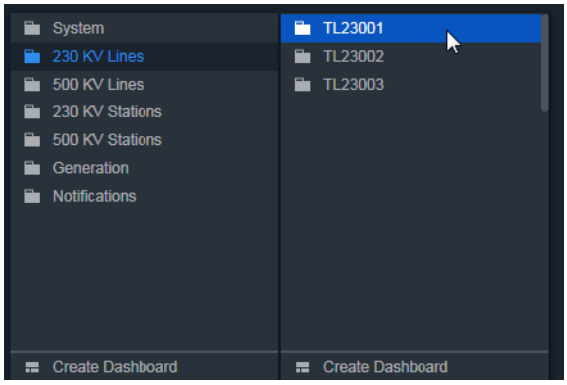



**Figure 3.68 Resulting Dashboard Navigation Menu**

When a dashboard needs to be updated, select that dashboard and make the necessary modifications. This modified dashboard is automatically saved to your user account. Go to the Dashboard Manager and publish the update to overwrite the old version of the dashboard. Now the dashboard updates are available to all users.

## Creating Dashboards to Be Used as Templates

Dashboards for templates are created by adding the Context Measurement Point to each panel in the dashboard. When the dashboard is selected, the Context is replaced with the Measurement Points from the Power System Asset with which the dashboard is associated.

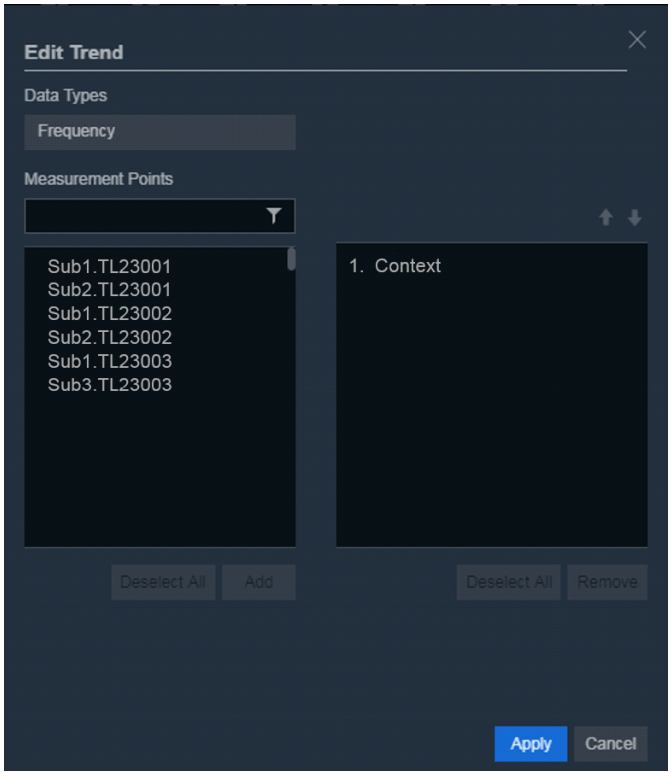



**Figure 3.69 Adding Context to Dashboard Panels**

## Associating Dashboards to Multiple Dashboard Paths

To simplify the association of a dashboard with multiple assets, compound associations are specified as follows.

A specified path includes all subpaths unless the path is terminated with a dollar sign ($) character. For example, to specify all 230 kV stations and lines, type **/Templates/Assets/230 KV** into the **Path Association** text box. This results in the **/Templates/Assets/230 KV Lines** and **/Templates/Assets/230 KV Stations** as well as all subpaths being included in the association.

Specific paths are separated using the vertical bar (|) character. For example, to include both the 230 kV and 500 kV lines but none of the stations, the Path Association would appear as follows:

```
/Templates/Assets/230 KV Lines|/Templates/Assets/500 KV Lines
```

## Associating Dashboards to Notifications

Similar to the **/Templates/Assets** path, a hierarchy of notifications are available under the **/Templates/Notifications** path. To associate a dashboard with the main Notifications view (accessed by selecting the Notifications button on the left side of the Operations screen), associate it with the following:

```
/Templates/Notifications
```

A dashboard containing a Notification Table is often a good choice for the main Notifications view.

To associate dashboards with only specific notification types, such as Frequency and Power, associate it as follows:

```
/Templates/Notifications/Frequency | /Templates/Notifications/
Power
```

To associate dashboards with all notifications except Power and Angle, associate it as follows:

```
/Templates/Notifications/(?!Angle)(?!Power)
```

**NOTE**
The Assets and Notifications paths are not strictly required to be placed beneath the Templates path; however, SEL recommends the described placement strategy in most cases.

# Changing Dashboard Display Order in a Folder

By default, dashboards are displayed in alphabetical order in the Dashboard menu and Dashboard toolbar. Change the display order through Dashboard Settings in the Dashboard Manager. Dashboards with the lowest Sort Index are displayed first. The Sort Index range supports negative and positive values, and the default value is 0.

**Figure 3.70 Changing the Dashboard Display Order**

# Changing Dashboard Theme

Synchrowave software includes a light theme mode. This is useful for taking screen captures that are to be printed.

**Figure 3.71 Light Theme Dashboard Display**

Use the Change Theme toggle button in the Synchrowave Monitoring banner to toggle between dark and light dashboard themes. Use the Font Size button to switch between small, medium, and large display fonts.

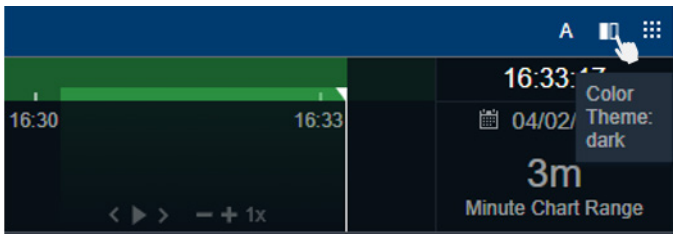



**Figure 3.72 Theme Toggle Button**

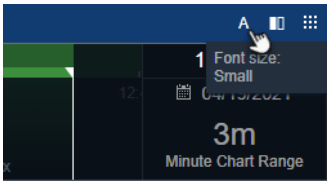



**Figure 3.73 Theme Font Size**

# Playback Application

Playback is an operator training tool that enables Synchrowave Operations to stream historical data as if it were occurring in real-time. The streaming data are processed by applications on the platform, including the monitors that generate warnings and alerts. This enables operators to learn how to react to scenarios and use Synchrowave Operations in a no-risk environment.

Playback should never be used in a real-time operations environment. The operations page banner provides a playback mode indicator to signify that playback is in progress.

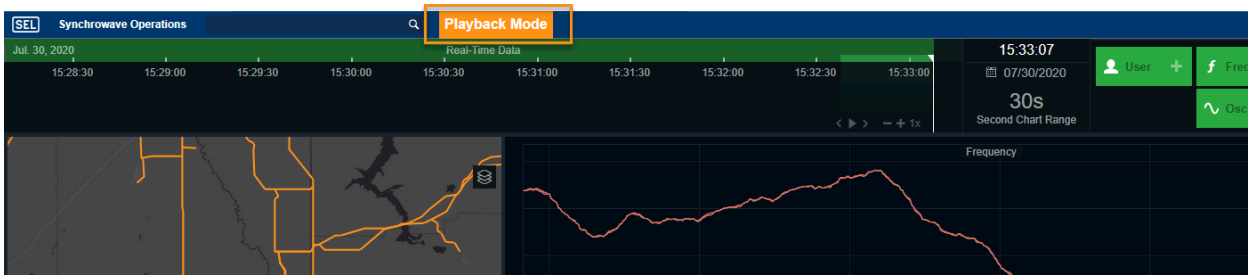



**Figure 3.74 Playback Mode**

## Installation

Run the platform installer on a dedicated training server to install the Synchrowave Platform. Once installed, add and configure each required application with the Application Manager. Finally, provide the server historical data by copying or mounting an existing Synchrowave Historian database to the [*Application Data Directory*]/sel-playback directory.

## Start/Stop Playback

Navigate to the Playback Manager by using the ▦ (Synchrowave Platform Navigation) button and select **Playback**. Choose a date and time and select **Start**. Navigate back to Operations. The playback banner should appear, indicating the playback is in progress.

Stop Playback by navigating back to the Playback Manager and selecting **Stop**.

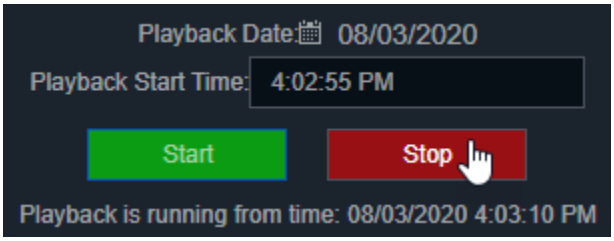



**Figure 3.75 Playback Manager**

This page intentionally left blank

SECTION 4

# Applications

## Introduction

Most applications require configuration either via a user interface or file import and export in the Application Manager. For generic details on this process, see *Application Configuration on page 10*. The following sections will omit descriptions of the import and export procedure, but discuss application-specific configuration details.

## Power System Applications

### Introduction

Power system applications enable monitoring of various power system conditions. These conditions are generated from the analysis of quantities such as frequency, voltage, angle, power conditions, and other derived quantities. The applications compare one or more of these quantities to the configured limits and generate conditions as the limits are passed. The conditions are then grouped and passed to the Notification application.

### Condition Monitoring Configuration

Condition monitoring configuration for the Monitor applications is done via two files: TimeSettings.csv and Thresholds.csv. For initial configuration or if new signals have been added to the system, download the Thresholds.csv file using the Query and Download option. This will auto-populate the file with signals in the system that can be monitored. Modify both files as necessary (see details below) and import back into Synchrowave.

### Condition Generation

A condition is generated when a signal crosses a configured threshold and exceeds the threshold for at least the configured pickup time. The signal condition is determined by comparing a signal sample to the thresholds specified in the monitor applications configuration. Conditions are then grouped based on proximity in time. Monitor applications report the grouped conditions to the Notification application for operators. *Figure 4.1* chart shows the overall process of condition generation by a monitor application.

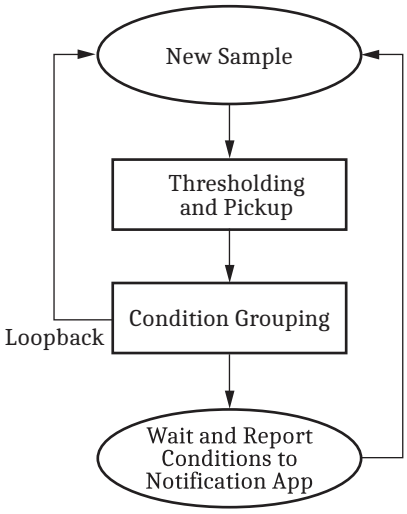



**Figure 4.1 Flow Chart of Condition Generation by the Monitor Applications**

## Dynamic Thresholds

Some thresholds change over time. For example, a transmission line can safely transmit more power during the winter and at night. Dynamic Thresholds are supported by associating a threshold with a signal published to the Synchrowave Platform.

## Condition Grouping

Conditions are grouped in two ways. Multiple conditions may be generated from an individual signal over time. If the dropout of the condition and the pickup of the next condition fall within a predefined time period, those conditions are grouped. Similarly, multiple signals may generate conditions close together in time. These conditions are grouped if they occur within a predefined time period of each other.

*Figure 4.4* shows the condition grouping algorithm. Condition grouping outputs a list of conditions to be reported to the Notification application. The blocks of the flow chart work as follows:

- **Condition filtering.** When a condition is created, it will only create a notification if it remains valid for a duration greater than the PickupTime. This assists in minimizing spurious alarms. To filter out single-sample anomalies, set the PickupTime to be greater than the sampling period. For example, with a sampling period of 30 samples per second, a pickup time of 0.034 seconds (slightly larger than 1/30 = 0.03333) could be set.
- **Signal grouping.** When a condition is created for the first time for a signal and remains valid longer than the PickupTime, any other signals of the same group that go into the warning or alert state within GroupTime seconds (specified in the monitor Configuration) are grouped into the same condition when they are not already grouped into any other ongoing conditions.

- **Ungrouping.** A signal is ungrouped from a condition if it returns to the normal state and remains there continuously for at least *DropoutTime* seconds (specified in the monitor Configuration). After that, if the signal goes into the alert or warning state again, it is grouped into another recently created condition when possible; otherwise, a new condition is created.
- **Update condition.** A condition is updated every 0.5 seconds based on the most severe states of all signals in the condition during the previous 0.5 seconds. The alert state is considered more severe than the warning state. The warning state is considered more severe than the normal state. When a signal is ungrouped from a condition, it will not be considered for the condition update.
- **End of condition.** A condition is considered ended when all signals that are grouped into the condition return to the normal state and remain there for at least *DropoutTime* seconds. After the DropoutTime is elapsed, if any of the signals in the condition go into the alert or warning state again, they are grouped into a created condition when possible; otherwise, a new condition is created.
- **Drop condition.** When a condition ends, the monitor will report it once and then will no longer report it.

The condition filtering and grouping settings are contained in the TimeSettings.csv file for each monitor configuration. At least one time group must be defined for each monitor. Additional time groups can be defined by adding additional rows and assigning a unique TimeGroupID. Conditions of multiple signals are not grouped if GroupTime is set to zero, even if they cross a threshold at the same time instant. The CSV files can be edited in a CSV or TXT editor of your choice.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | TimeGroupID | PickupTime (s) | DropoutTime (s) | GroupTime (s) |
| 2 | F_Monitor_Times | 1 | 10 | 3 |

**Figure 4.2 TimeSettings.csv Open in a Spreadsheet Application**

TimeSettings.csv

```
1 TimeGroupID,PickupTime (s),DropoutTime (s),GroupTime (s)
2 F_Monitor_Times,1,10,3
```

**Figure 4.3 TimeSettings.csv Open in a Text Editor**

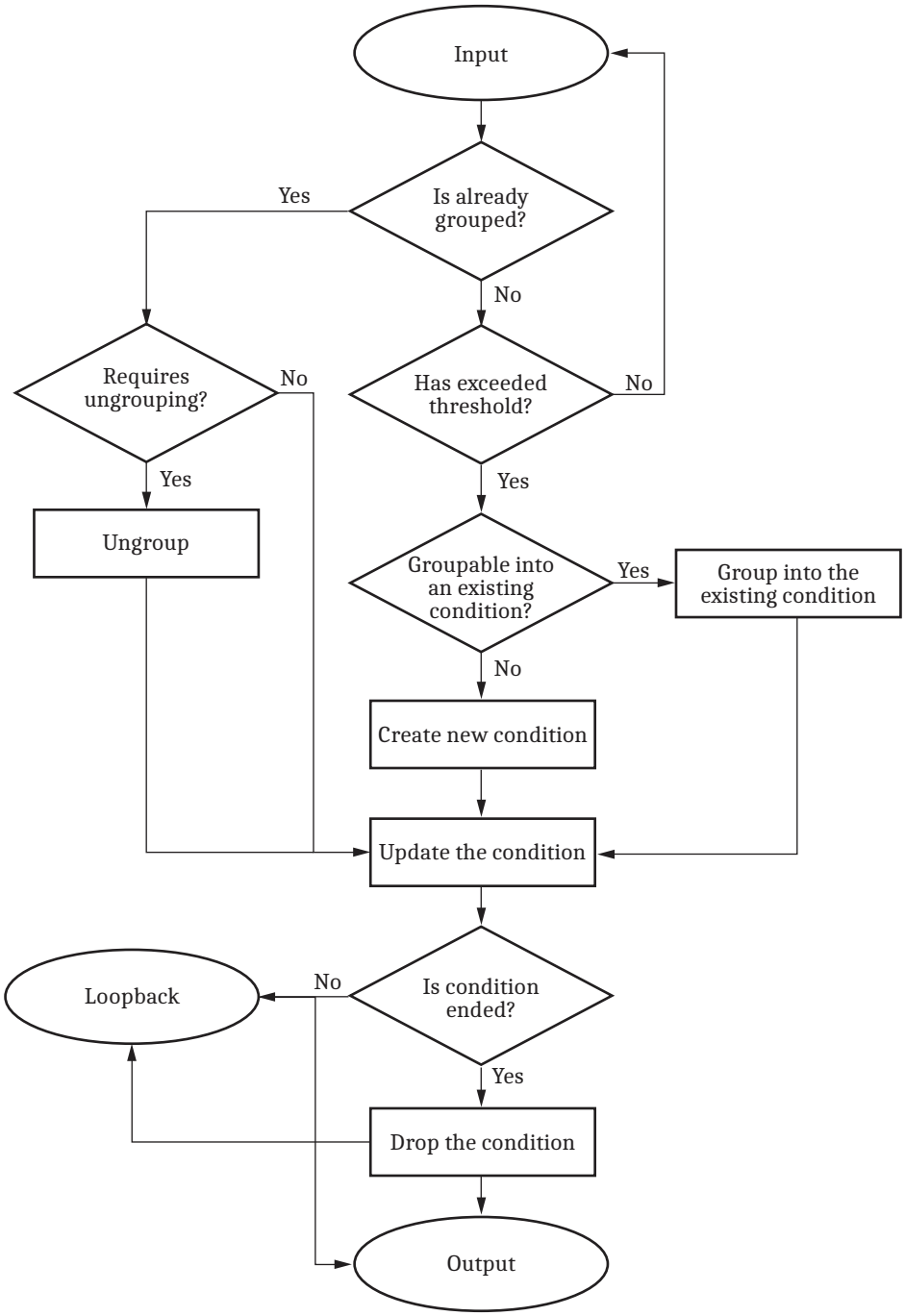



**Figure 4.4 Flow Chart of Condition Grouping Algorithm Used by the Monitor Applications**

# Frequency Monitor Application

The Frequency Monitor application monitors frequency and derivative of frequency (df/dt) signals. The frequency conditions are reported to the Notification application.

# Configuring the Frequency Monitor

## Opening Configuration File

To configure thresholds for frequency and df/dt signals, download Thresholds.csv and TimeSettings.csv for the Frequency Monitor Application. For initial configuration or if new signals have been added to the system, use the Query and Download option for the Thresholds.csv file. Modify both files as necessary (see details below) and import back into Synchrowave.

## Set Grouping Parameters (Pickup Time, DropoutTime, and GroupTime)

Set the grouping parameters in TimeSettings.csv as described in *Condition Generation on page 69*.

## Set Thresholds and Assign Time Groups

Thresholds are set independently for frequency and df/dt signals in Hz and Hz/s, respectively, for each measurement point where monitoring is desired. For static thresholds, enter float values into the HighAlert, HighWarning, LowWarning, and LowAlert columns in the Thresholds.csv file. For dynamic thresholds, enter signal names directly into the file. Signal names are defined as MeasurementPoint:DataType. Each measurement point can support a mixture of static and dynamic thresholds. Any of the thresholds can be individually disabled by assigning the numerical value to **NaN**. The thresholds must satisfy HighAlert ≥ HighWarning ≥ LowWarning ≥ LowAlert and all of them cannot be set to zero. Assign a TimeGroupID consistent with the time groups defined in TimeSettings.csv. The Thresholds.csv file can be edited in a CSV or TXT editor of your choice (see *Figure 4.5* and *Figure 4.6*).

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | MeasurementPoint | Quantity | Units | HighAlert | HighWarning | LowWarning | LowAlert | TimeGroupID |
| 2 | PMU.BUS1 | Frequency | Hz | 61 | 60.8 | 59.2 | 59 | F_Monitor_Times |
| 3 | PMU.BUS1 | Frequency.DxDt | Hz/s | PMU1.BUS:HighAlert.Calculated | NaN | NaN | PMU1.BUS:LowAlert.Calculated | F_Monitor_Times |

**Figure 4.5 Frequency Monitor Application Configuration, Thresholds.csv Shown in a Spreadsheet Application**

Thresholds.csv

```
1 MeasurementPoint,Quantity,Units,HighAlert,HighWarning,LowWarning,LowAlert,TimeGroupID
2 PMU.BUS1,Frequency,Hz,61,60.8,59.2,59,F_Monitor_Times
3 PMU.BUS1,Frequency.DxDt,Hz/s,PMU1.BUS:HighAlert.Calculated,NaN,NaN,PMU1.BUS:LowAlert.Calculated,F_Monitor_Times
```

**Figure 4.6 Frequency Monitor Application Configuration, Thresholds.csv Shown in a Text Editor**

## Frequency Condition

The Frequency Monitor generates conditions of the frequency type according to the Condition Generation procedure. Conditions for frequency and df/dt signals are generated independently when they have different TimeGroupIDs. Otherwise, conditions for both signal types are grouped by frequency condition.

# Voltage Monitor Application

The Voltage Monitor application monitors voltage magnitude and derivative of voltage magnitude (dv/dt) signals. If line-to-line voltage and its derivative are not already available, the voltage monitor calculates them from available phase-to-ground voltages. Voltage magnitudes supported for monitoring are positive-sequence line-to-line voltage; positive-, negative-, and zero-sequence line-to-neutral voltages; single phase-to-ground voltages; and single line-to-line voltages. The voltage conditions are reported to the Notification application.

## Line-to-Line Voltage and dv/dt Calculation

The Voltage Monitor calculates positive-sequence line-to-line voltage magnitude $V_{1,LL}[n]$ from positive-sequence line-to-neutral voltage magnitude $V_{1,LN}[n]$ according to *Equation 4.1*.

$$V_{1,LL}[n] = \sqrt{3} \cdot V_{1,LN}[n]$$

**Equation 4.1**

where $n$ is the sample index at time $t_n$ sec. The dv/dt signals are calculated according to *Equation 4.2*.

$$\frac{d}{dt} V_{1,LL}[n] = \frac{V_{1,LL}[n] - V_{1,LL}[n-1]}{t_n - t_{n-1}}$$

**Equation 4.2**

where $t_n > t_{n-1}$.

## Configuring the Voltage Monitor

### Opening Configuration File

To configure thresholds for voltage magnitude and dv/dt signals, download Thresholds.csv and TimeSettings.csv for the Voltage Monitor application. For initial configuration or if new signals have been added to the system, use the Query and Download option for Thresholds.csv file. Modify both files as necessary (see details below) and import back into Synchrowave.

### Set Grouping Parameters (PickupTime, DropoutTime, and GroupTime)

Set the grouping parameters in TimeSettings.csv as described in *Condition Generation on page 69*.

### Set Thresholds and Assign Time Groups

Thresholds are set independently for voltage magnitude and dv/dt signals in volts and volts/s, respectively, for each measurement point where monitoring is desired. For static thresholds, enter float values into the HighAlert, HighWarning, LowWarning, and LowAlert columns in the Thresholds.csv file. For dynamic thresholds, enter signal names directly into the file. Signal names are defined as MeasurementPoint:DataType. Each measurement point can support a mixture of static and dynamic thresholds. Any of the thresholds can be

individually disabled by assigning the numerical value to **NaN**. The thresholds must satisfy HighAlert ≥ HighWarning ≥ LowWarning ≥ LowAlert and all of them cannot be set to zero. Assign a TimeGroupID consistent with the time groups defined in the TimeSettings.csv.

## Voltage Condition

The Voltage Monitor generates conditions of the voltage type according to the Condition Generation procedure. Conditions for voltage magnitude and dv/dt signals are generated independently when they have different TimeGroupIDs. Otherwise, conditions for both signal types are grouped by voltage condition.

# Phase Angle Monitor Application

The Phase Angle Monitor application provides the ability to monitor phase angle differences (PAD) across transmission lines. The phase angle conditions are reported to the Notification application.

## PAD Calculation

The PAD is calculated from positive-sequence line-to-neutral voltage angles $\phi_X$ and $\phi_Y$ measured respectively at two distinct terminals (X and Y) of a transmission line according to *Equation 4.3*.

$$PAD = |\phi_X - \phi_Y|$$

**Equation 4.3**

where | | represents the absolute value of the underlying quantity. The PAD is wrapped within [0, 180] degrees.

## Configuring the Phase Angle Monitor

### Opening Configuration File

To configure thresholds for PAD signals, download Thresholds.csv and TimeSettings.csv for the Phase Angle Monitor application. For initial configuration or if new signals have been added to the system, use the Query and Download option for the Thresholds.csv file. Modify both files as necessary (see details below) and import back into Synchrowave.

## Set Grouping Parameters (PickupTime and DropoutTime)

Set the grouping parameters in TimeSettings.csv as described in *Condition Generation on page 69*. Conditions for multiple PAD signals cannot be grouped, and therefore the GroupTime parameter is ignored.

### Set Thresholds

Thresholds are set independently for each transmission line where monitoring is desired. For static thresholds, enter float values into the HighAlert, HighWarning, LowWarning, and LowAlert columns in the Thresholds.csv file. For dynamic thresholds, enter signal names directly into the file. Signal

names are defined as MeasurementPoint:DataType. Each measurement point can support a mixture of static and dynamic thresholds. Any of the thresholds can be individually disabled by assigning the numerical value to **NaN**. The thresholds must satisfy HighAlert ≥ HighWarning and both cannot be set to zero. Assign a TimeGroupID consistent with the time groups defined in the TimeSettings.csv file.

## Angle Condition

The Phase Angle Monitor generates conditions of the angle type according to the Condition Generation procedure. The conditions of multiple PAD signals are not grouped when GroupTime is set to 0 seconds. Therefore, two separate conditions are generated when two PAD signals cross their configured threshold at the same time.

# Power Monitor Application

The Power Monitor automatically computes real, reactive, and apparent powers, and power factors for power system line assets. See *Power System Model Application on page 176* for details on defining line assets. The power monitor compares power measurements to their limits and provides operators with an indication of the amount of power being transferred by an asset.

## Power Calculation

Single- and three-phase powers and power factors are calculated at each terminal of a transmission line from current and voltage phasor measurements at that terminal. Current measurements are associated with the Line Asset measurement points. Voltage measurements can be associated with the either measurement point on the Line Asset itself or on the adjacent Bus to the Line Asset. The resulting power calculations will be assigned to the measurement point associated with the Line Asset.

**NOTE**
The Power Monitor only works on voltage and current signals that use standard quantity names (see Standard Quantities on page 24).

Consider the voltage and current phasor measurements at a terminal line for phase $x$ by using $V_x\angle\theta_{Vx}$ and $I_x\angle\theta_{Ix}$, respectively. Then power and power factors for phase $x = [A,B,C]$ are calculated according to the following:

Single-phase apparent power: $S_x = V_x I_x$

Single-phase real power: $P_x = V_x I_x \cos(\theta_{Vx} - \theta_{Ix})$

Single-phase reactive power: $Q_x = V_x I_x \sin(\theta_{Vx} - \theta_{Ix})$

Single-phase power factor: $PF_x = |\cos(\theta_{Vx} - \theta_{Ix})|$

The three-phase powers are then calculated according to the following:

Three-phase apparent power: $S_{ABC} = \sqrt{P_{ABC}^2 + Q_{ABC}^2}$

Three-phase real power: $P_{ABC} = P_A + P_B + P_C$

Three-phase reactive power: $Q_{ABC} = Q_A + Q_B + Q_C$

Three-phase power factor: $PF_{ABC} = \left|\frac{P_{ABC}}{S_{ABC}}\right|$

When A-, B-, and C-phase voltages and currents are not available, then three-phase powers are calculated from positive-sequence voltage $V_1\angle\theta_{V1}$ and current $I_1\angle\theta_{I1}$ according to the following:

Positive-sequence apparent power: $S_1 = 3V_1I_1$

Positive-sequence real power: $P_1 = 3V_1I_1 \cos(\theta_{V1} - \theta_{I1})$

Positive-sequence reactive power: $Q_1 = 3V_1I_1 \sin(\theta_{V1} - \theta_{I1})$

Positive-sequence power factor: $PF_1 = |\cos(\theta_{V1} - \theta_{I1})|$

# Configuring the Power Monitor

## Opening Configuration File

To configure thresholds for power signals, download Thresholds.csv and TimeSettings.csv for the Power Monitor application . For initial configuration or if new signals have been added to the system, use the Query and Download option for the Thresholds.csv file. Modify both files as necessary (see details below) and import back into Synchrowave.

## Set Grouping Parameters (PickupTime, DropoutTime, and GroupTime)

Set the grouping parameters in TimeSettings.csv as described in *Condition Generation on page 69*.

## Set Thresholds and Assign Time Groups

Thresholds are set for three-phase apparent power, real power, and reactive power signals for each terminal of transmission lines in volt-amperes (VA), watts (W), and in volt-amperes reactive (VAR), respectively. For static thresholds, enter float values into the HighAlert, HighWarning, LowWarning, and LowAlert columns in the Thresholds.csv file. For dynamic thresholds, enter signal names directly into the file. Signal names are defined as MeasurementPoint:DataType. Each measurement point can support a mixture of static and dynamic thresholds. Any of the thresholds can be individually disabled by assigning the numerical value to **NaN**. The thresholds must satisfy HighAlert ≥ HighWarning ≥ LowWarning ≥ LowAlert and all of them cannot be set to zero. Assign a TimeGroupID consistent with the time groups defined in TimeSettings.csv.

# Power Condition

The Power Monitor generates conditions of the power type according to the Condition Generation procedure. Using TimeGroupID settings conditions for real, reactive, and apparent powers can be generated independently or grouped by power condition.

# Oscillation Monitor Application

The Oscillation Monitor application detects and characterizes sustained oscillations in power system signals. Its primary use is to quickly and reliably detect oscillations and bring them to the attention of the user. Supported signal types are Frequency, Voltage Magnitude, PAD, Real Power, and Reactive Power.

The Oscillation Monitor uses a frequency-domain technique to break the input signal into configurable frequency bands and estimate the rms oscillation magnitude in each. The oscillation magnitudes are published with the same Measurement Point as the input signals, and with Quantities of the form [Input Signal Quantity].[BinName].Oscillation.Magnitude. For example, if the input signal is Pullman.North:Phase1.Voltage.Magnitude and two oscillation frequency bands named bin1 and bin2 were configured, the resulting oscillation signal names would be Pullman.North:Phase1.Voltage.Magnitude.bin1.Oscillation.Magnitude and Pullman.North:Phase1.Voltage.Magnitude.bin2.Oscillation.Magnitude.

*Figure 4.7* shows an example of the Oscillation Monitor output. The input voltage waveform (the top graph in the figure) shows a 0.35 Hz oscillation with a magnitude of about 1,400 V peak-to-peak, which corresponds to just under 500 Vrms. During the oscillation, the Oscillation Monitor reports an oscillation magnitude of about 500 V in bin2 (i.e., in the frequency range of 0.15 Hz to 1 Hz, as shown in *Configuring the Frequency Bins on page 79*).

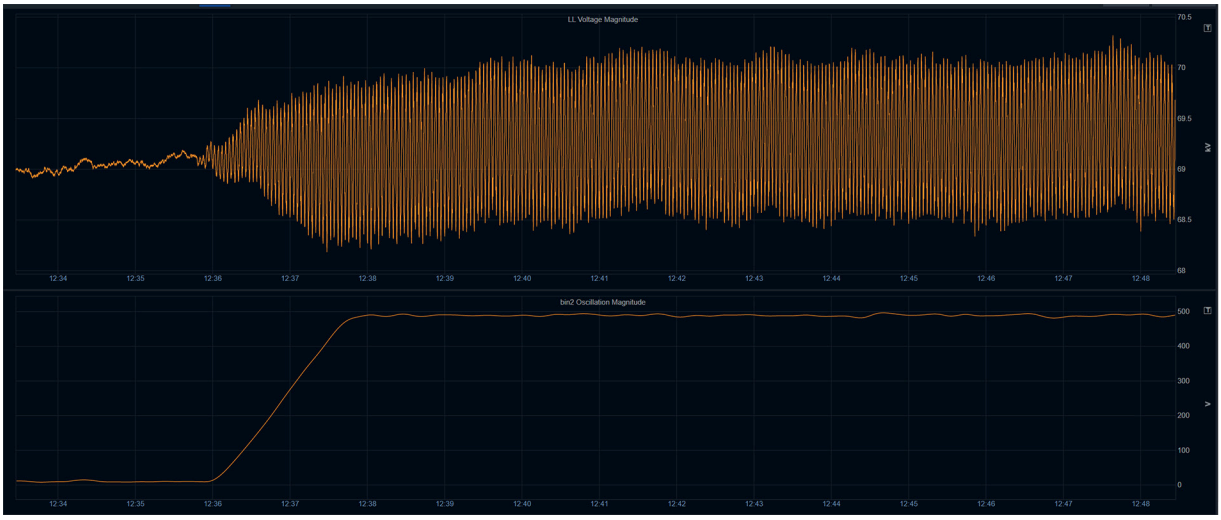



**Figure 4.7 Oscillation Monitor Output Example**

Oscillation magnitudes can be monitored to produce notifications when they exceed configurable thresholds. Multiple signals can be grouped for monitoring. When two or more grouped signals exceed their thresholds and a notification is created, the application sorts the measurement points reported by the notification in order of oscillation magnitude. The largest magnitude is reported as the first measurement point. In many cases, the largest oscillation magnitude is seen nearest to the source of the oscillation. Therefore, the order of the measurement points in the notification list can be used as an indication of the oscillation source location.

# Configuring the Oscillation Monitor

The Oscillation Monitor is configured from the Application Manager page via .csv files. Configuration is simplest if performed in the following order.

## Configuring the Frequency Bins

RMS oscillation magnitudes will be computed for each frequency range defined in the FrequencyBins.csv file. Define a frequency bin by adding a string in the BinName column and specify its frequency range in the StartFrequency (Hz) and StopFrequency (Hz) columns. The range is inclusive on start and exclusive on stop, and frequency ranges for different bins can overlap. As many as ten frequency bins can be defined. Frequency ranges are limited on the upper end by the Nyquist rate (i.e., half the message rate) of the input signal. *Figure 4.8* shows the default configuration.

| | A | B | C |
|---|---|---|---|
| 1 | BinName | StartFrequency (Hz) | StopFrequency (Hz) |
| 2 | bin1 | 0.01 | 0.15 |
| 3 | bin2 | 0.15 | 1 |
| 4 | bin3 | 1 | 5 |
| 5 | bin4 | 5 | 14 |

**Figure 4.8 Oscillation Monitor Frequency Band Configuration**

## Configuring the Signals

The Signals.csv file defines signals to be analyzed, as shown in the example file in *Figure 4.9*. One Measurement Point per station is often sufficient for detecting and locating persistent oscillations.

| | 1 | 2 |
|---|---|---|
| 1 | MeasurementPoint | Quantity |
| 2 | Station1.Bus3 | Phase1.Voltage.Magnitude |
| 3 | Station2.Bus1 | Phase1.Voltage.Magnitude |
| 4 | Station3.Bus1 | Phase1.Voltage.Magnitude |

**Figure 4.9 Oscillation Monitor Signals Configuration**

## Configuring Oscillation Monitoring

Monitoring of oscillation magnitude signals for producing notifications is configured using the Thresholds.csv and TimeSettings.csv files. Once the Signals.csv and FrequencyBins.csv files have been configured, select **Query and Download** to autopopulate the Thresholds.csv file with all the oscillation magnitude signals presently being published by the Oscillation Monitor. *Figure 4.10* shows an example Thresholds.csv file.

To determine threshold levels, SEL recommends first allowing the Oscillation Monitor to run for a few weeks. Then examine typical levels and set the thresholds just higher than those. Enter "NaN" (not a number) for any Warning or Alert levels that you do not want active.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | MeasurementPoint | Quantity | Units | HighAlert | HighWarning | LowWarning | LowAlert | TimeGroupID |
| 2 | Station1.Bus3 | Phase1.Voltage.Magnitude.bin1.Oscillation.Magnitude | V | 200 | NaN | NaN | NaN | groupLow1 |
| 3 | Station1.Bus3 | Phase1.Voltage.Magnitude.bin2.Oscillation.Magnitude | V | 200 | NaN | NaN | NaN | groupLow2 |
| 4 | Station1.Bus3 | Phase1.Voltage.Magnitude.bin3.Oscillation.Magnitude | V | 100 | NaN | NaN | NaN | groupHigh1 |
| 5 | Station1.Bus3 | Phase1.Voltage.Magnitude.bin4.Oscillation.Magnitude | V | 100 | NaN | NaN | NaN | groupHigh2 |
| 6 | Station2.Bus1 | Phase1.Voltage.Magnitude.bin1.Oscillation.Magnitude | V | 200 | NaN | NaN | NaN | groupLow1 |
| 7 | Station2.Bus1 | Phase1.Voltage.Magnitude.bin2.Oscillation.Magnitude | V | 200 | NaN | NaN | NaN | groupLow2 |
| 8 | Station2.Bus1 | Phase1.Voltage.Magnitude.bin3.Oscillation.Magnitude | V | 100 | NaN | NaN | NaN | groupHigh1 |
| 9 | Station2.Bus1 | Phase1.Voltage.Magnitude.bin4.Oscillation.Magnitude | V | 100 | NaN | NaN | NaN | groupHigh2 |
| 10 | Station3.Bus1 | Phase1.Voltage.Magnitude.bin1.Oscillation.Magnitude | V | 200 | NaN | NaN | NaN | groupLow1 |
| 11 | Station3.Bus1 | Phase1.Voltage.Magnitude.bin2.Oscillation.Magnitude | V | 200 | NaN | NaN | NaN | groupLow2 |
| 12 | Station3.Bus1 | Phase1.Voltage.Magnitude.bin3.Oscillation.Magnitude | V | 100 | NaN | NaN | NaN | groupHigh1 |
| 13 | Station3.Bus1 | Phase1.Voltage.Magnitude.bin4.Oscillation.Magnitude | V | 100 | NaN | NaN | NaN | groupHigh2 |

**Figure 4.10 Oscillation Monitor Thresholds Configuration**

Signal grouping and timing characteristics are configured in the TimeSettings.csv file. See *Condition Generation on page 69* for details on timing parameters. *Figure 4.11* shows an example TimeSettings.csv file. The NotificationType field is used for associating these notifications with Notification Template folders. It cannot contain spaces.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | TimeGroupID | PickupTime (s) | DropoutTime (s) | GroupTime (s) | NotificationType |
| 2 | groupLow1 | 60 | 5 | 20 | Oscillation_Voltage |
| 3 | groupLow2 | 60 | 5 | 20 | Oscillation_Voltage |
| 4 | groupHigh1 | 20 | 5 | 20 | Oscillation_Voltage |
| 5 | groupHigh2 | 20 | 5 | 20 | Oscillation_Voltage |

**Figure 4.11 Oscillation Monitor Time Settings Configuration**

Consider the following when filling out the Thresholds.csv and TimeSettings.csv files:

- Signals with the same TimeGroupID must have the same Quantity.
- Oscillation magnitudes are estimated from windows of data. For frequency ranges that contain frequencies below 0.2 Hz, the window is 40 seconds long; for ranges in which all frequencies are above 0.2 Hz, the window is 10 seconds long. To avoid spurious notifications, the PickupTime should be set longer than these window lengths. For example, in *Figure 4.11*, the two low frequency ranges have pickup times greater than 40 seconds and the two high frequency ranges have pickup times longer than 10 seconds.
- As previously noted, if multiple signals with the same TimeGroupID move into an alarm state, the signals in the resulting notification are sorted by oscillation magnitude. Oscillations are often largest at stations nearest to the oscillation source, so this ordering can be used as a guide for finding the source. This works best if the signals at each station are as similar as possible. For example, voltage magnitude signals should only be grouped for locating purposes if they have the same nominal voltage level.

## Configuring Algorithm Parameters

The oscillation_monitor_parameters.json file contains internal algorithm parameters. Consult SEL before changing any parameters in this file.

# Disturbance Detector Application

The disturbance detector application is a frequency-domain anomaly estimator used to identify unusual disturbances on the power system. The application calculates spectral energy contained in windows of synchrophasor frequency measurements, grouping that energy into predefined frequency bins, and statistically analyzing the variation of the energy contained in these frequency bins for anomalous behavior. The spectral energy estimates are published as energy signals for all specified frequency bins.

In addition to the energy signals, the application also produces statistical disturbance estimates as ZLevel signals. The ZLevel signal value is calculated by subtracting the present value for the bin energy from its mean and dividing by the standard deviation. The ZLevel value is therefore a derived statistic, given in units of standard deviations. Mean and standard deviation are calculated individually for each frequency bin from recent synchrophasor measurements.

The Energy and ZLevel signals can be monitored using the Signal Monitor (see *Signal Monitor Application on page 82*) to detect disturbances. When expected energy levels of the signals being used for disturbance monitoring are known (perhaps via some baseline analyses) in normal operating conditions, the thresholds can be set for the Energy signals based off those expected values. The ZLevel signals are advantageous for disturbance detection when a good knowledge of the signal energy is not available. As Zlevels are normalized quantities, their thresholds will be in terms of standard deviations to detect statistical abnormality. In many applications, monitoring the ZLevel signals is sufficient for disturbance detection.

## Configuring the Disturbance Detector

### Opening the Configuration File

To configure the Disturbance Detector application, download the FrequencyBins.csv and Signals.csv. Modify these files as necessary and import back into Synchrowave.

### Defining the Frequency Bins and Specify Signal

In the FrequencyBins.csv file, define a frequency bin by adding a string in the BinName column and specify its frequency range in the StartFrequency (Hz) and StopFrequency (Hz) columns. The range is inclusive on start and exclusive on end. The frequency ranges for different bins can overlap. No more than ten frequency bins can be defined. An example is shown in *Figure 4.12*.

| | A | B | C |
|---|---|---|---|
| 1 | BinName | StartFrequency (Hz) | StopFrequency (Hz) |
| 2 | Band1_0p01_0p15_Hz | 0.01 | 0.15 |
| 3 | Band2_0p15_1_Hz | 0.15 | 1 |
| 4 | Band3_1_5_Hz | 1 | 5 |
| 5 | Band4_5_14_Hz | 5 | 14 |

**Figure 4.12 Disturbance Detector Frequency Band Configuration**

Energy and ZLevel estimation signals are specified in the Signals.csv file using measurement points and quantity columns. Only frequency signals are allowed for disturbance estimation. An example is shown in *Figure 4.13*.

| | A | B | C |
|---|---|---|---|
| 1 | MeasurementPoint | Quantity | |
| 2 | BE.TL23010 | Frequency | |
| 3 | CE.TL23042 | Frequency | |
| 4 | CF.TL50005 | Frequency | |
| 5 | CJ.BUS230 | Frequency | |
| 6 | EL.BUS230 | Frequency | |
| 7 | GC.BUS230 | Frequency | |

**Figure 4.13 Disturbance Detector Signals Configuration**

# Signal Monitor Application

The Signal Monitor application provides the ability to monitor any signals that do not have a dedicated monitor and report conditions to the Notification application. Example signals include current, temperature, and calculated signals from the Calculation application. Conditions generated by the Signal Monitor are of type General by default, but type is also configurable. If a custom type is configured, conditions are displayed in the All tile.

**Figure 4.14 Signal Monitor Conditions Display Via General or All Notification Tile**

## Configuring the Signal Monitor

### Opening Configuration File

To configure thresholds, download Thresholds.csv and TimeSettings.csv for the Signal Monitor application. Modify both files as necessary (see details below) and import back into Synchrowave.

### Setting Grouping Parameters (PickupTime and DropoutTime) and Notification Type

Set the grouping parameters in TimeSettings.csv as described in *Condition Generation on page 69*. Set the Notification Type in the last column of the TimeSettings.csv file. If empty, the Notification Type defaults to General. Setting the Notification Type allows for the creation of dashboard templates that are displayed when conditions associated with a given type occur.

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | TimeGroupID | PickupTime (s) | DropoutTime (s) | GroupTime (s) | NotificationType |
| 2 | g1 | 0.1 | 0.1 | 1 | Disturbance |

**Figure 4.15 Grouping Parameters and Notification Type Configuration**

### Setting Thresholds

Thresholds are set independently for each signal where monitoring is desired. For static thresholds, enter float values into the HighAlert, HighWarning, LowWarning, and LowAlert columns in the Thresholds.csv file. For dynamic thresholds, enter signal names directly into the file. Signal names are defined as MeasurementPoint:DataType. Each measurement point can support a mixture of static and dynamic thresholds. Any of the thresholds can be individually disabled by assigning the numerical value to **NaN**. The thresholds must satisfy HighAlert ≥ HighWarning and both cannot be set to zero. Assign a TimeGroupID consistent with the time groups defined in the TimeSettings.csv file.

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | MeasurementPoint | Quantity | Units | HighAlert | HighWarning | LowWarning | LowAlert | TimeGroupID |
| 2 | SubstationA | Temperature | | 100 | 90 | 32 | 0 | Temperature |
| 3 | SubstationB | Temperature | | 100 | 90 | 32 | 0 | Temperature |
| 4 | SubstationA | Humidity | | 95 | 90 | NaN | NaN | Humidity |
| 5 | SubstationB | Humidity | | 95 | 90 | NaN | NaN | Humidity |

**Figure 4.16 Signal Monitor Application Configuration, Thresholds.csv Shown in a Spreadsheet Application**

## Signal Condition

The Signal Monitor generates conditions of the general type according to *Condition Generation on page 69*. Conditions for general signals are generated independently when they have different TimeGroupIDs.

# Instrument Transformer Monitor Application

The Instrument Transformer Monitor application monitors three-phase voltage signals for anomalies that may indicate a failing instrument transformer, such as a potential transformer (PT) or its fuse. These devices often exhibit rapid, intermittent voltage deviations for a variety of reasons; for example, arcing between transformer coils. The application computes and publishes signals for each phase that indicate the percentage of recent signal samples showing anomalous behavior. The signals have the same Measurement Point as the input signal and Quantity name Phase[A,B,C].Voltage.FailPercent. Notifications are generated when the percentages exceed a configurable threshold.

**NOTE**
Instrument transformer monitoring is supported for three-phase voltage measurements captured at the following message rates: 25 samples/s, 30 samples/s, 50 samples/s, and 60 samples/s.

## Configuring Instrument Transformer Monitor

To configure the Instrument Transformer Monitor, select the application in the Application Manager page. Download the MeasurementPoints.csv file, fill out the desired measurement points, and import back into Synchrowave.

| | A |
|---|---|
| 1 | MeasurementPoint |
| 2 | StationA.Bus1 |

**Figure 4.17 Instrument Transformer Monitor Configuration, MeasurementPoints.csv**

Then download the Thresholds.csv file using the Download and Query option. It will automatically populate with the available anomaly detection signals. Configure the desired warning and alert thresholds (a good starting point for high thresholds is 1-3 percent, but ideal values are system-dependent). In most cases, the low thresholds should be disabled by assigning them a value of **NaN**. Download the TimeSettings.csv file and edit as necessary. In the Thresholds.csv file, assign a TimeGroupID consistent with the time groups defined in the TimeSettings.csv. Import both files back into Synchrowave.

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | MeasurementPoint | Quantity | Units | HighAlert | HighWarning | LowWarning | LowAlert | TimeGroupID |
| 2 | StationA.Bus1 | PhaseA.Voltage.FailPercent | % | 2.5 | 1.5 | NaN | NaN | group1 |
| 3 | StationA.Bus1 | PhaseB.Voltage.FailPercent | % | 2.5 | 1.5 | NaN | NaN | group1 |
| 4 | StationA.Bus1 | PhaseC.Voltage.FailPercent | % | 2.5 | 1.5 | NaN | NaN | group1 |

**Figure 4.18 Instrument Transformer Monitor Configuration, MeasurementPoints.csv**

All Measurement Points configured in the Instrument Transformer Monitor must also be configured in the Power System Model with the correct line-line nominal voltage. Notifications from this application will appear under the All button in the Notifications Summary with **Instrument** as their NotificationType. Custom dashboards can be created for this NotificationType.

## Configuring Algorithm Parameters

The instrument_transformer_monitor_parameters.json file contains internal algorithm parameters. Consult SEL before changing any parameters in this file.

# Modal Analysis Application

The Modal Analysis application characterizes low-frequency electromechanical oscillations by estimating mode frequency, damping, and relative mode shape from synchrophasor measurements. During ambient conditions, it applies an ambient processing algorithm to a long window of data. If a significant event is detected in the data, it attempts to use a faster and more responsive algorithm to detect when mode properties are changing rapidly. If the faster algorithm is successful, a mode magnitude signal that is an estimate of the mode size in units of the input signal is also published.

Modal Analysis is supported for frequency, real power, reactive power, voltage magnitude, and phase angle difference (PAD) measurements captured at the following message rates: 25 samples per second, 30 samples per second, 50 samples per second, and 60 samples per second.

An example Modal Analysis output is shown in *Figure 4.19*. The data analyzed are from SEL's network of office PMUs and show results for the well-studied North-South A mode in the Western Interconnection. Estimated mode frequency and damping are shown on the left and mode shapes for several locations are shown on the right.

**Figure 4.19 Modal Analysis Example**

Mode damping and mode magnitude signals can be monitored to generate notifications when they cross user-configurable thresholds.

# Configuring Modal Analysis

Modal Analysis is configured from the Application Manager page via .csv files. Configuration is simplest if performed in the following order.

## Configure Signal Groups

Modal analysis uses a multichannel algorithm capable of estimating mode properties from multiple signals simultaneously. This means that for grouped signals, a single mode frequency and damping will be estimated for each configured mode.

The SignalGroups.csv file defines groups of signals for analysis and allows for enabling or disabling the mode shape calculation. An example is shown in *Figure 4.20*. Multiple groups are allowed, but measurement points with the same GroupName must have the same Quantity. Set EnableModeShape to True to enable mode shape calculations or False to disable them. (Not calculating mode shapes reduces required processing power.) EnableModeShape should be set the same for all measurement points in a group. When EnableModeShape is True for multiple measurement points in the same group, mode shapes are calculated relative to the first measurement point listed in the group.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | MeasurementPoint | Quantity | GroupName | EnableModeShape |
| 2 | Calgary_AB | Frequency | WI | TRUE |
| 3 | Irvine_CA | Frequency | WI | TRUE |
| 4 | Phoenix_AZ | Frequency | WI | TRUE |
| 5 | Provo_UT | Frequency | WI | TRUE |
| 6 | Pullman_WA | Frequency | WI | TRUE |

**Figure 4.20 Modal Analysis Signal Group Configuration**

## Configure Modes

For each configured group of signals, frequency ranges for modes to be reported are configured in the ModeMappings.csv file. An example is shown in *Figure 4.21*.

Each mode is associated with a frequency band and a GroupName. The frequency band is defined as ModeFrequency ± Tolerance. The frequency bands must not overlap for multiple modes assigned to the same signal group. As many as ten modes are allowed for each signal group. Frequency bands are limited to between 0.05 Hz and 2.5 Hz. ModeName must be unique for each row in ModeMappings.csv (including across multiple groups).

Modes with an unknown frequency range can be defined by assigning the value "NaN" to both ModeFrequency and Tolerance. The strongest dominant electromechanical mode outside the defined frequency bands is automatically assigned to a mode with an unknown frequency range.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | GroupName | ModeName | ModeFrequency (Hz) | Tolerance (Hz) |
| 2 | WI | NSA | 0.275 | 0.05 |
| 3 | WI | Other | NaN | NaN |

**Figure 4.21 Modal Analysis Mode Configuration**

## Set Thresholds and Assign Time Groups

Mode damping and magnitude thresholds are configured in the Thresholds.csv file. Once the SignalGroups.csv and ModeMappings.csv files are successfully imported, select **Query and Download** to autopopulate the Thresholds.csv file with all mode damping and magnitude signals available for monitoring. *Figure 4.22* shows an example Thresholds.csv file.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | MeasurementPoint | Quantity | Units | HighAlert | HighWarning | LowWarning | LowAlert | TimeGroupID |
| 2 | NSA | Mode.Damping | % | NaN | NaN | 8 | 3 | damping |
| 3 | Calgary_AB.NSA | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 4 | Irvine_CA.NSA | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 5 | Phoenix_AZ.NSA | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 6 | Provo_UT.NSA | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 7 | Pullman_WA.NSA | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 8 | Other | Mode.Damping | % | NaN | NaN | 8 | 3 | damping |
| 9 | Calgary_AB.Other | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 10 | Irvine_CA.Other | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 11 | Phoenix_AZ.Other | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 12 | Provo_UT.Other | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |
| 13 | Pullman_WA.Other | Frequency.Mode.Magnitude | Hz | 0.1 | NaN | NaN | NaN | magnitude |

**Figure 4.22 Modal Analysis Threshold Configuration**

Timing characteristics are configured in the TimeSettings.csv file. See *Condition Generation on page 69* for details on timing parameters. *Figure 4.23* shows an example TimeSettings.csv file.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | TimeGroupID | PickupTime (s) | DropoutTime (s) | GroupTime (s) | NotificationType |
| 2 | damping | 1 | 5 | 10 | Oscillation_Mode_Damping |
| 3 | magnitude | 1 | 5 | 10 | Oscillation_Mode_Magnitude |

**Figure 4.23 Modal Analysis Time Settings Configuration**

## Configuring Algorithm Parameters

The modal_analysis_parameters.json file contains internal algorithm parameters. Consult SEL before changing any parameters in this file.

# Modal Analysis Published Signals

Modal Analysis publishes mode damping and frequency signals continuously for each mode in ModeMappings.csv as long as mode frequencies are found in the configured range(s). Mode frequencies are published as [ModeName].Mode.Frequency and damping is published as [ModeName].Damping. Mode frequency is reported in Hz and damping is reported as a percentage.

If EnableModeShape is True for a group of measurement points in SignalGroups.csv, mode shapes are also published continuously for each measurement point and mode combination for that group. Mode shapes are relative quantities with a magnitude and angle. Magnitudes are normalized to the largest current value in the group, so they are always between 0 and 1 (and unitless). Mode shape magnitudes are published as [MeasurementPoint].[ModeName]:ModeShape.Magnitude and angles are published as [MeasurementPoint].[ModeName]:ModeShape.Angle. Mode shapes can be effectively visualized on a Phase Scope panel by selecting ModeShape.Angle as the Quantity, turning on the **Show Magnitudes** option, and setting **Magnitude Limit** to 1.

When a significant event is detected, the algorithm attempts to calculate modal properties from the ringdown from the event. If successful, mode magnitudes are also published with the same units as the input signal for each measurement and mode combination in each group. These quantities will be published rarely. Mode magnitudes are published as [MeasurementPoint].[ModeName]:[UnitPrefix].ModeShape.Magnitude. UnitPrefix is one of the following (depending on the quantity of the input signal): Frequency, Voltage, PAD, Power.Real, or Power.Reactive.

# Generation Trip Locator Application

The Generation Trip Locator application attempts to localize events involving an abrupt and significant real power deficit. When significant real power is lost on a network because of, for example, a large generation trip or loss of a tie line, a rapid, system-wide drop in frequency follows. The order in which measurement stations observe the frequency drop is a good proxy for their proximity to the event. The Generation Trip Locator application detects significant system-wide frequency drops and then sorts configured signals by the order in which they experience the drop. It provides the ordered list to the Notifications application and includes a map layer for visualization. Notifications for this application will appear under the All button in the Notifications Summary with **GenerationTrip** as their NotificationType.

**NOTE**
Generation Trip Locator supports positive-sequence voltage measurements captured at the following message rates: 25 samples/s, 30 samples/s, 50 samples/s, and 60 samples/s.

## Configuring Generation Trip Locator

To configure the Generation Trip Locator, download the MeasurementPoints.csv file, enter desired Measurement Points, and import back into Synchrowave. All configured measurement points must also be in the Power System Model. For best performance, no more than one measurement point per station should be configured.

| | A |
|---|---|
| 1 | MeasurementPoint |
| 2 | Station1.Bus1 |
| 3 | Station2.Bus1 |
| 4 | Station3.Bus3 |

**Figure 4.24 Generation Trip Locator Configuration, MeasurementPoints.csv**

## Configuring Algorithm Parameters

The Generation Trip Locator application has a number of configurable parameters to fine-tune performance contained in the gen_trip_monitor_parameters.json file. For example, there are parameters for minimum frequency deviation and minimum number of stations affected (the default is 6) for an event to be declared a generation trip. If generation trips are not being detected or the algorithm is generating notifications spuriously for a specific customer system, please contact Schweitzer Engineering Laboratories.

# Configuring Generation Trip Map Layer

The Generation Trip Map Layer draws circles of configurable number and size to visualize proximity to the event. The largest circles are drawn at locations nearest to the event and circle size decreases as stations are farther from the event.

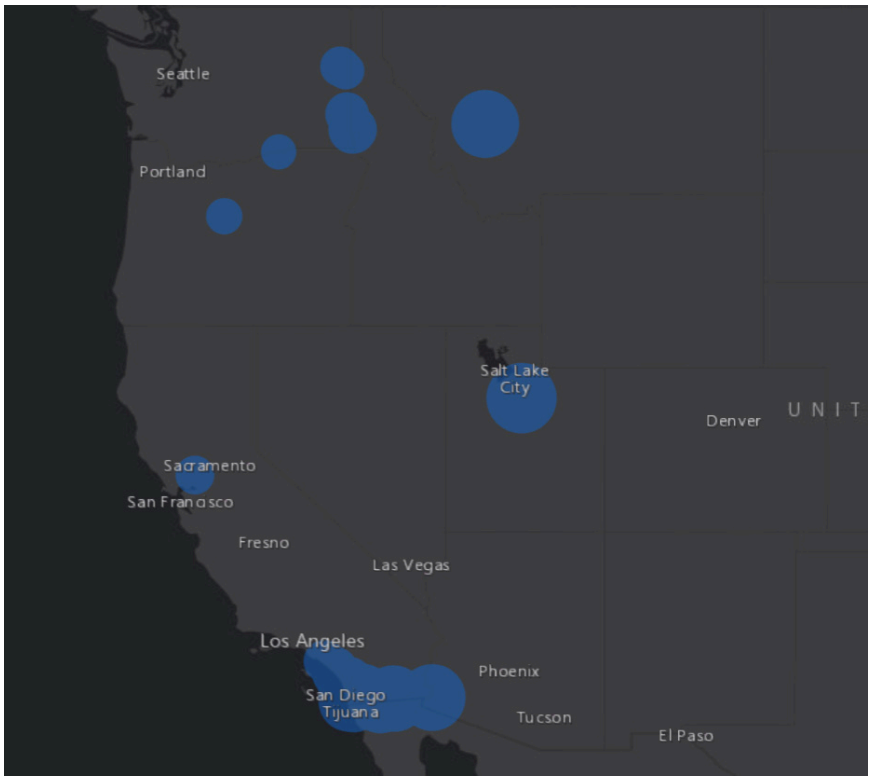



**Figure 4.25 Generation Trip Map Layer**

To configure the map layer, first create a Notification Template for a NotificationType of **GenerationTrip**. Place an Esri Map Panel on the dashboard template and set the GenerationTrip Map Layer as Visible. The number and size of circles can be configured on the **Layer Options** tab.

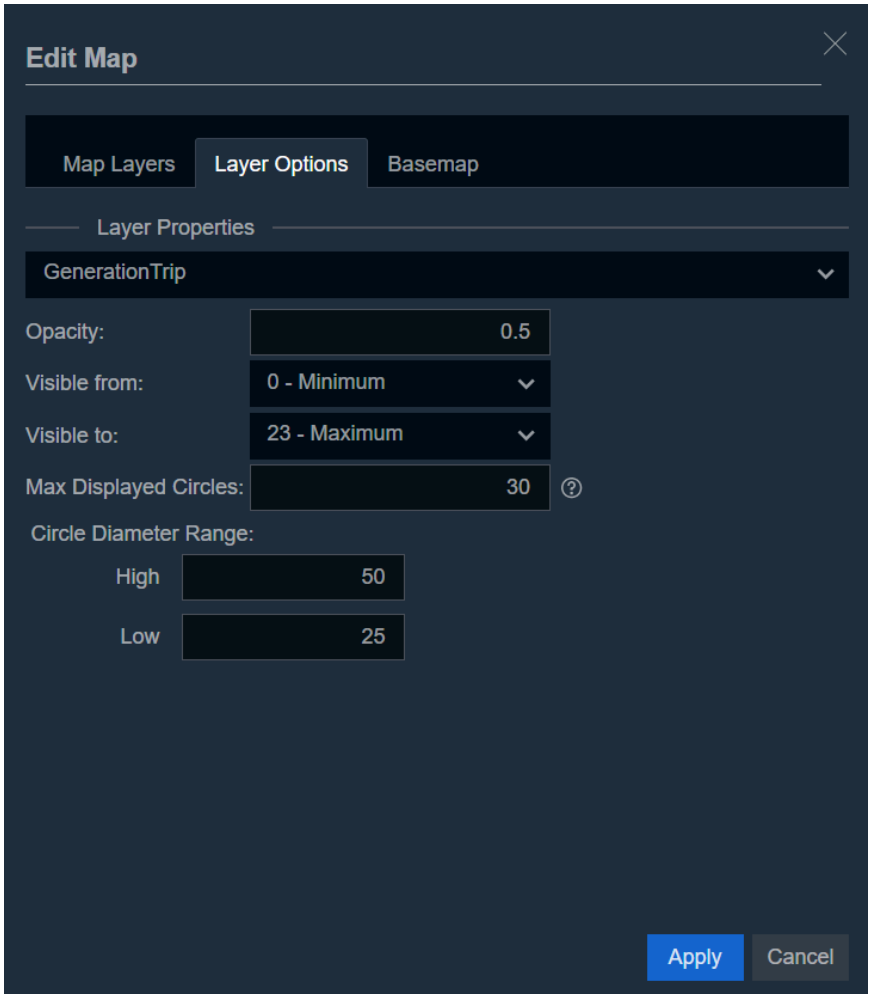



**Figure 4.26 Generation Trip Map Layer Configuration**

# Synchrowave Vision

Synchrowave Vision annotates a Time-Series Trend Panel with an indicator that a Generation Trip and/or Oscillation has been detected, along with the nearest Measurement Point.

**Figure 4.27 Synchrowave Vision Indicator**

Any Time-Series Trend Panel can be configured to include Synchrowave Vision from the **Settings** tab of the Trend Panel configuration. Select the dropdown icon beneath **Vision Alarm Type** to select the desired type(s). If **Oscillation** is selected, any alarms produced by either the Oscillation Monitor or Modal Analysis applications will appear as Synchrowave Vision annotations.

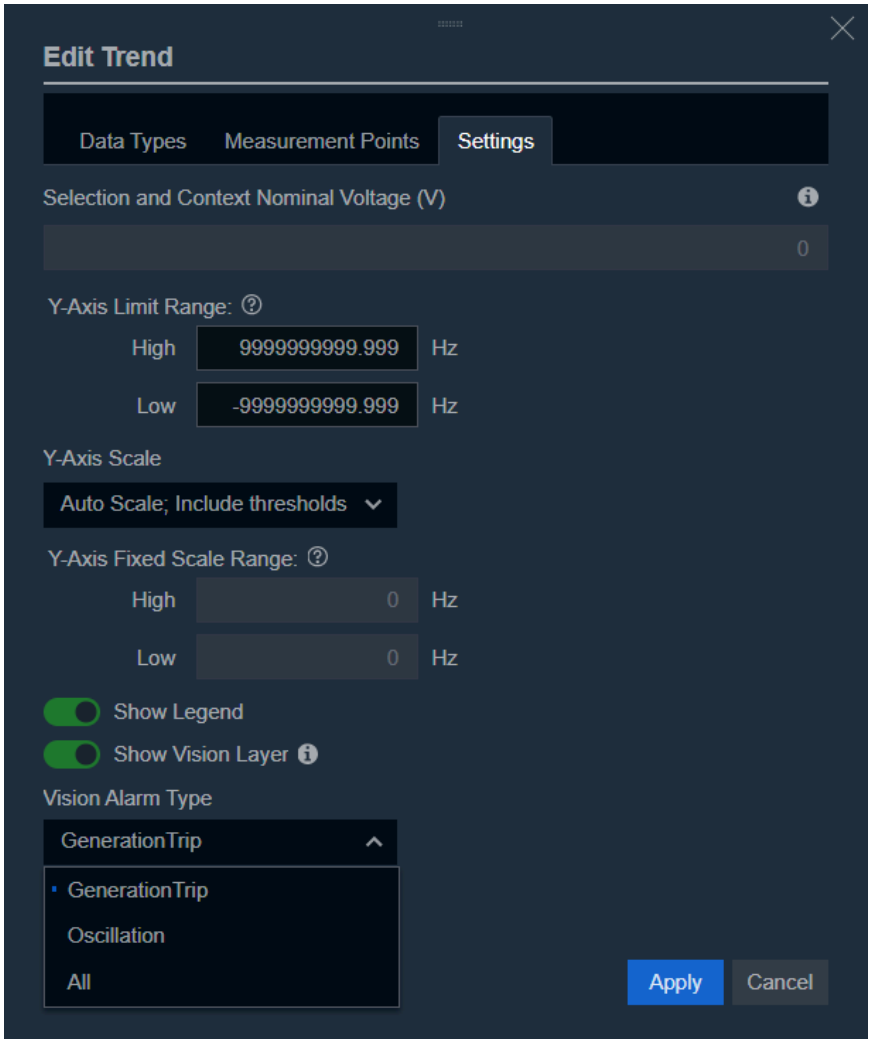



**Figure 4.28 Enable Synchrowave Vision**

# Sequence Calculator Application

The Sequence Calculator application calculates line-to-line and positive-, negative-, and zero-sequence voltages and currents from three-phase voltage and current inputs. It publishes these calculated signals to the Synchrowave Platform signal bus.

## Sequence (Symmetrical) Component Calculations

Given three-phase voltage or current inputs, sequence component calculations are defined in the following subsections, depending on configurable phase rotation.

### ABC Phase Rotation

When phase rotation is configured to *abc*, sequence components are calculated from three-phase voltage ($V_A$, $V_B$, $V_C$) and current ($I_A$, $I_B$, $I_C$) phasor measurements as follows:

Zero-sequence voltage: $V_0 = \left(V_A + V_B + V_C\right)/3$

Positive-sequence voltage: $V_1 = \left(V_A + \alpha V_B + \alpha^2 V_C\right)/3$

Negative-sequence voltage: $V_2 = \left(V_A + \alpha^2 V_B + \alpha V_C\right)/3$

Zero-sequence current: $I_0 = \left(I_A + I_B + I_C\right)/3$

Positive-sequence current: $I_1 = \left(I_A + \alpha I_B + \alpha^2 I_C\right)/3$

Negative-sequence current: $I_2 = \left(I_A + \alpha^2 I_B + \alpha I_C\right)/3$

(Where: $\alpha = e^{j2\pi/3}$)

### ACB Phase Rotation

When phase rotation is configured to *acb*, sequence components are calculated as follows:

Zero-sequence voltage: $V_0 = \left(V_A + V_B + V_C\right)/3$

Positive-sequence voltage: $V_1 = \left(V_A + \alpha^2 V_B + \alpha V_C\right)/3$

Negative-sequence voltage: $V_2 = \left(V_A + \alpha V_B + \alpha^2 V_C\right)/3$

Zero-sequence current: $I_0 = \left(I_A + I_B + I_C\right)/3$

Positive-sequence current: $I_1 = \left(I_A + \alpha^2 I_B + \alpha I_C\right)/3$

Negative-sequence current: $I_2 = \left(I_A + \alpha I_B + \alpha^2 I_C\right)/3$

## Line-to-Line Calculations

Regardless of phase rotation, line-to-line quantities are calculated as follows:

Voltages:
$$V_{AB} = V_A - V_B$$
$$V_{BC} = V_B - V_C$$
$$V_{CA} = V_C - V_A$$

## Configuring the Sequence Calculator

To configure the Sequence Calculator, select **Export** from the Sequence Calculator page in the Application Manager. This downloads a CSV file with three columns. Each row defines a set of measurement points, calculations to be performed on them, and the phase rotation to use. The MeasurementPoints column supports an asterisk (*) as a wildcard. A single asterisk alone applies the associated calculations to all measurement points with three-phase voltages and/or currents available. If a row contains one or more asterisks combined with a string, the calculations from that row are applied to all measurement points containing the string and any other strings in the position(s) of the asterisk(s). If a measurement point is matched by more than one row, the calculations from the last matching row are applied to the measurement point.

For example, the CSV file shown in *Figure 4.29* would call for the following calculations:

1. No calculations for measurement points containing the string "230"
2. All calculations (ACB phase rotation) for StationA.TL501
3. Positive-, negative- and zero-sequence voltage calculations for all measurement points beginning with "StationA" (except StationA.TL501 and any containing "230")
4. Positive-sequence voltage and current calculations for all measurement points containing "TL" (except those containing "StationA" or "230")
5. Positive-sequence voltage calculations for all other measurement points with three-phase voltage available

Supported strings in the Calculations column are V0, V1, V2, I0, I1, I2, and VLL, separated by commas or semicolons. If VLL is in the Calculations column, all three line-to-line voltages are calculated. Supported strings in the PhaseRotation column are ABC or ACB.

Once the CSV file is filled in, select **Import** and choose the edited file.

| | A | B | C |
|---|---|---|---|
| 1 | MeasurementPoints | Calculations | PhaseRotation |
| 2 | * | V1 | ABC |
| 3 | *TL* | V1,I1 | ABC |
| 4 | StationA* | V1,V2,V0 | ACB |
| 5 | StationA.TL501 | V1,V2,V0,VLL,I1,I2,I0 | ACB |
| 6 | *230* | | |

**Figure 4.29 Sequence Calculator CSV Setting File Format**

**NOTE**
Depending on the number of three-phase voltage and current signals in the system, configuring all calculations for all measurement points can result in the calculation and storage of a large number of signals. The impact on storage capacity could be significant.

# Panel Applications

## Introduction

Dashboards provide visualization of power system data and information through a collection of panels. Panels can be added, removed, resized, and rearranged on any dashboard. See *Dashboard Application Overview on page 32* for details regarding how panels are integrated into dashboards.

**NOTE**
For installation simplicity, SEL combined the Time-Series Trend panel, Table panel, Numeric panel, Dial panel, Bar Chart panel, Phasor Scope, and XY Chart panel into one panel application for the initial Synchrowave Platform release.

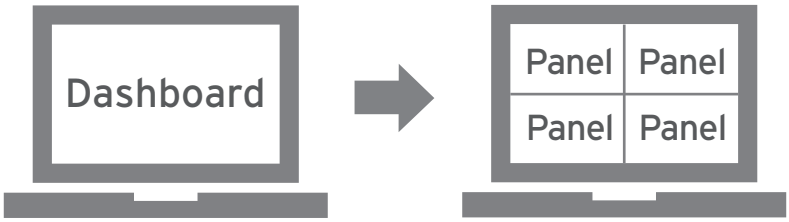



**Figure 4.30 Dashboard Panel Overview**

Panels can be copied and pasted. To copy a panel, click the three dots in the upper right corner and select **Copy Panel**.

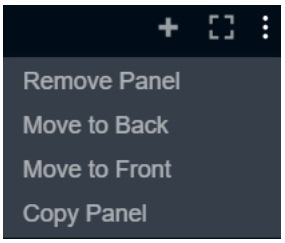



**Figure 4.31 Selecting Copy Panel**

To paste the panel, first create a new panel. Then, in the new panel, click the clipboard icon.

**Figure 4.32 The Clipboard Icon for Pasting Panel**

Panels can be temporarily maximized to fill the entire dashboard by selecting the full-screen icon or by pressing the **<V>** key while hovering the mouse over the panel. Return to normal size by selecting the same icon or pressing **<V>** again.

# Time-Series Trend Panel Application

Time-Series Trend shows signals from measurement points throughout the power system together over various time ranges.

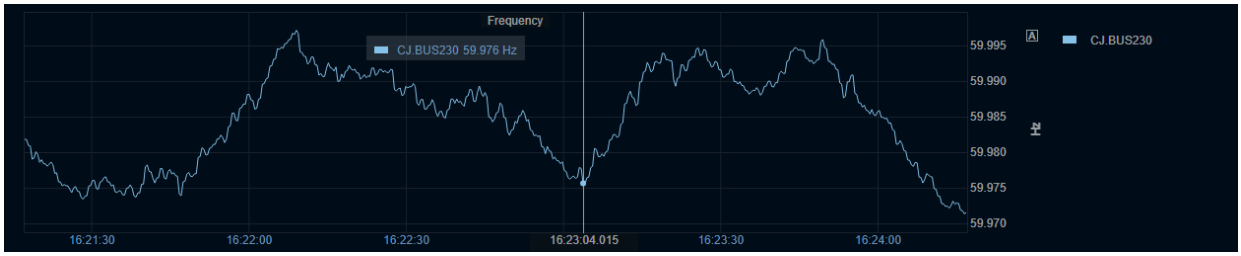



**Figure 4.33 Time-Series Trend Panel Overview**

# Navigating the Time-Series Trend

## Panning

Pan the x-axis time range by selecting the time-series trend panel and dragging forwards or backwards in time. The x-axis chart range can also be panned from the Timeline application.

If in real-time mode, manually panning the time-series trend will cause the software to enter historic mode.

## X-Axis Zooming

Zoom in and out the x-axis time range by scrolling over the trend. The trend will zoom in or out from the location of the mouse on the trend panel. The x-axis zoom range can also be changed from the Chart Range control in the Timeline application.

If in real-time mode, zooming in on a time-series trend will cause the software to enter historic mode. Zooming out while in real-time mode, will not cause the software to enter historic mode.

At x-axis zoom ranges greater than four minutes the time-series trend uses a min/max index for displaying time-series data to improve trend performance with large sets of data. See *Data Indexing on page 148* for additional details.

## Box Zooming

Box zoom in on an individual trend by holding the **<Ctrl>** key while selecting and dragging over the desired region to zoom in on. Box zoom is independent of the time range selected in the timeline or other time-series trends.

To exit box zoom mode for a trend:

- Select the **X** on the Y-scale button.
- Mouse wheel out.
- Select real-time mode.

## Y-Axis Scaling

Toggle through the Y-axis scale options by selecting the Y-Axis toggle button on each Time-Series Trend. If thresholds are not available or common between signals or a fixed-scale is not configured, auto-scale is automatically selected as the default Y-axis scale.

## Time-Marker

Select a time-series trend to place the time-marker on the trend. The time-marker shows data values for the selected time. Select and drag the time-marker to see how values change over time. All panels will update to display data for the time of the time-marker. Remove the time-marker by selecting real-time mode.

## Selection

Select measurement points in the time-series trend legend. When a measurement point is selected, the trend legend highlights. Selecting a measurement point in any panel, highlights and adds the selected measurement point to all panels (if Display Point Selection is enabled in the panel settings).

## Exporting Data

Selecting the **Export Data** button on Time-Series Trend automatically opens the Export Data application user interface with the time range, data type, and measurement points automatically populated. Data can be quickly downloaded in CSV or COMTRADE format. See *Data Export Application on page 193* for additional information.

# Configuring the Time-Series Trend

## Opening Edit Menu

To configure the signals displayed on the Time-Series Trend, select the + in the top right corner of the panel.

**NOTE**
Hold down **<Shift>** to select multiple measurement points.

**Figure 4.34 Selecting the Time-Series Trend Edit Button**

## Changing the Data Type

To change the data type displayed in the Time-Series Trend, in the **Data Type** tab, search for and select the desired Data Type(s).

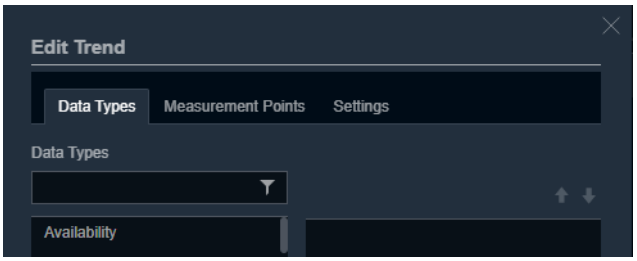



**Figure 4.35 Edit Data Type**

## Adding/Removing Measurement Points

To add measurement points to the Time-Series Trend, in the **Signals** tab, search for the desired measurement point, select the points, and then select **Add**. Measurement points are removed from the Time-Series Trend by selecting a previously added measurement point and then selecting **Remove**.

**NOTE**
The measurement point color is edited from the Edit Time-Series Trend menu. When changing the color of a measurement point, the color changes for that measurement point on all dashboards.

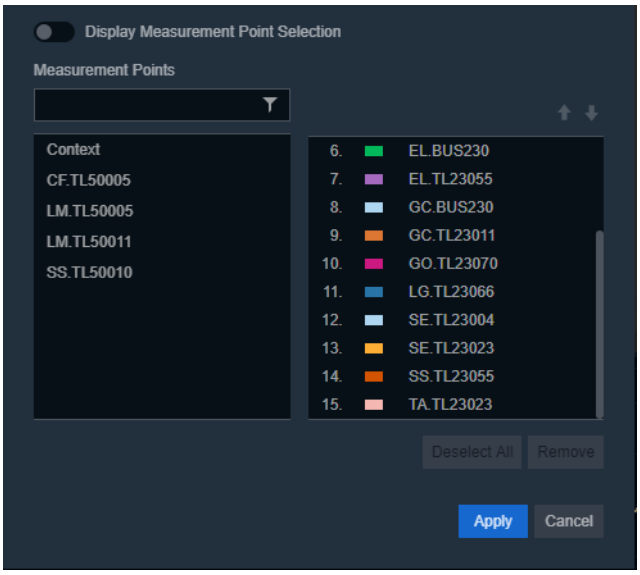



**Figure 4.36 Add/Remove Measurement Points From Time-Series Trend**

## Configuring Time-Series Trend Settings

The **Settings** tab contains the following options for configuring the Y-axis:

- **Y-Axis Limit Range** (**High** and **Low**): These specify the maximum and minimum extent of the Y-axis scaling.
- **Y-Axis Scale**: This allows you to choose between three scaling options:

  **NOTE**
  Both Auto Scale options are subject to the **Y-Axis Limit Range**. The Y-axis will not exceed the set limit range values if the maximum and/or minimum data values in the time range are higher and/or lower, respectively, than the High and Low values set in the Y-Axis Limit Range.

  - **Auto Scale; Exclude thresholds**. Use the maximum and minimum data values in the time range to set the Y-axis scale.
  - **Auto Scale; Include thresholds**. If the signals displayed all have common threshold values, thresholds are displayed and used for scaling. (Note: Only included in Synchrowave Operations.)
  - **Fixed**. Maximum and minimum Y-axis scale values can be set manually in the **Y-Axis Fixed Scale Range** High and Low text boxes. (These are grayed out unless Fixed is selected for the Y-Axis Scale.)
- **Line Thickness (0.1 - 10)**: This specifies the thickness of all lines on the trend.
- **Show Legend**: This allows you to toggle the legend on and off.

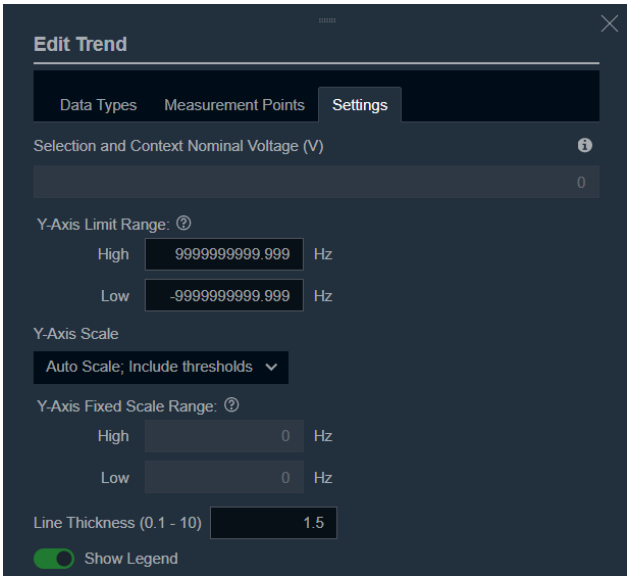



**Figure 4.37 Setting Up Default Time-Series Trend**

# Bar Chart Panel Application

The bar chart panel provides the ability to visualize instantaneous signals from measurement points throughout the power system.

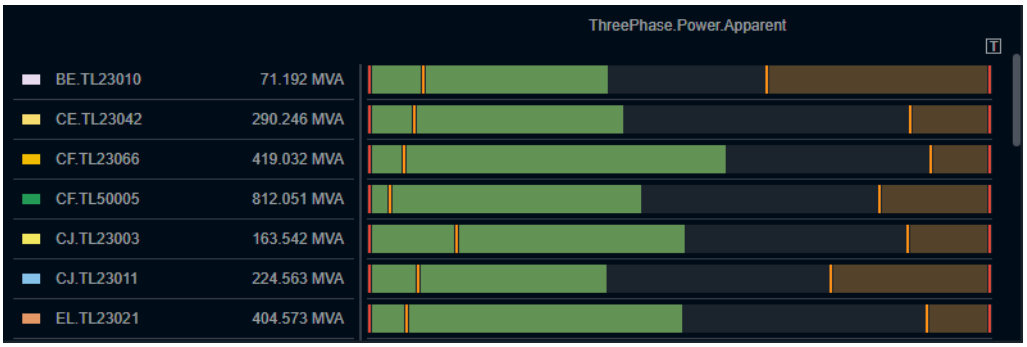



**Figure 4.38 Bar Chart Panel Overview**

## Navigating the Bar Chart Panel

### Panning

In real-time mode, the bar chart panel updates to show the most recent values. If you pan through historic data with the time-series trend or timeline, the bar chart panel automatically updates to show the data values at the time of the time marker indicator shown in the timeline.

### Thresholds

The bar chart displays threshold values as solid lines and displays threshold regions with shading.

Bars in the bar chart change color based on threshold regions:

- Green bars indicate the value is within the normal region.
- Orange bars indicate the value is within the warning threshold region.
- Red bars indicate the value has exceeded the alert threshold.

If a signal does not have configured thresholds, the default view range is used to define the bar range in the bar chart. Solid white lines indicate the default view range and that there are no thresholds for the bar. White triangles indicate the origin.

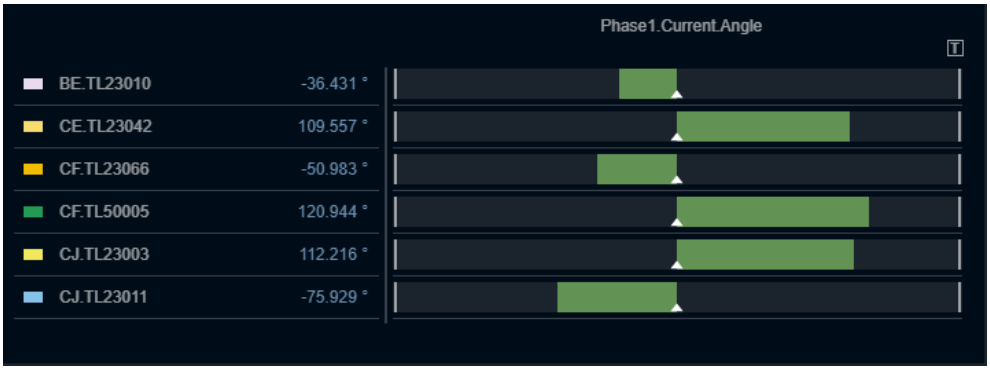



**Figure 4.39 Bar Chart Panel With No Thresholds**

## Zoom and Scale

Toggle between Threshold scaling and Fixed scaling by selecting the **T** or **F** toggle button in the top right corner of the bar chart panel.

**Figure 4.40 Bar Chart Panel Toggle Scale Button**

Threshold scaling uses configured alert levels from power system monitor applications to scale each measurement point individually. Indicator lines are drawn at the low-alert, low-warning, high-warning, and high-alert threshold values. The chart automatically resizes if the displayed value is out of range.

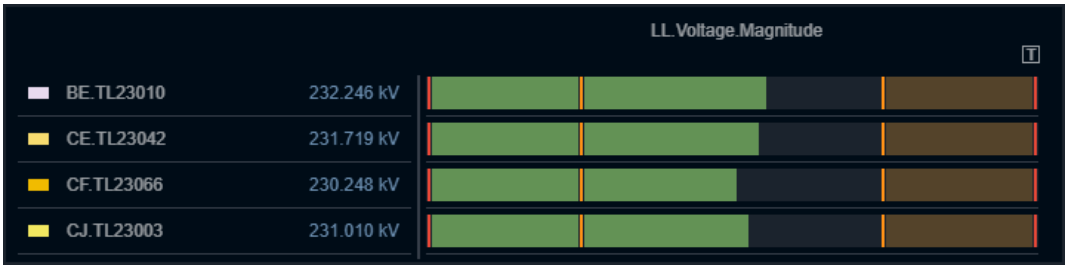



**Figure 4.41 Bar Chart Panel Threshold Scale**

Fixed scaling uses the bar chart panel default view range. Every row uses the same scaling. The chart will not resize when displayed values are out of range.

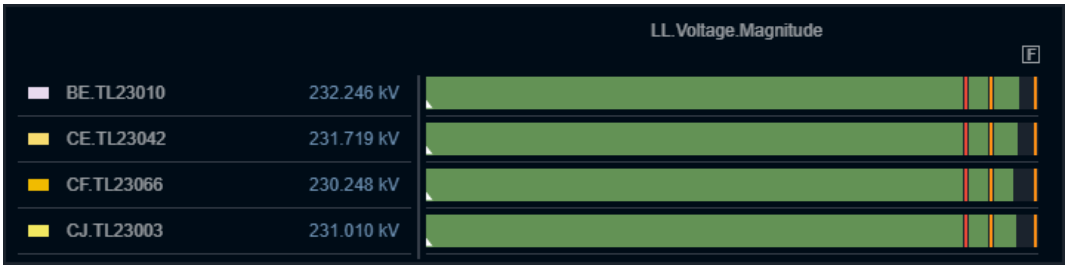



**Figure 4.42 Bar Chart Panel Fixed Scale**

### Hovering

Hovering over a bar in a bar chart shows threshold values along with the signal name and measurement value in a pop-up box.

### Selection

Select measurement points in the bar chart legend. Selecting a measurement point in any panel highlights and adds the selected measurement point to all panels (if **Display Measurement Point Selection** is enabled in the panel settings).

**NOTE**
Hold down **<Shift>** to select multiple measurement points.

## Configuring the Bar Chart Panel

### Opening the Edit Menu

To configure the signals displayed in the bar chart panel, select the + in the top right corner of the panel.

### Changing the Data Type

To change the data type displayed in the bar chart panel, select the **Data Type** tab, then select from the available data types.

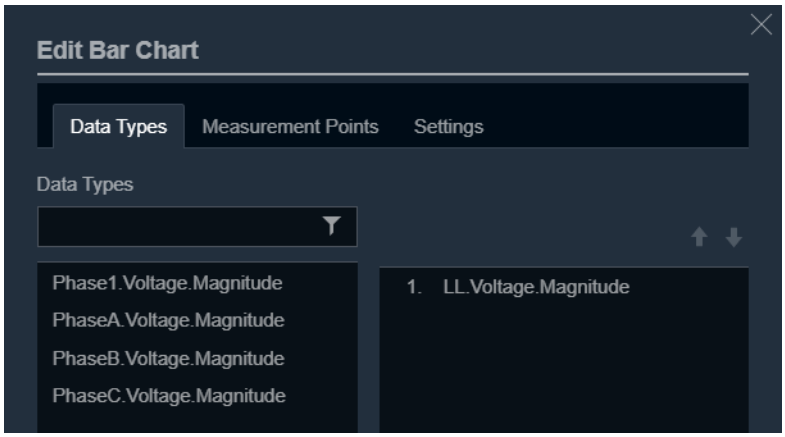



**Figure 4.43 Edit Bar Chart Panel Data Type**

## Adding/Removing Measurement Points

To add measurement points to the bar chart panel, in the **Signals** tab, search for the desired measurement point or select the measurement point name. Remove measurement points from the bar chart panel by selecting a previously added measurement point and selecting **Remove**.

The bar chart is limited to displaying 50 measurement points per bar chart panel.

### NOTE

The measurement point color can be changed from the Edit Bar Chart menu. When you change the color of a measurement point, the color changes for that measurement point on all dashboards.

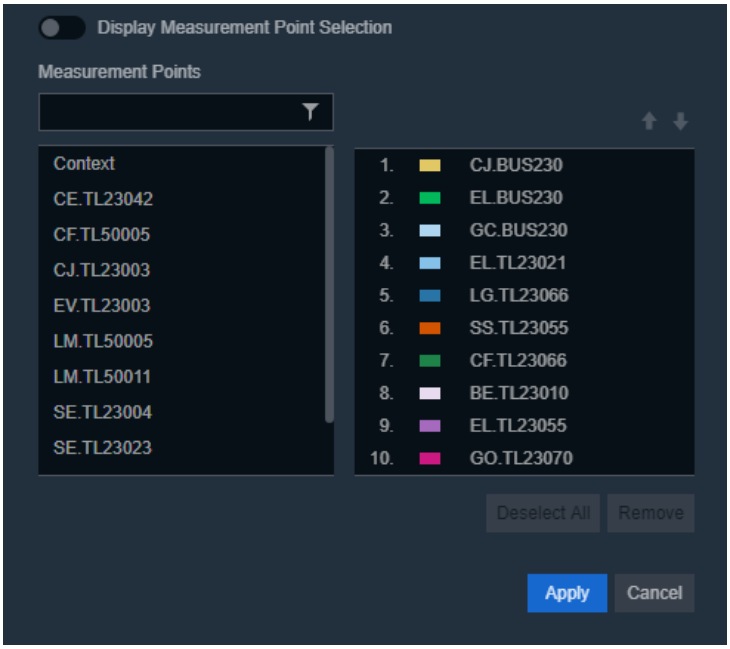



**Figure 4.44 Add/Remove Measurement Points From Bar Chart Panel**

## Configuring the Default View Range

In the **Settings** tab, enter the high and low values for the Default View Range. If a signal does not have configured thresholds, the **Default View Range** is used for scaling the bar chart.

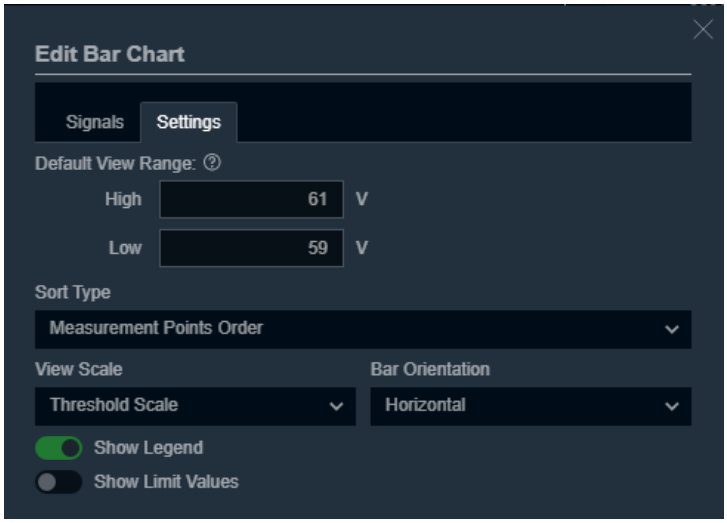



**Figure 4.45 Configure the Bar Chart Panel Default View Range**

## Configuring the Sort Order

The order in which measurement points are displayed in the bar chart can be configured through the following methods:

- **Measurement Point Order.** The measurement point order can be manually arranged in the Edit Bar Chart menu.
- **Measurement Point Name.** Alphabetical
- **Value.** The measurement point order dynamically updates in the bar chart based on the signal value.
- **Severity.** The measurement point order dynamically updates in the bar chart based on how close a signal is to an alert threshold.

**Figure 4.46 Configure the Bar Chart Panel Sort Order**

## Configuring the View Scale

Configure the view scale as Threshold Scale or Fixed Scale. See *Zoom and Scale on page 100* for details.

## Show Limit Values

Superimpose low and high alert limit values on the bar chart by selecting the **Show Limit Values** switch.

*Figure 4.47* shows an example.

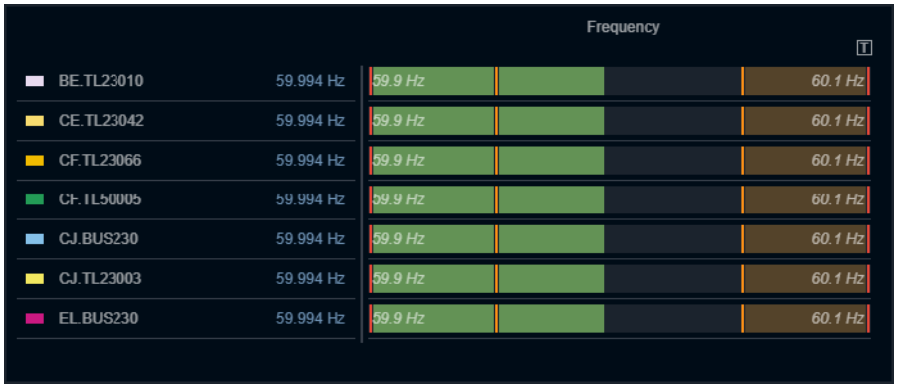



**Figure 4.47 Bar Chart Panel With Limits Shown**

## Change Bar Orientation

To change the bar chart orientation, select the **Bar Orientation** dropdown menu in the **Settings** tab, then select either **Horizontal** or **Vertical**.

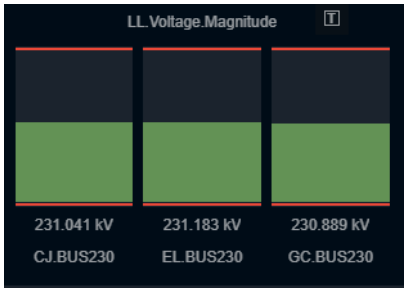



**Figure 4.48 Bar Chart Panel With Vertical Bar Orientation**

# Histogram Panel Application

The Histogram Panel plots a histogram of one measurement point over the selected time ranges greater than 3 minutes.

**NOTE**
For high-performance, the histogram is computed using an indexing approximation algorithm. Contact SEL for further details.

This Histogram Panel Application indexes data to provide for rapid visualization of histogram data. The indexing parameters can be configured in the Application Manager. See *Time-Series Historian Application on page 148* for a discussion of the other configuration parameters.

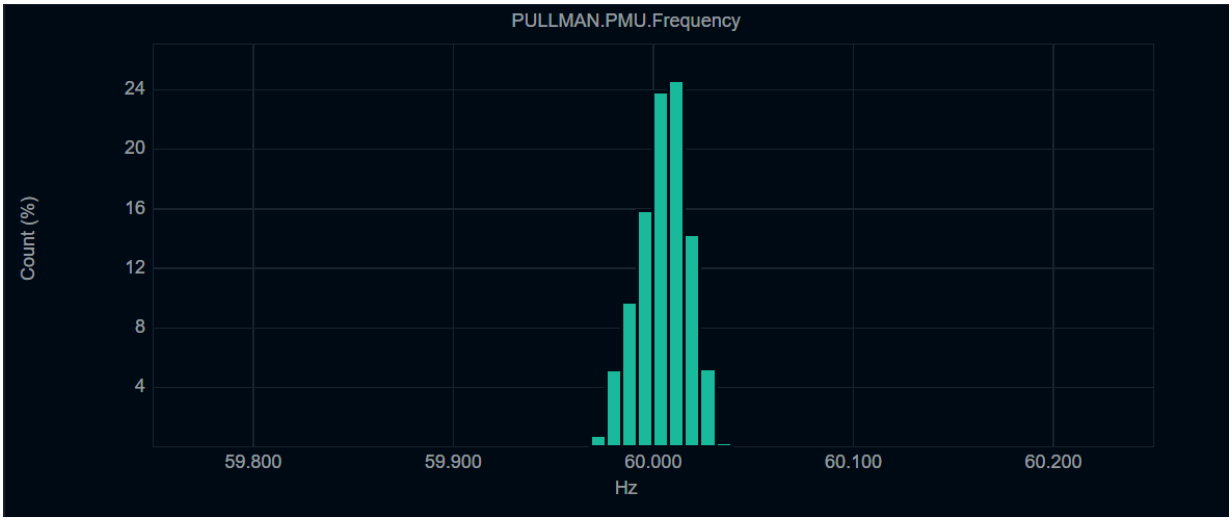



**Figure 4.49 Histogram Panel Overview**

# Navigating the Histogram Panel

## Panning

In real-time mode, the Histogram Panel updates to include the most recent values. If you pan through historic data with the time-series trend or timeline, the Histogram Panel automatically updates to provide a histogram of data within the time range.

# Configuring the Histogram Panel

## Opening Edit Menu

To configure the signal displayed in the Histogram Panel, select the + in the top right corner of the panel.

**Figure 4.50 Selecting the Histogram Edit Button**

## Adding Measurement Point

Search for a measurement point in the search bar. Select the desired measurement point to add it to the histogram. You can select only one measurement point per histogram panel.

**Figure 4.51 Adding Measurement Point to Histogram Panel**

## Configuring Y-Axis

Configure the histogram Y-axis scale by selecting the **Y-Axis Scale** dropdown menu and choosing one of the following options:

- **Absolute.** Y-axis expressed as a number equal to the bin count.
- **Relative.** Y-axis expressed as a percentage based on the total distribution.

## Configuring Bins

Specify the number of bins by typing a number in the corresponding text box. This must be an integer between 3 and 64, inclusive.

## Configuring Display Range

Specify the low and high values for the histogram by typing in the corresponding text box. These values must be numbers between $-10^{12}$ and $+10^{12}$, exclusive. Units are determined by the selected measurement point. Do not include unit prefixes (i.e., use 230000 instead of 230 kV). Values outside this range will be ignored.

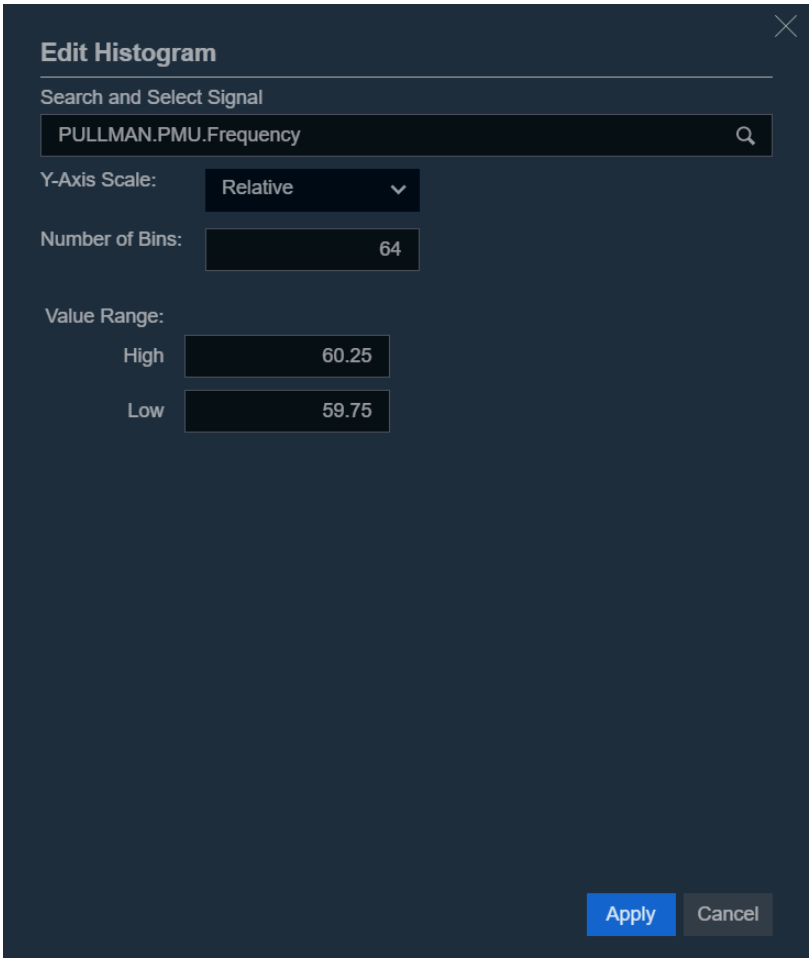



**Figure 4.52 Configuring Histogram Panel**

# Dial Panel Application

The dial panel provides the ability to visualize instantaneous signals from measurement points throughout the power system.

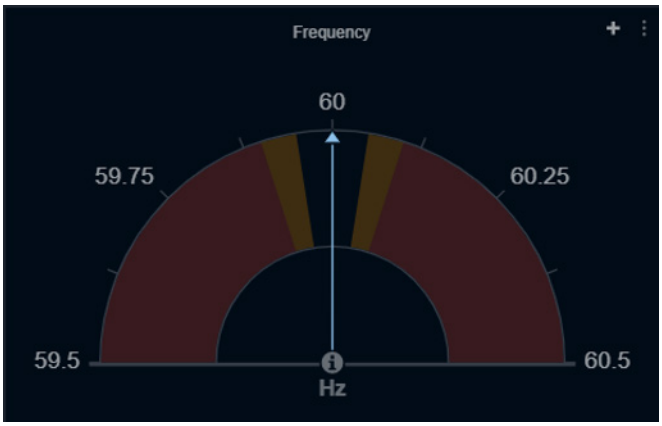



**Figure 4.53 Dial Panel Overview**

# Navigating the Dial Panel

## Panning

In real-time mode, the dial panel updates to show the most recent values. If you pan through historic data with the time-series trend or timeline, the dial panel automatically updates to show the data values at the time of the time marker indicator shown in the timeline.

## Insight Button

To see exact numerical values for measurement points shown in the dial panel, select the insight button.

## Thresholds

Thresholds are automatically displayed on the dial when:

- Thresholds are within in the configured Dial Range.
- All signals displayed have common limits.

## Selection

To select measurement points in the dial panel, select the measurement point name. When a measurement point is selected, the measurement point name highlights. Selecting a measurement point in any panel highlights and adds the selected measurement point to all panels (if **Display Measurement Point Selection** is enabled in panel settings).

**NOTE**
Hold down **<Shift>** to select multiple measurement points.

# Configuring the Dial Panel

## Opening Edit Menu

To configure the signals displayed in the dial panel, select the + in the top right corner of the panel.

## Changing the Data Type

To change the data type displayed in the dial panel, select the **Data Type** menu, then select from the available data types.

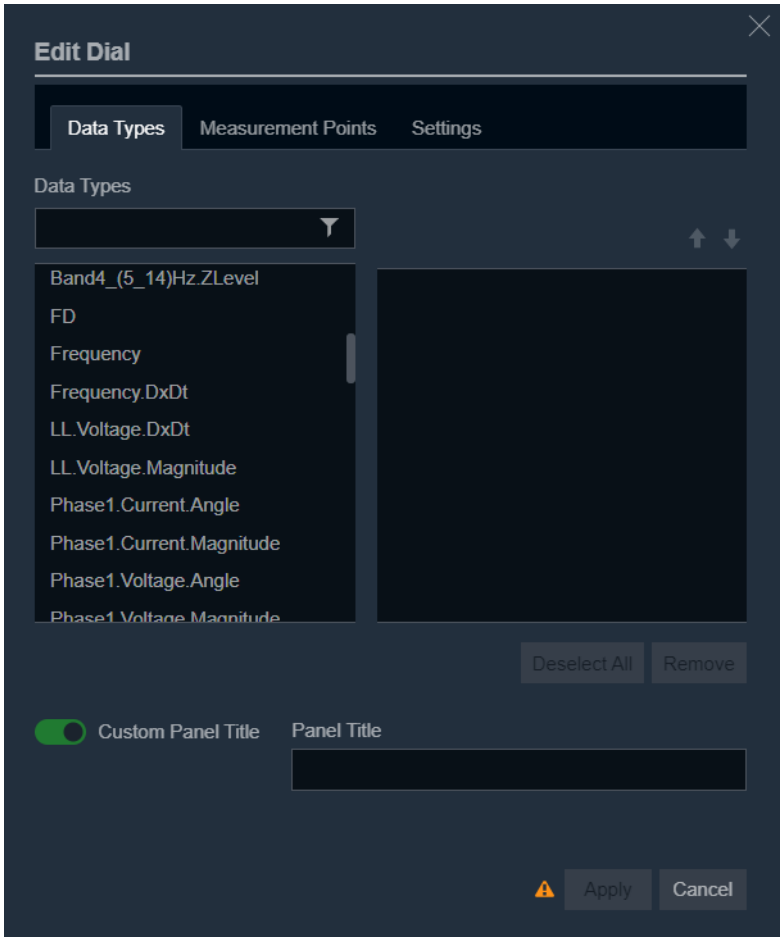



**Figure 4.54 Edit Dial Panel Data Type**

## Adding/Removing Measurement Points

To add measurement points to the dial panel, search for the desired measurement point or select the measurement point name. Remove measurement points from the dial panel by selecting a previously added measurement point and then select **Remove**.

### NOTE

The measurement point color can be changed from the Edit Dial menu. When you change the color of a measurement point, the color changes for that measurement point on all dashboards.

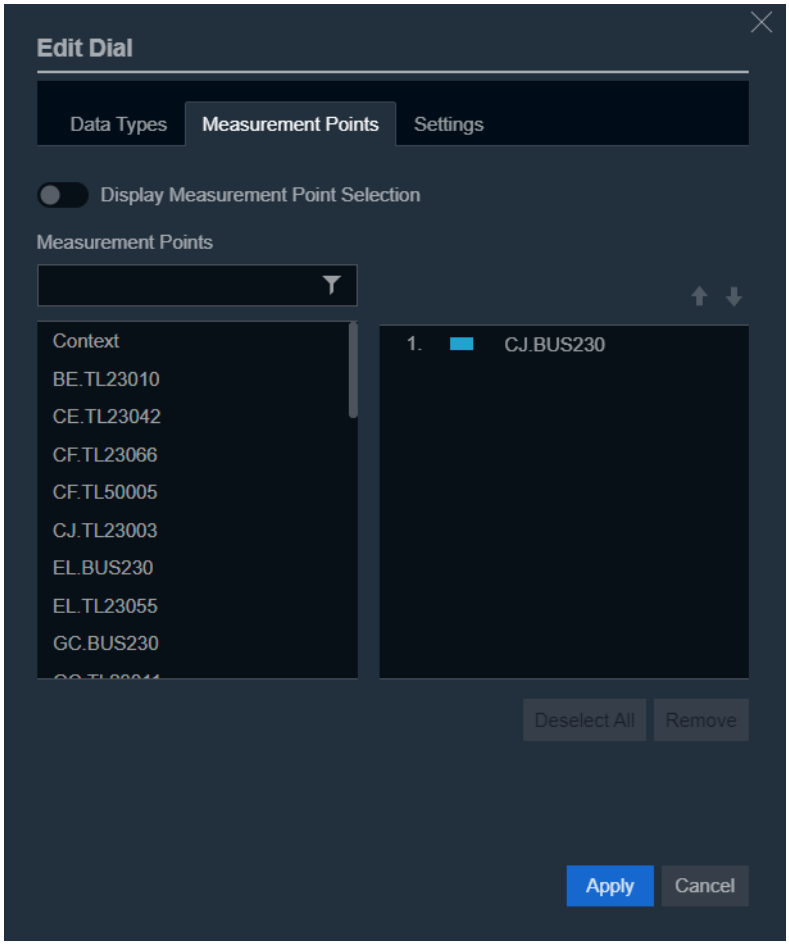



**Figure 4.55 Add/Remove Measurement Points From Dial Panel**

## Configuring the Dial Range

Enter high and low data range values for the Dial Range. Arrows appear on the dial for signal values within the Dial Range.

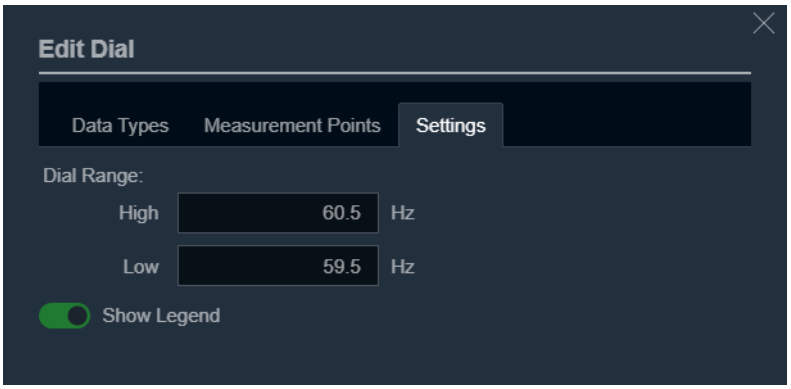



**Figure 4.56 Configure the Dial Range**

# Phasor Scope Panel Application

The phasor scope panel provides the ability to visualize instantaneous phase angle signals from measurement points throughout the power system.

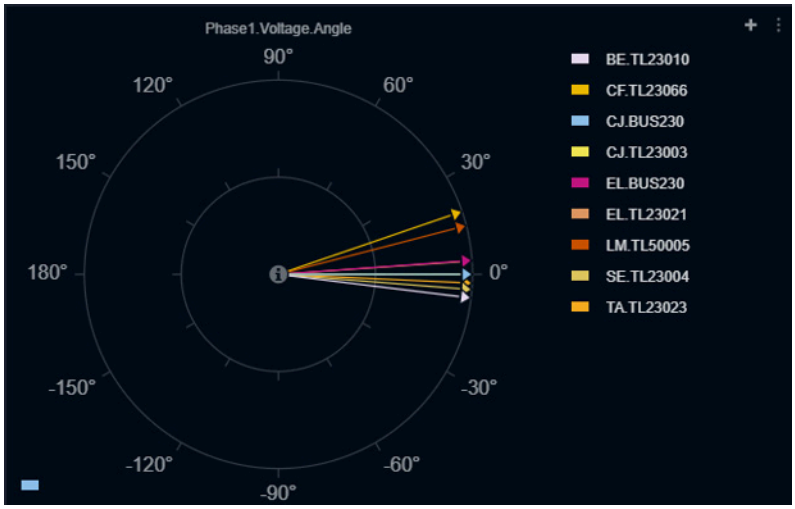



**Figure 4.57 Phasor Scope Panel Overview**

## Navigating the Phasor Scope Panel

### Panning

In real-time mode, the phasor scope panel updates to show the most recent phase angle values. If you pan through historic data with the time-series trend or timeline, the phasor scope panel automatically updates to show the data values at the time of the time marker indicator shown in the timeline.

### Insight Button

To see exact numerical phase angle values for measurement points shown in the phasor scope panel, select the insight button.

### Phasor Reference

The color of the measurement point configured as the reference phasor is displayed in the lower left corner of the phasor scope panel. Hovering over the measurement point color reveals the measurement point name of the reference phasor.

## Selection

To select measurement points in the phasor scope panel, select the measurement point name. When a measurement point is selected, the measurement point name highlights. Selecting a measurement point in any panel highlights and adds the selected measurement point to all panels (if **Display Measurement Point Selection** is enabled in panel settings).

**NOTE**
Hold down **<Shift>** to select multiple measurement points.

# Configuring the Phasor Scope Panel

## Opening Edit Menu

To configure the signals displayed in the Phasor Scope Panel, select the + in the top right corner of the panel.

**Figure 4.58 Selecting the Phasor Scope Edit Button**

## Changing the Data Type

To change the data type displayed in the Phasor Scope panel, in the **Data Type** tab, search for and select the desired data type(s).

**NOTE**
To display A-, B-, and C-Phases at the same time on a Phasor Scope panel, use the **PhaseABC** data type.

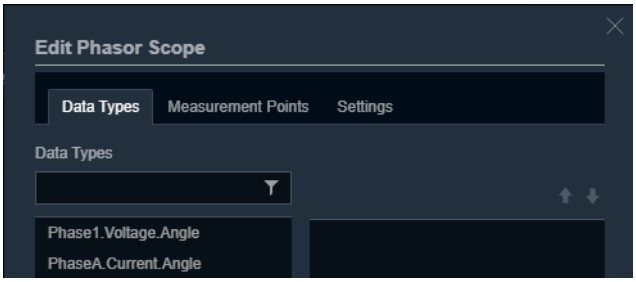



**Figure 4.59 Edit Phasor Scope Panel Data Type**

## Adding/Removing Measurement Points

To add measurement points to the phasor scope panel, in the **Measurement Points** tab, search for the desired measurement point or select the measurement point name. Remove measurement points from the phasor scope panel by selecting a previously added measurement point and then select **Remove**.

**NOTE**

The measurement point color can be changed from the Edit Phasor Scope menu. When you change the color of a measurement point, the color changes for that measurement point on all dashboards.

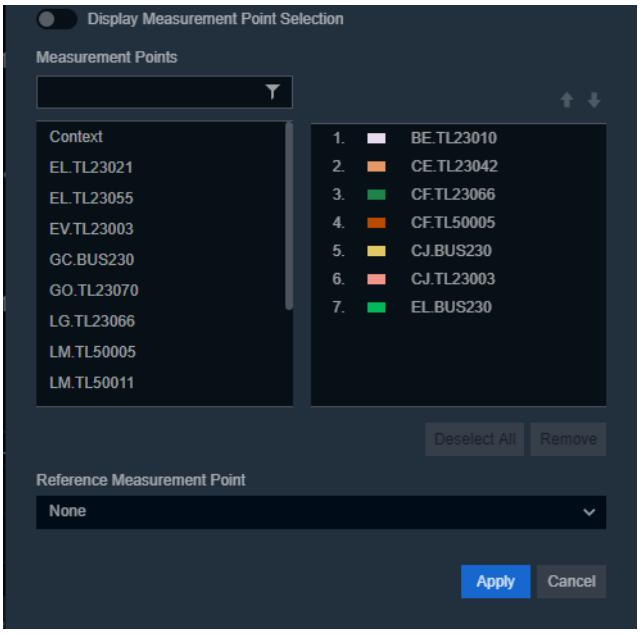



**Figure 4.60 Add/Remove Measurement Points From Phasor Scope Panel**

## Configuring the Reference Measurement Point and Time Align Delay

Compare phase angles from multiple measurement points in the phasor scope from across the system by selecting a phasor reference. Under the **Settings** tab, select the reference measurement point from the dropdown menu of selected Measurement Points. The Time Align Delay field sets the amount by which all signals will be delayed before display. The delay is inserted to ensure that all signals display measurements from the same time.

**Figure 4.61 Configuring the Reference Measurement Point**

## Configuring Angle Range

Enter a value θ between 1 and 180 degrees for the Angle Range in the Settings tab. The Phasor Scope shows phasors between 0 and ±θ degrees.

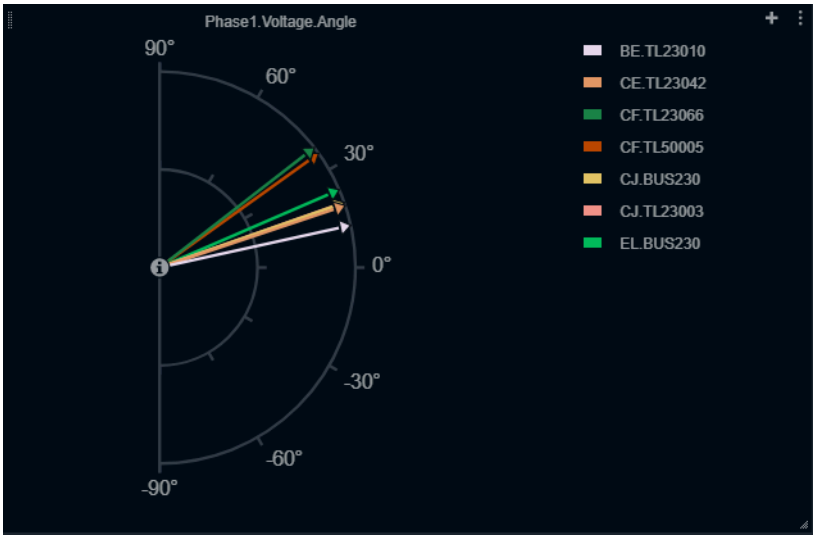



**Figure 4.62 Phasor Scope With Custom Angle Range**

## Setting Zero Position

Set the Zero Position from the **Zero Position** dropdown menu in the **Settings** tab. Choose between **Right** and **Top**.

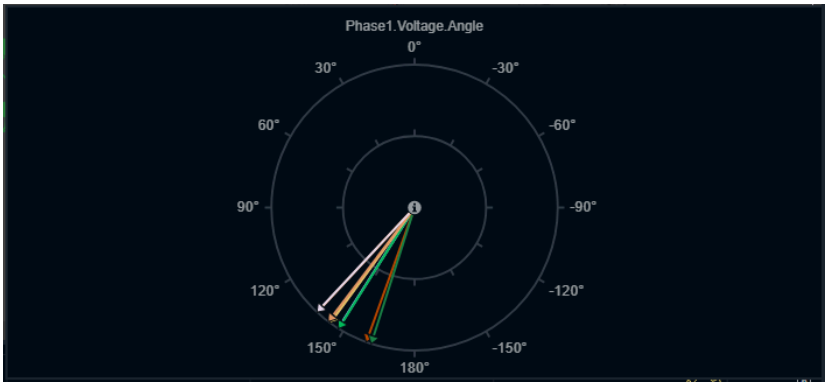



**Figure 4.63 Phasor Scope With Zero Position at Top**

## Displaying Magnitude

Optionally, the Phasor Scope can display magnitude along with phase. Turn on the **Show Magnitudes** toggle and enter a **Magnitude Limit**. The length of the phasors will be scaled such that the full circle radius corresponds to the value of Magnitude Limit. Magnitudes can only be shown if the magnitudes of all configured signals are in the same units.

**Figure 4.64 Phasor Scope Show Magnitudes Configuration**

# XY Panel Application

The XY Panel provides the ability to visualize the relationship between two instantaneous signals from measurement points throughout the power system over time.

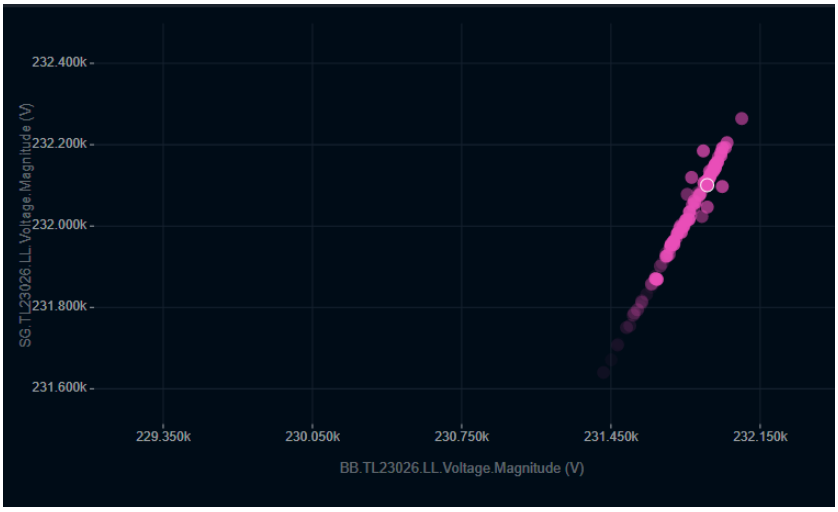



**Figure 4.65 XY Panel Overview**

## Navigating the XY Panel

### Panning

In real-time mode, the XY panel highlights the most recent values. By panning through historic data with the time-series trend or timeline, the XY panel automatically highlights the data values at the time of the time marker indicator shown in the timeline. Both real-time and historic data are superimposed on each other. The opacity of each time marker enables the operator to distinguish outliers from the rest of the data and observe long-term trends.

## Configuring the XY Panel

### Opening the Edit Menu

To configure the signals displayed on the XY panel, select the + button in the top right corner of the panel.

## Configuring X- and Y-Axis Signals

To configure the signals displayed on the XY panel, search for the signal name in the provided search boxes. Choose the desired signal from the dropdown list. Multiple signals can be plotted on the Y-axis.

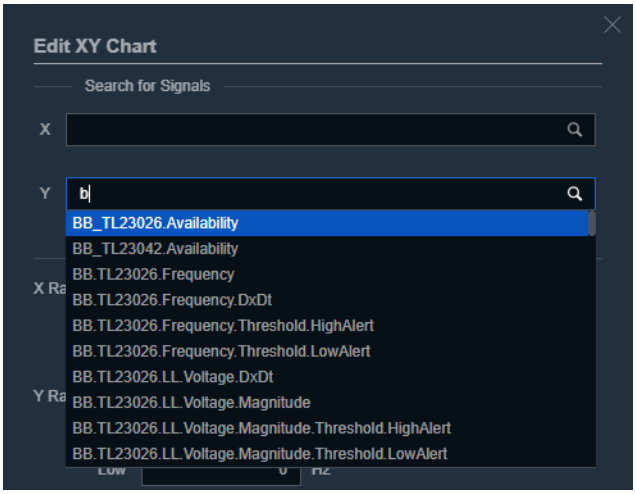



**Figure 4.66 Configure the XY Chart Signals**

## Configuring the Default View Range

To configure the default view range, type the high and low limits in the provided input boxes. The units are automatically set based on the selected signals.

**Figure 4.67 Configure the XY Chart Default View Range**

# Device Events Panel Application

The Device Events panel shows the collected event reports from measurement point devices throughout the power system together over various time ranges.

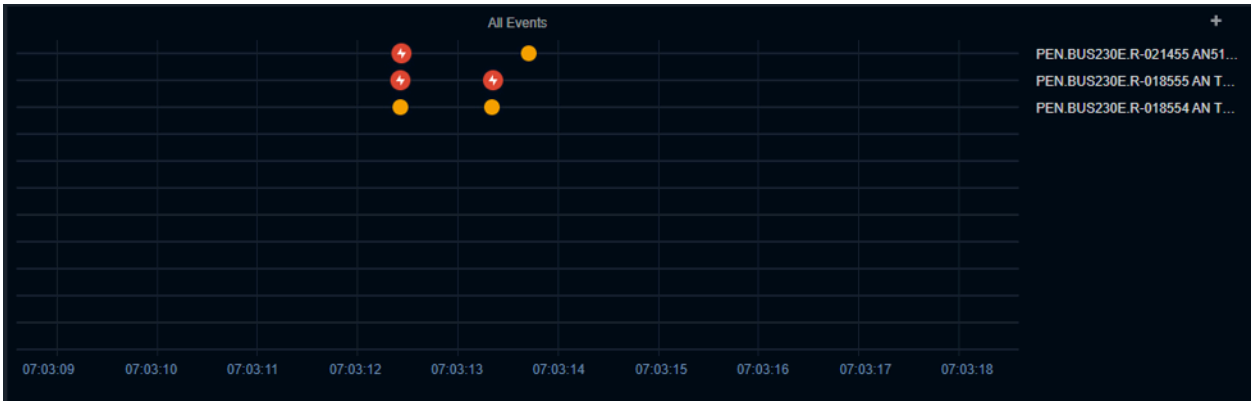



**Figure 4.68 Device Events Panel Overview**

# Navigating the Event Panel

## Panning

Pan the x-axis time range by selecting the Device Events panel and dragging forward or backward in time. The x-axis chart range can also be panned from the Timeline application.

If in real-time mode, manually panning the Device Events panel will cause the software to enter historic mode.

## X-Axis Zooming

Zoom in and out the x-axis time range by scrolling over the event panel. The event panel will zoom in or out from the location of the mouse on the event panel. The x-axis zoom range can also be changed from the Chart Range control in the Timeline application.

As the event panel is zoomed out, event reports for the same devices that occurred closely together in time, are automatically grouped together. Zooming in on the x-axis ungroups the event reports.

If in real-time mode, zooming in on a Device Events panel causes the software to enter historic mode. Zooming out while in real-time mode does not cause the software to enter historic mode.

At x-axis zoom ranges greater than 90 days, the event panel does not display event reports.

## Y-Axis Scaling

The Y-axis of the event panel lists the measurement point devices that have an event report in the selected time range. Measurements point devices are ordered on the Y-axis by most recent event.

## Selection

Select an event report icon in the Device Events panel to see summary information related to the collected event report.

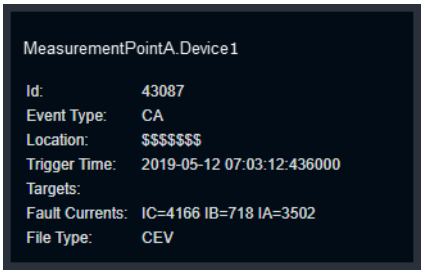



**Figure 4.69 MeasurementPointA.Device1 Summary Example**

## Downloading Events

Download event reports for further analysis by selecting one or more event reports and selecting **Download Events**. To select multiple event reports to download, hold the **<Shift>** key during selection. Event reports are downloaded from the database to the local computer in the .EVZIP format for analysis with SEL-5601-2 SYNCHROWAVE Event Software by using the built-in download capacity of the browser.

# Configuring the Event Panel

## Opening Edit Menu

To configure the event reports displayed on the Device Events panel, select the + in the top right corner of the panel.

**Figure 4.70 Selecting the Device Events Panel Edit Button**

## Changing the Event Type

To change the type of event reports displayed in the Device Events panel, select the **Event Type** dropdown menu and select from the available event types.

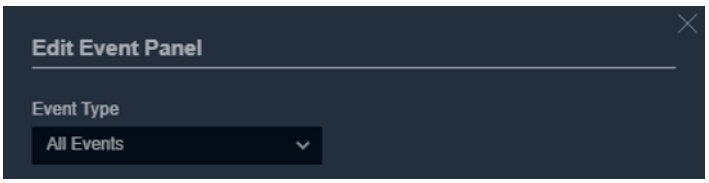



**Figure 4.71 Edit Event Type**

## Adding/Removing Measurement Point Devices

By default, all measurement point devices are added to the Device Events panel. When the All Devices measurement point device is added to the event panel, measurement point devices are displayed in the Device Event panel if there is an event report in the selected time range.

Specific measurement point devices can be added to a Device Events panel. When a specific measurement point device is added to a Device Events panel, the measurement point device is displayed in the event panel for viewing regardless of whether or not there is an event report in the selected time range.

To add measurement point devices to the Device Events panel, search for the desired measurement point device and select the device. Select multiple measurement point devices with the left mouse button. Measurement points are removed from the event panel by selecting a previously added measurement point device and then selecting **Remove**.

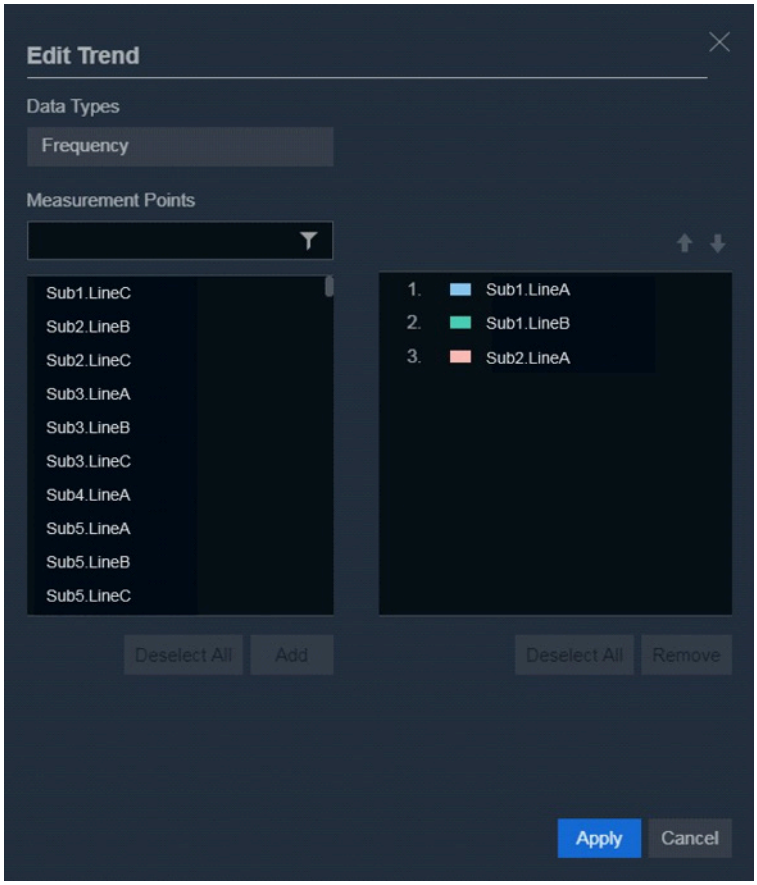



**Figure 4.72 Add/Remove Measurement Point Devices From Device Events Panel**

# Notification Table Application

The notification table panel provides the ability to visualize notifications from power system applications in a tabular format.

| Type | Location | Start Time | Duration | Latched Level | Latched Limit | Shelved | Acknowledged | Acknowledged By |
|---|---|---|---|---|---|---|---|---|
| Power | GC.TL23015, EL.TL2... | 10:10:09 | 10 Seconds | Low Warning | -6.250M | Unshelved | Acknowledged | Auto-Acknowledge Timeout |
| Frequency | BE.TL23010, SE.TL2... | 10:10:09 | 14 Minutes | Low Alert | 59.900 | Unshelved | Acknowledged | Auto-Acknowledge Timeout |
| Frequency | SE.TL23004, CF.TL2... | 09:33:22 | 5 Minutes | Low Warning | 59.950 | Unshelved | Acknowledged | Auto-Acknowledge Timeout |
| Frequency | CF.TL23066, BE.TL2... | 09:29:09 | 20 Seconds | Low Warning | 59.950 | Unshelved | Acknowledged | Auto-Acknowledge Timeout |

Showing 4 rows. Filtered by: Start Time.
Sync To Timeline

**Figure 4.73 Notification Table Panel Overview**

# Configuring the Table

## Show/Hide Columns

Right-click the panel and select **Show/Hide Columns**. Select all the columns that will appear in the table and select **OK**.

**Figure 4.74 Notification Table Show or Hide Columns**

## Filtering

Filter columns by selecting the funnel icon next to the column title and entering text. Active filters are shown with a blue funnel. Remove individual filters by selecting the funnel icon and selecting the **X** button. Clear all filters by right-clicking the panel and selecting **Clear Filters**.

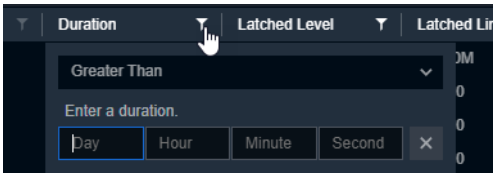



**Figure 4.75 Notification Table Filtering**

## Column Sorting

During analysis, it can be helpful to sort a column in ascending or descending order. Select the column title to toggle between sorting modes. An indicator arrow appears next to the column title. Clear sorting by right-clicking the panel and selecting **Clear Sort**.

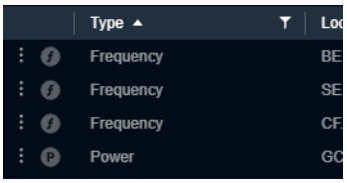



**Figure 4.76 Notification Table Column Sorting**

## Sync to Timeline

By default, only notifications in the current Timeline range are shown. To show all notifications, disable synching to the timeline by selecting the toggle switch next to **Sync to Timeline**.

## Changing Column Widths

Column widths can be changed in three ways: automatically, all at once, or by manually changing each column.

Right-click the panel and select **Enable Auto-Fit** to allow the panel to automatically resize as notifications are added or filtered from the table. This feature will be active until **Disable Auto-Fit** is selected.

Fit all columns at once by right-clicking the panel and selecting **Fit Width**. To reset the width to the default size, select **Reset Width**. Note that **Fit Width** is different from **Enable Auto-Fit** because **Enable Auto-Fit** dynamically resizes the table as new rows are added or removed, while **Fit Width** only resizes the table once. Further changes to filtering or adding new notifications will not resize the table.

Change a single column width by hovering the cursor over the divider line between columns. Select and drag to resize the column.

**Figure 4.77 Notification Table Change Column Width**

## Saving Changes

To save the current table configuration to the dashboard, select the floppy disk icon.

## Reverting Changes

Select the revert arrow icon to discard all changes and return to the last saved configuration. To quickly revert to the original default configuration, remove the panel and add a new Notification Table panel. Alternatively, use the right-click menu to manually discard each change to the table.

# Other Operations

## Selection

Selecting a notification icon in the Notification Table opens the selected notification in Notification Analysis mode. **<Ctrl>+click** a notification icon to open Notification Analysis mode in a new tab.

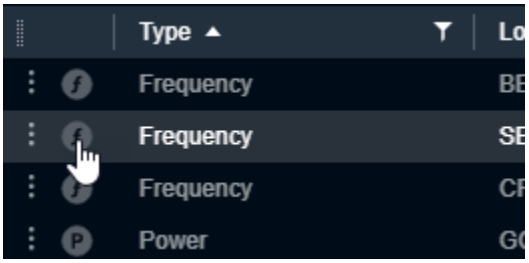



**Figure 4.78 Notification Table Selecting Notification**

**NOTE**
Hold down **<Shift>** to select multiple measurement points.

Selecting a row in the Notification Table highlights the table row and selects all (as many as 10) measurement points associated with the notification. Corresponding signals will be added to all panels (if **Display Measurement Point Selection** is enabled in panel settings). The measurement points are also added to the Map Panel.

Select the row again to deselect it.

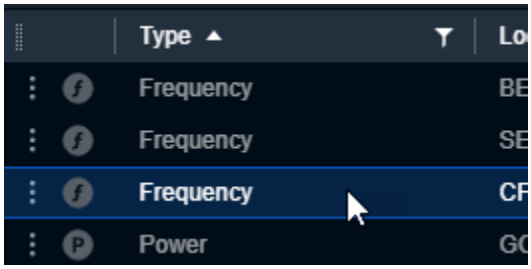



**Figure 4.79 Notification Table Selecting Row**

## Shelve/Unshelve Notifications

Notifications can be shelved or unshelved by selecting the ⋮ button on the left-hand column and selecting **Shelve** or **Unshelve**. Shelved notifications appear in the Notification Table with a corresponding shelving time stamp.

If the ⋮ button on the left-hand column is not visible, make sure that Column 1 is added to the table. See *Show/Hide Columns on page 120*.

## Inhibit Measurement Points

Measurement points can be inhibited from producing further notifications by selecting the ⋮ button in the left-most column and selecting **Inhibit Measurement Points**. Select the measurement points to inhibit and then select **Ok**. See *Notification Inhibit Table on page 123* for more details.

If the ⋮ button in the left-most column is not visible, make sure that Column 1 is added to the table (see *Show/Hide Columns on page 120*).

## Acknowledge/Unacknowledge Notifications

Notifications can be acknowledged or unacknowledged by selecting the ⋮ button on the left-hand column and selecting **Acknowledge** or **Unacknowledge**.

# Notification Inhibit Table

If a signal is producing nuisance notifications (e.g., because a piece of equipment is out of service or a PMU is having data quality problems), the associated measurement point can be manually inhibited from producing further notifications. No notifications will be created for inhibited measurement points.

The Notification Inhibit Table is used to view and manage the inhibited/uninhibited status of measurement points. Measurement points can be inhibited in any of the following ways:

- Selecting the configuration button for the Notification Inhibit Table and adding the desired measurement points to the menu on the right side.
- Selecting the ⋮ button for a notification on the Notification Table (see *Inhibit Measurement Points on page 122*). Measurement points inhibited in this way automatically appear on any Notification Inhibit Tables.
- Selecting the ⋮ button for a notification on the Notification List (see *Inhibiting Measurement Points on page 39*). Measurement points inhibited in this way automatically appear on any Notification Inhibit Tables.

Once a measurement is inhibited, it can be uninhibited from the Notification Inhibit Table by selecting the switch icon in the Inhibited column. A red icon indicates that the measurement point is currently inhibited.

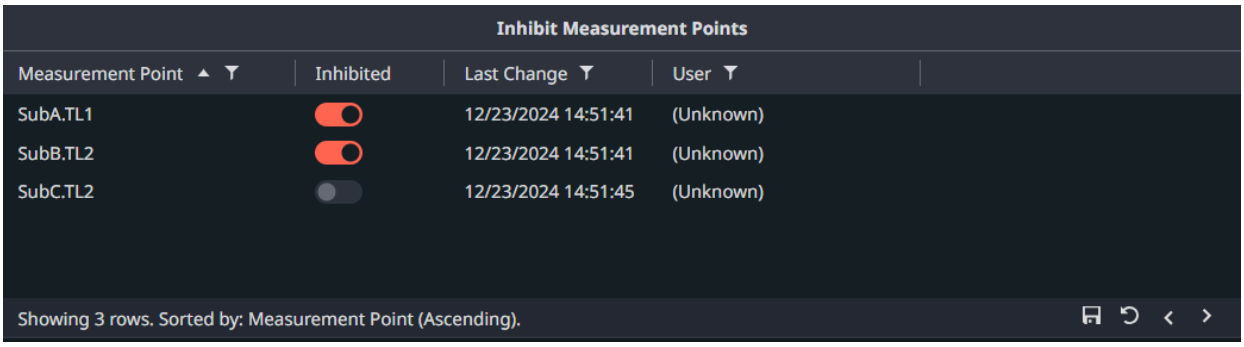



**Figure 4.80 Notification Inhibit Table Overview**

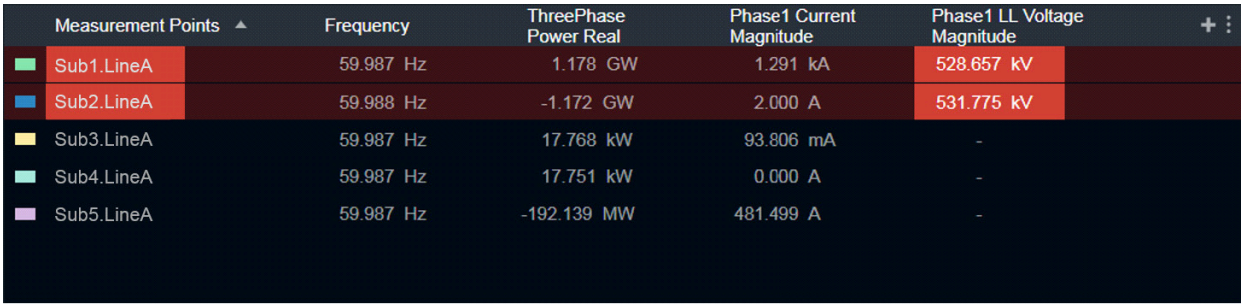
Columns and rows in the Notification Inhibit Table can be sorted, resized, and shown or hidden in a similar manner to the Notification Table (see *Notification Table Application on page 119*). To make changes such as sorting persist, select the save icon.

You can uninhibit or inhibit *all* measurement points currently on the Notification Inhibit Table by selecting the left (<) or right (>) arrow icons, respectively, in the lower right corner of the table.

**NOTE**
The Notification Inhibit Table is unique among panels in that the currently selected set of measurement points to be displayed are displayed on all instantiations of the table, on all dashboards across Synchrowave.

# Table Panel Application

The table panel provides the ability to visualize instantaneous signals from measurement points throughout the power system together across multiple data types at once.



| Measurement Points | Frequency | ThreePhase Power Real | Phase1 Current Magnitude | Phase1 LL Voltage Magnitude |
|---|---|---|---|---|
| Sub1.LineA | 59.987 Hz | 1.178 GW | 1.291 kA | 528.657 kV |
| Sub2.LineA | 59.988 Hz | -1.172 GW | 2.000 A | 531.775 kV |
| Sub3.LineA | 59.987 Hz | 17.768 kW | 93.806 mA | - |
| Sub4.LineA | 59.987 Hz | 17.751 kW | 0.000 A | - |
| Sub5.LineA | 59.987 Hz | -192.139 MW | 481.499 A | - |

**Figure 4.81 Table Panel Overview**

## Navigating the Table

### Panning

In real-time mode, the table panel updates to show the most recent values. Panning through historic data with the time-series trend or timeline causes the table panel to automatically update to show the data values at the time of the time cursor indicator shown in the timeline.

### Temporary Column Sorting

During analysis, it can be helpful to temporarily change the default column sort to a different displayed column. Do this by hovering over the column title and selecting the sort indicator.

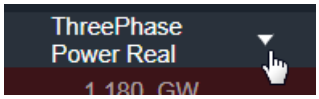



**Figure 4.82 Temporary Table Column Sorting**

### Selection

To select measurement points in the table panel, when a measurement point is selected, the table row highlights. Selecting a measurement point in any panel highlights and adds the selected measurement point to all panels (if **Display Measurement Point Selection** is enabled in panel settings).

**NOTE**
Hold down **<Shift>** to select multiple measurement points.

| Measurement Points | Frequency | ThreePhase Power Real | Phase1 Current Magnitude | Phase1 LL Voltage Magnitude |
|---|---|---|---|---|
| Sub1.LineA | 60.016 Hz | 1.181 GW | 1.293 kA | 528.622 kV |
| Sub2.LineA | 60.017 Hz | -1.175 GW | 4.472 A | 531.838 kV |
| Sub3.LineA | 60.016 Hz | -7.244 kW | 18.881 mA | - |
| Sub4.LineA | 60.016 Hz | 2.563 kW | 0.000 A | - |
| Sub5.LineA | 60.017 Hz | -198.953 MW | 499.016 A | - |

**Figure 4.83 Table Measurement Point Selection**

# Configuring the Table

## Opening Edit Menu

To configure the signals and columns displayed in the able, select the + in the top right corner of the panel.

## Adding/Removing Measurement Points

To add measurement points to the table, search for the desired measurement point by typing the desired name using the search box. Then select **Add**. Remove measurement points from the table by selecting a previously added measurement point and then select **Remove**.

### NOTE

The measurement point color is changed using the Edit Table menu. Select the color next to the measurement point to open a color selection menu. When changing the color of a measurement point, the color changes for that measurement point on all dashboards.

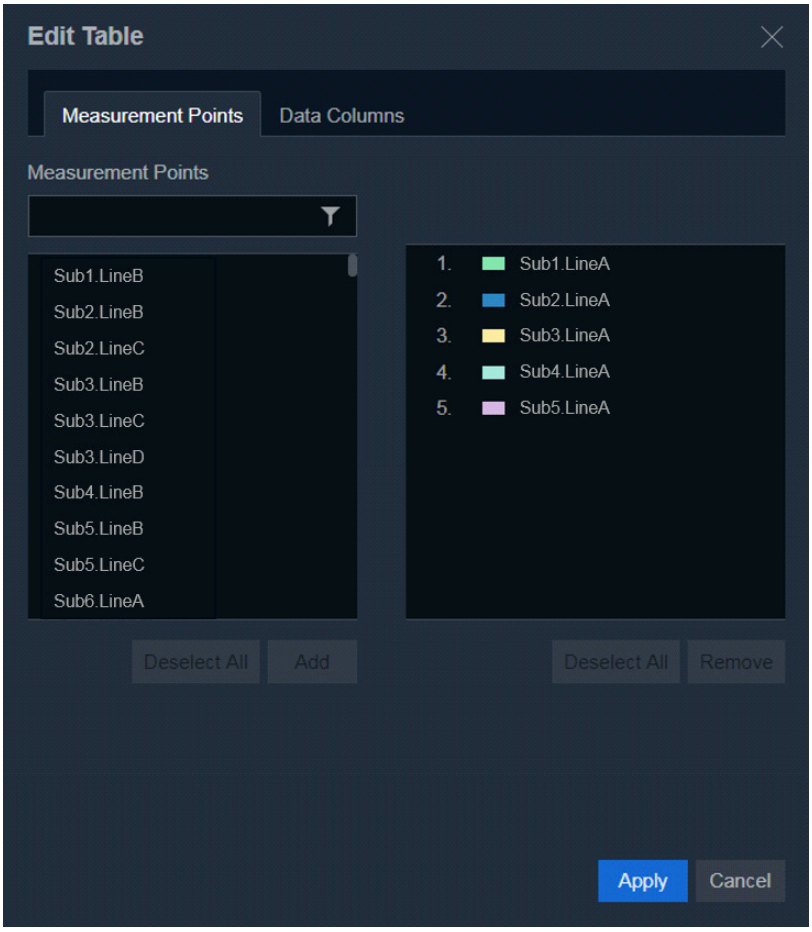



**Figure 4.84 Add/Remove Measurement Points From the Table**

## Adding/Removing Data Columns

To add data columns to the table, search for the desired data column and then select **Add**. To remove data columns from the table, select a previously added data column and then select **Remove**.

To configure the order that the table columns are displayed, select an added data column and use the up/down arrows to reorder the data columns.

The default sort column can also be selected from the Data Columns tab. Use the default sort column to order the measurement points displayed in the table panel. Sort order is ascending or descending and set by the **Ascending** toggle.

If a real or reactive power quantity is selected as one of the data columns, the **Show Total Row** toggle appears. If switched to on, the table will have a Total row pinned to the top which contains the sum of any data columns that contain real or reactive power quantities.

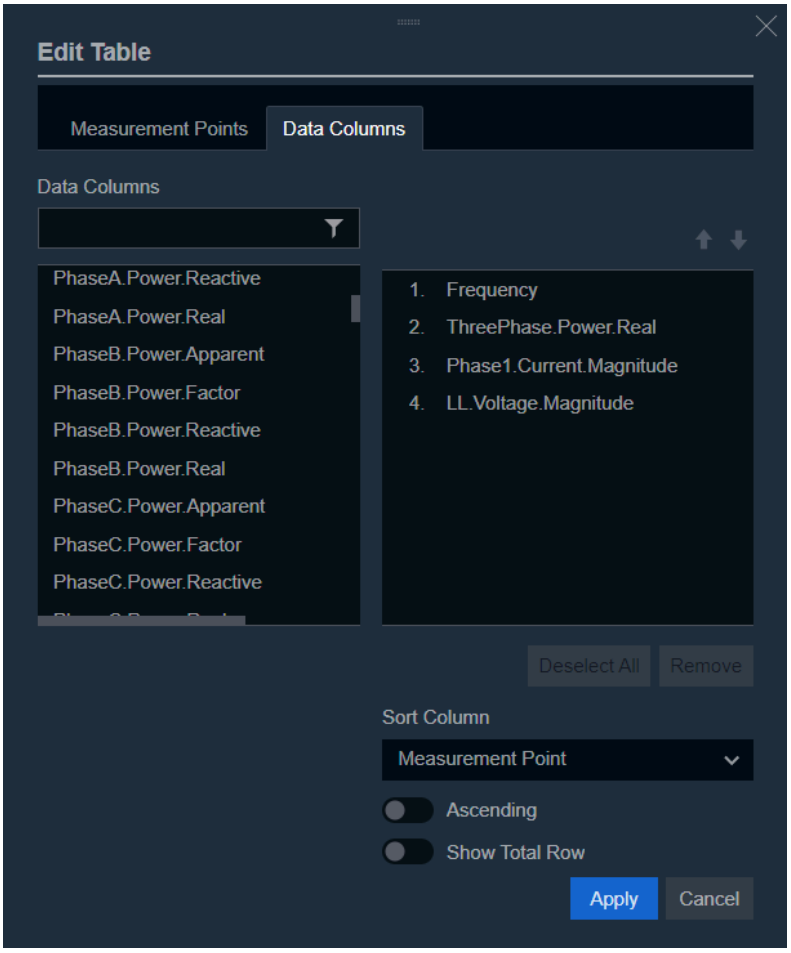



**Figure 4.85 Table Data Columns Options Menu**

# Numeric Panel Application

The Numeric panel provides the ability to visualize instantaneous signals from measurement points throughout the power system.

**Figure 4.86 Numeric Panel Overview**

# Navigating the Numeric Panel

## Panning

In real-time mode, the numeric panel updates to show the most recent values. If you pan through historic data with the time-series trend or timeline, the numeric panel automatically updates to show the data values at the time of the time marker indicator shown in the timeline.

## Selection

To select measurement points in the numeric panel, when a measurement point is selected, the table row highlights. Selecting a measurement point in any panel highlights and adds the selected measurement point to all panels (if **Display Measurement Point Selection** is enabled in panel settings).

# Configuring the Numeric Panel

## Opening Edit Menu

To configure the signals displayed in the Numeric Panel, select the + in the top right corner of the panel.

**NOTE**
Hold down **<Shift>** to select multiple measurement points.

**Figure 4.87 Selecting the Numeric Edit Button**

## Changing the Data Type

To change the data type displayed in the Numeric panel, in the **Data Type** tab, search for and select the desired data types.

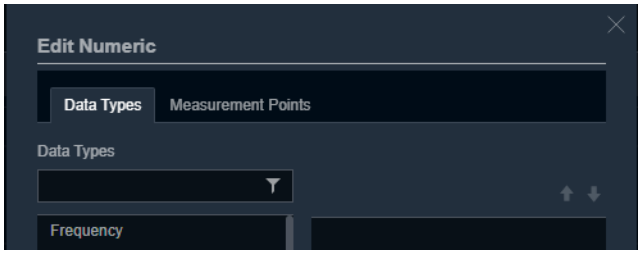



**Figure 4.88 Edit Numeric Panel Data Type**

## Adding/Removing Measurement Points

To add measurement points to the numeric panel, in the **Measurement Points** tab search for the desired measurement point and then select **Add**. Remove measurement points from the numeric panel by selecting a previously added measurement point and then select **Remove**.

### NOTE

The measurement point color is changed using the Edit Numeric menu. Select the color next to the measurement point to open a color selection menu. When changing the color of a measurement point, the color changes for that measurement point on all dashboards.

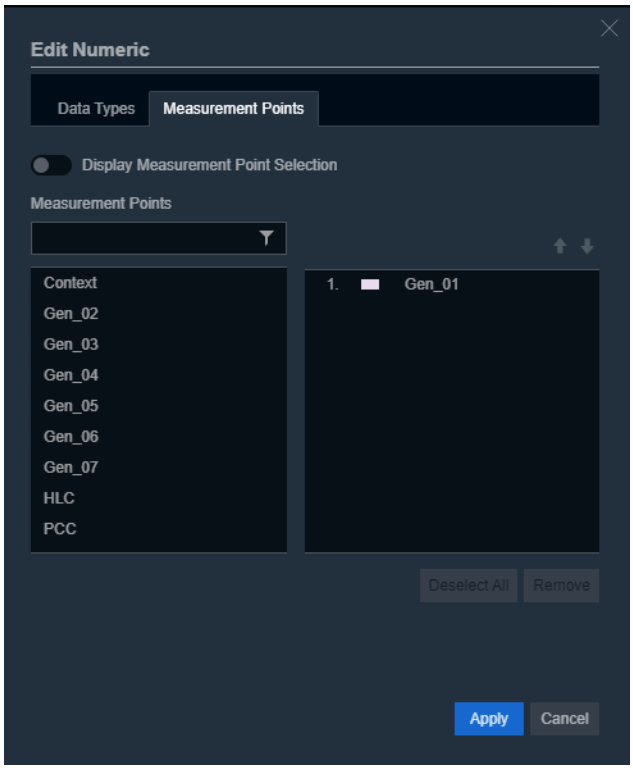



**Figure 4.89 Add/Remove Measurement Points From Numeric Panel**

# Digital Chart Application

The Digital Chart allows the visualization of digital signals at various time scales.

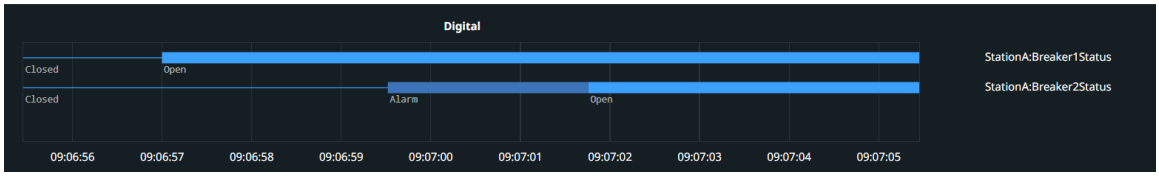



**Figure 4.90 Digital Chart**

# Configuring the Digital Chart

Configure a new Digital Chart by selecting the **Add Signal** button in the center of the panel, or change the configuration of an existing chart by selecting the plus button in the upper right corner.

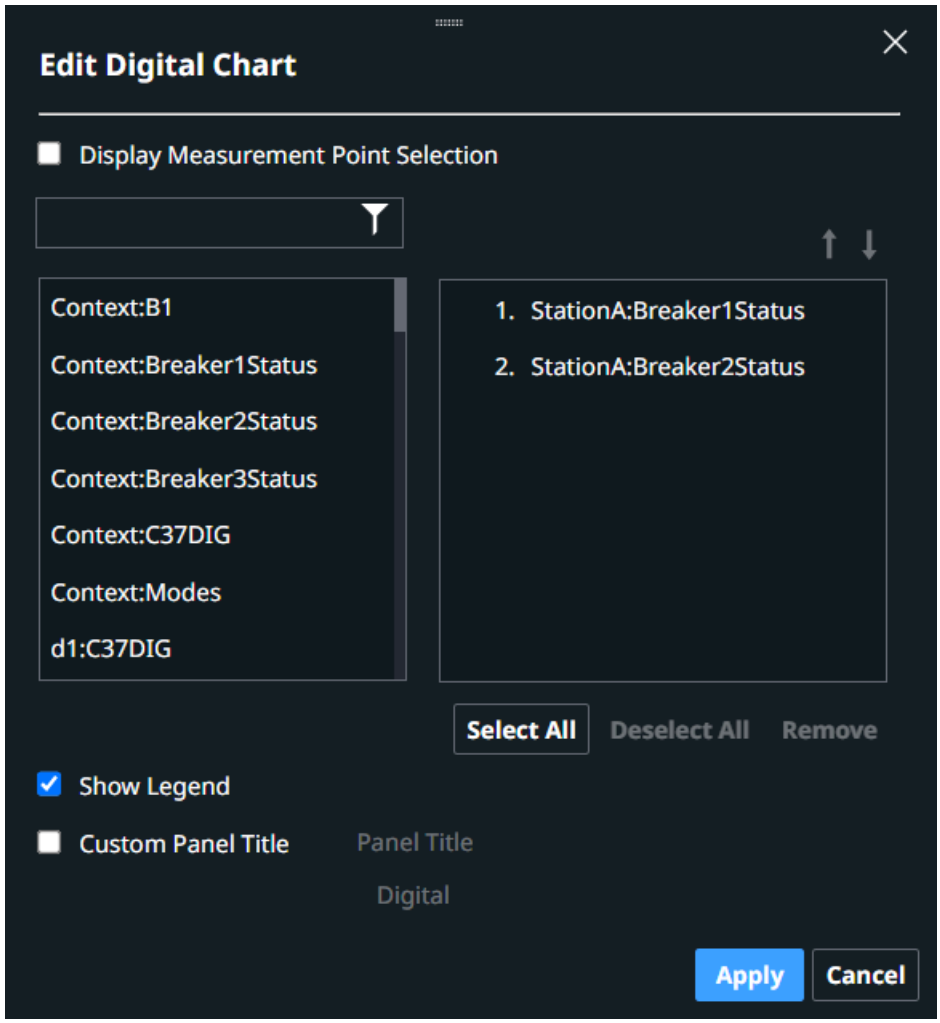



**Figure 4.91 Digital Chart Configuration Dialog**

## Adding Signals to the Digital Chart

Add signals to the Digital Chart by selecting them from the list on the left side of the configuration dialog. Signals in the list on the right will appear on the chart after selecting **Apply**. Signals are listed using the format MeasurementPoint:Quantity.

The list on the left side of the dialog contains only signals that have been configured as digital in the Digitals.csv file for the Signals application. See *SEL Signals Diagnostics Menu and Configuration on page 25* for details on configuring digital signals.

Selecting a signal with the Measurement Point "Context" will cause the chart to add signals automatically according to the context defined by the current view in either Asset or Notification mode. Context is supported only for Synchrowave Operations.

### Other Chart Settings

If **Display Measurement Point Selection** is checked, signals currently selected on the dashboard will be dynamically added to the chart. Once deselected, they are removed from the chart.

The chart legend can be shown or hidden using the **Show Legend** check box. The default title for the chart is "Digital".

A custom title can be used by checking **Custom Panel Title** and filling out the Panel Title field with the desired title.

## Digital Chart Display

The Digital Chart displays a thin line when the value of the signals is 0, a thick line when the value is 1, and a darker colored thick line when the value is anything other than 0 or 1. If state labels are configured, they are displayed beneath the line any time the signal has the value associated with the state. If state labels are not configured, the value of the signal is displayed beneath it instead.

If the chart time range is zoomed out far enough, it is possible that there is not sufficient resolution to distinguish a single transition from multiple transitions. This situation is indicated by a narrow, darker colored band at the transition point, as shown in *Figure 4.92*. Zooming in at the transition point will increase resolution and the band will disappear when full resolution is available.

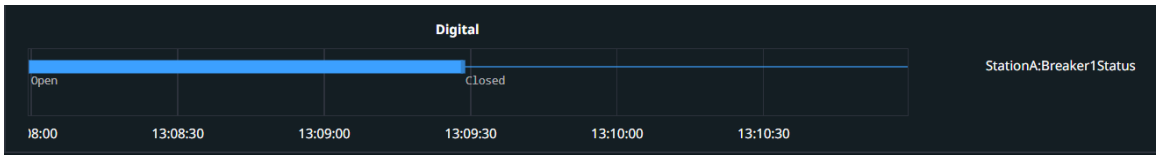



**Figure 4.92 Digital Chart Insufficient Resolution**

A maximum of 25 signals can be displayed in the chart. If more than 25 signals are selected, those beyond 25 are not displayed.

# ESRI Map Panel Application

The ESRI Map panel provides the ability to visualize power system assets and the location of power system conditions geospatially.

**Figure 4.93 ESRI GIS Map Overview**

# Navigating the GIS Map

## Panning

Pan the geographic information system (GIS) map by selecting the map and dragging the cursor across the map panel.

## Zooming

Zoom in and out on the GIS map with the mouse wheel or with the + and – buttons in the lower left corner. These methods provide a coarse zoom to fixed levels. Perform a box zoom on the GIS map by holding the **<Shift>** key and dragging the cursor across the map if zooming to a more precise region of the map is desired.

Set the default zoom level for the GIS Map panel by zooming to the desired zoom level, then select **Set** from the pop-up menu in the lower right corner of the map. Select **Restore** to return to the default zoom level. Select **Clear** to return the default zoom level to the original value.

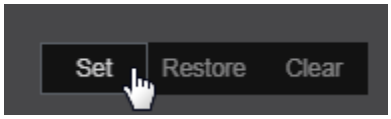



**Figure 4.94 Set the GIS Map Panel Default Zoom**

## Dashboard Navigation

Use the GIS map to quickly navigate to additional information and dashboards for power system assets displayed on the GIS map. Automatically navigate to any dashboard created for the selected power system asset by holding the **<Ctrl>** key and selecting a power system asset (line, substation). See *Dashboard Navigation on page 52* for additional information in configuring dashboards for power system assets.

## Selection

Use the GIS map to add measurement points to other panels on the selected dashboard. To do this, select a power system asset on the GIS map. The GIS map then selects all of the measurement points associated with the selected asset. Selecting a measurement point in any panel highlights and adds the selected measurement point to all panels (if **Display Measurement Point Selection** is enabled in panel settings).

### NOTE

Hold down **<Shift>** to select multiple assets. **<Ctrl>+click+drag** to select all assets within a region.

## Satellite Base Map

To switch between the configured base map and a satellite base map, select the satellite layer icon in the lower left corner of the GIS Map panel.

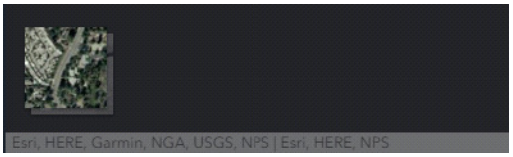



**Figure 4.95 Switching to Satellite Basemap**

# Configuring the ESRI Map Application

## Connecting to an ESRI Map Server

The Synchrowave Platform ESRI Map application supports connection to the following ESRI Map servers:

- Offline ESRI ArcGIS Server
- ArcGIS Online. SEL recommends never connecting critical infrastructure to the internet. See *Deployment Network Architecture on page 199* for recommended best practices.

To connect to an ESRI Map server, navigate to the Application Manager and select the ESRI Map application.

The configuration tab provides a location to enter the ESRI portal URL and ID. Contact your organization ESRI administrator for help connecting to the ESRI server of your organization.

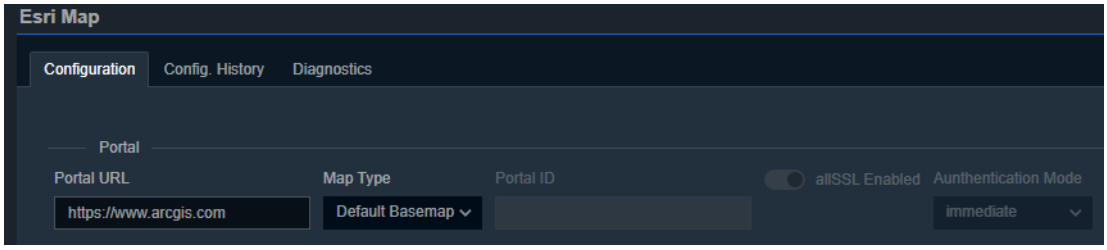



**Figure 4.96 Connecting to ESRI GIS Server**

# Configuring the GIS Map Panel

## Opening Edit Menu

To configure the layers displayed in the GIS Panel, select the + in the top right corner of the panel.

## Changing the Base Map

To change the base map displayed in the GIS Map panel, select the **Basemap** tab. Then select the **Basemap Options** dropdown menu and select from the available base maps.

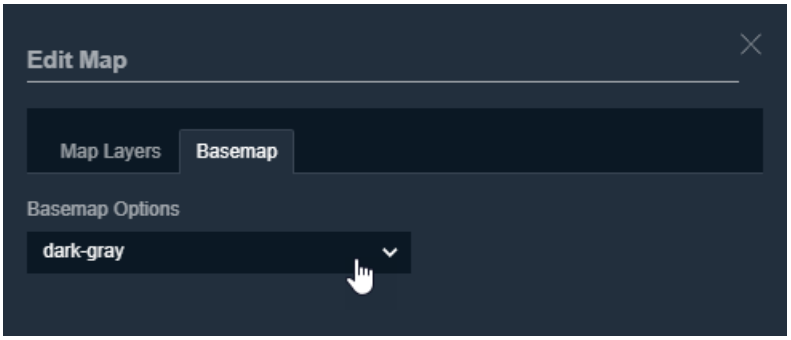



**Figure 4.97 Changing the GIS Map Base Map**

## Adding and Removing Map Layers

To add map layers to the GIS Map panel, search for the desired map layer and select **Add**. To remove map layers from the GIS Map panel, select a previously added map and select **Remove**.

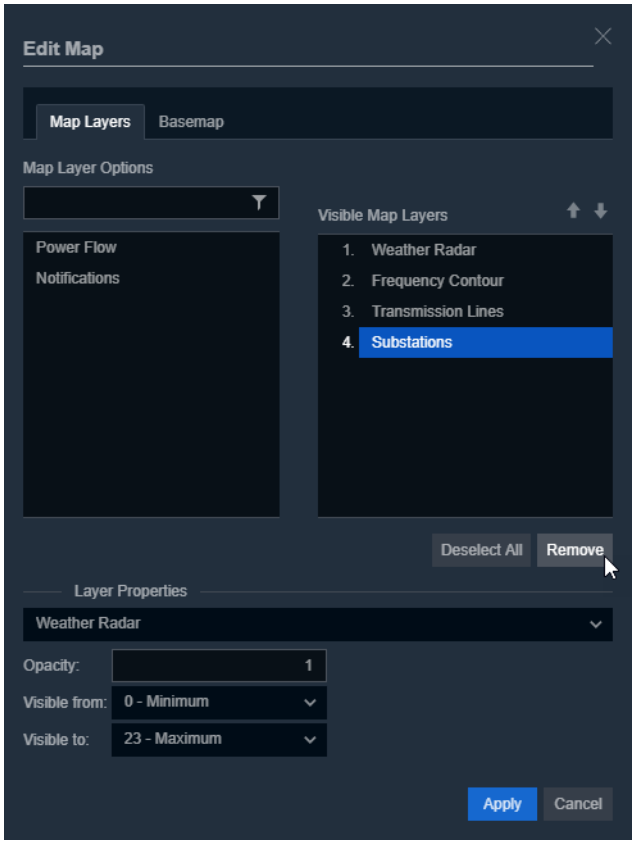



**Figure 4.98 Add/Remove Map Layers**

# Lines and Stations GIS Map Layers

The Lines and Stations map layers display the GIS coordinates of power lines and substations to provide users with location context.

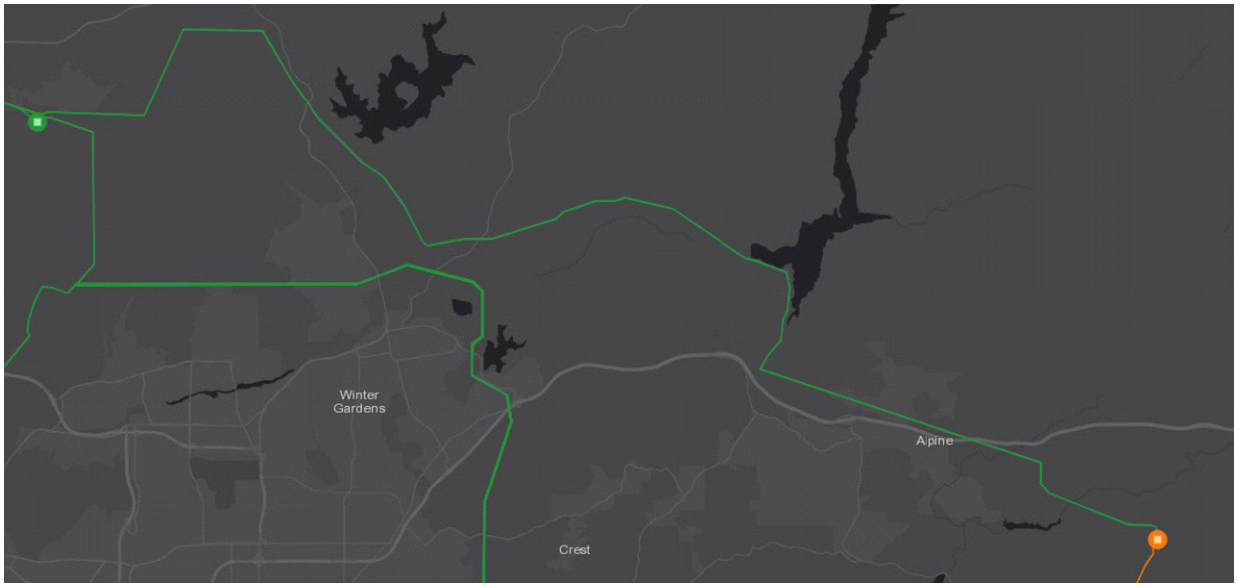



**Figure 4.99 Example of Lines and Stations Map Layers**

# Notifications GIS Map Layer

The Notification map layer displays the location of Notifications on the map for location context.

Notification locations are displayed if the Notification meets the following states:

- Notification is in Timeline time range
- Notification is active
- Notification is unacknowledged
- Notification is selected

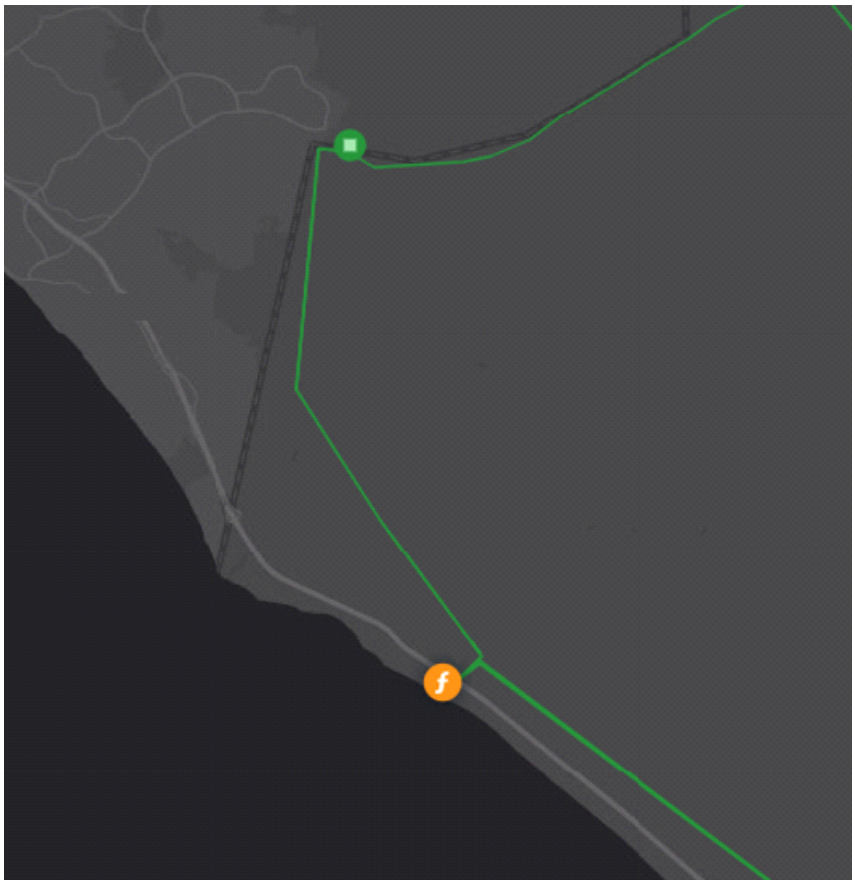


**Figure 4.100 Notification Map Layer**

If multiple notifications occur at the same location, the notifications are grouped and the number of notifications at that location is displayed. The most severe state of the grouped notifications at that location is displayed.

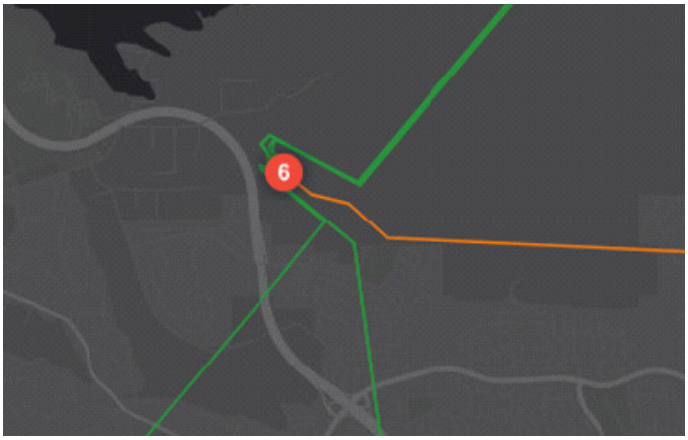



**Figure 4.101 Indication of Multiple Notifications at One Location**

# Power Flow GIS Map Layer

The Power Flow map layer provides users with visibility into the direction of power flow across each line segment.

**Figure 4.102 Power Flow Direction Map Layer**

# Select Visible Map Layers

Map layers can be quickly enabled or disabled using the Layer Visibility button on the map. Select the Layer Visibility button and then select the slide switches to toggle each layer. Green switches correlate to visible layers.

**Figure 4.103 Change Layer Visibility**

# Configuring Opacity and View Range

Each visible map layer has a configurable opacity and view range. To configure a layer, select it from the dropdown menu under Layer Properties. Fill out the fields and select **Apply**.

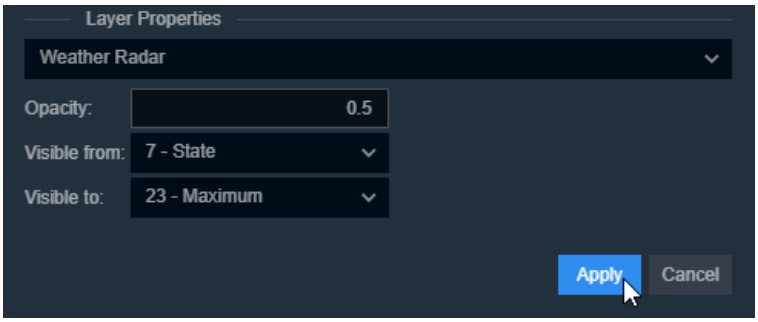



**Figure 4.104 Edit Layer Properties**

Opacity is a measure of how transparent a layer is. An opacity of 1 correlates to an opaque layer and an opacity of 0 correlates to a transparent layer. Choosing opacities between 0 and 1 allows overlapping layers to be seen. Type a number between 0 and 1 into the Opacity box to set the opacity for that layer.

The view range specifies when a layer is rendered on the map. Some layers contain a lot of detail, so rendering the entire layer could impact responsiveness. The map panel renders a layer when it is within a certain zoom range. Zoom ranges from 0 to 23, with 0 being fully zoomed out, and 23 being fully zoomed in. For example, selecting a **Visible from** value of 7 will begin to render the layer at the state level. All layers are rendered when the map is fully zoomed in. Select a **Visible from** value by selecting the corresponding dropdown menu.

# ArcGIS Map Layers

ArcGIS Map Layers are a powerful feature that allows GIS data to be superimposed on the ESRI Map Panel. Multiple layers can be superimposed on top of each other with configurable opacity and view ranges. Public and private Feature Layers, Imagery Layers, Map Image Layers, and FML Layers are supported. Time-enabled ArcGIS Map Layers are also supported, enabling users to go back in time and see a layer's historical state.

## Adding New ArcGIS Layers

The ESRI Map Configuration in the Application Manager shows all layers available to ESRI Map Panels. Each map panel is individually configured to display as many map layers as desired from this list. Layers can be added in two ways:

1. Use the search portal to search for map layers. Scroll through and navigate the search results. Select **Add** to add the layer. Select **Apply** to save changes. The ESRI Map Application then restarts.

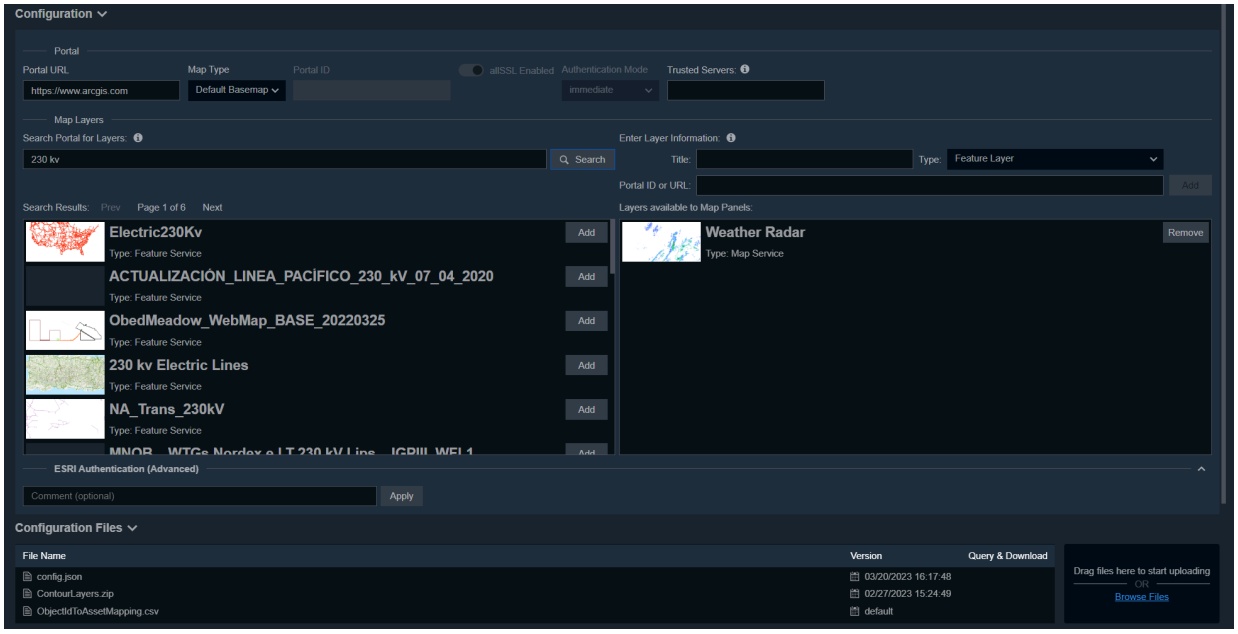



**Figure 4.105 Adding Layers By Using the Search Portal**

2. Enter the layer information directly. Enter the Title, Type, and URL of the ArcGIS map. Select **Add** to add the layer. An optional text box next to the Apply button allows you to enter a comment describing the changes. Select **Apply** to save changes. If entered, the comment will be stored in the configuration history of the config.json file. After **Apply** is selected, the ESRI Map Application restarts. Note that the Title attribute does not have to match the name of the Layer in ArcGIS; it can be arbitrarily chosen as long as each added layer has a unique Title.

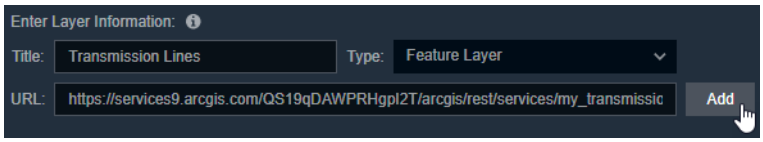



**Figure 4.106 Adding Layer With URL**

By selecting the thumbnail on any of the displayed layers, a new tab will open displaying more information about that map layer.

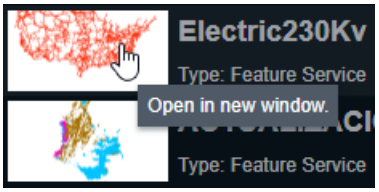



**Figure 4.107 Display Map Layer Information**

## Removing ArcGIS Layers

Select the **Remove** button to remove a layer from the Available Layers section. The removed layer will appear in the Search Results section. Select **Apply** to save changes.

**Figure 4.108 Removing Map Layers**

# Associating Assets With Map Layers

The ESRI map panel is interactive. When an asset on the map, such as a substation or transmission line, is selected, Synchrowave Operations shows the user additional information about that asset. It does this by associating specific Object IDs from the ArcGIS map layers with unique power system assets. A single csv file must be configured to enable this functionality.

## Configuring Asset Mapping

Download the ObjectIdToAssetMapping.csv file.

Open the CSV file in any text editor or spreadsheet application. For each applicable map layer, fill out the CSV file. The columns in the CSV are defined as follows:

- **LayerTitle.** Name of the layer, case insensitive. Find the ArcGIS layer title by selecting the thumbnail of the added layer and finding the list of layers, as shown in *Figure 4.109*. Replace all underscores with spaces. In this example, the layer title is **wa stations 230 0**.

**Figure 4.109 Finding Layer Title**

- **ObjectId.** Unique identifier. Obtained under the Data tab for the feature layer in the ArcGIS developer account. In some cases, the ObjectId assigned to a feature can change frequently when a layer is updated. If this is the case, a more stable field defined in the layer can be used for mapping and the ObjectId field should be left empty.
- **AssetName.** Name of the power system asset, case sensitive. Obtained from the Power System Model application configuration.
- **IdFieldName.** If a field other than ObjectId will be used for a given row of the ObjectIdToAssetMapping.csv file, enter the name of the desired field. If ObjectId will be used, leave IdFieldName blank.
- **IdFieldValue.** The particular value of the field defined in IdFieldName that is assigned to the asset. If ObjectId will be used, leave IdFieldValue blank.

*Figure 4.110* shows an example configuration.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | LayerTitle | ObjectId | AssetName | IdFieldName | IdFieldValue |
| 2 | Wa stations 230 0 | 1 | StationA | | |
| 3 | Wa stations 230 0 | 2 | StationB | | |
| 4 | Stations | | StationC | StationID | Station12 |
| 5 | Stations | | StationD | StationID | Station34 |
| 6 | Lines | | Line1 | TLID | TL_1 |
| 7 | Lines | | Line2 | TLID | TL_2 |

**Figure 4.110 Example Asset Mapping Configuration File**

Save the CSV file and import it back into Synchrowave. The ESRI Map Application restarts. Refresh Synchrowave Operations to complete the configuration process.

# Contour Layers

The Contour Map Layers enables users to visualize data types such as frequency and voltage magnitude across the entire power system at a glance. One contour layer can be visualized at a time.

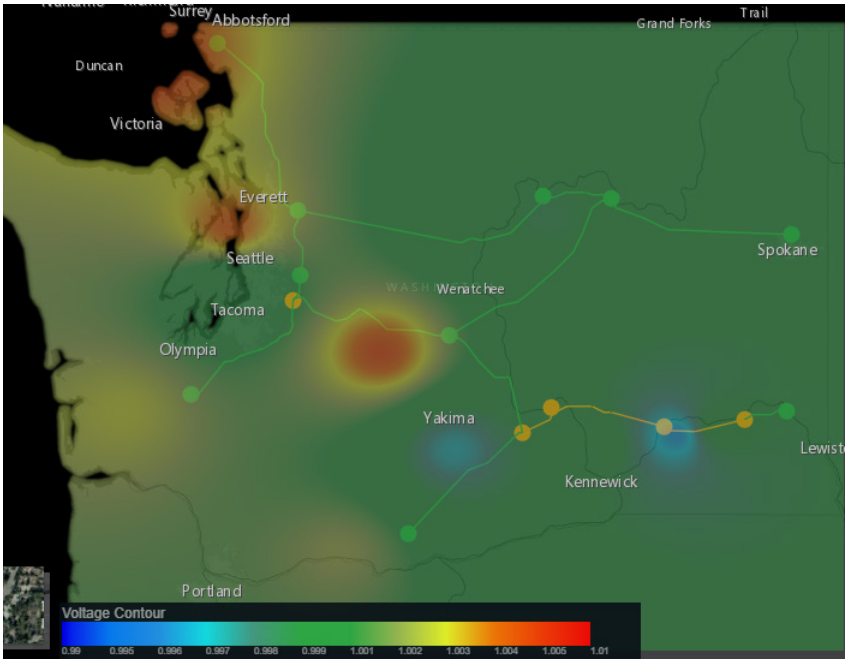



**Figure 4.111 Contour Map Layer**

## Configuring Contour Layers

Contour layers can be configured for any data type, including frequency, voltage magnitude, and phase angle. Each contour layer is associated with three configuration files. All configuration files can be imported and exported with one ZIP file. For example, if frequency and voltage magnitude contours are configured, the ZIP file contains six configuration files.

To configure contour layers, first download the ContourLayers.zip file.

Open the ZIP file and select **Extract All**. If there are zero or one configured contours, there will be three files in the folder. SEL recommends renaming the configuration files for each contour as shown in *Figure 4.112*. This helps identify each contour configuration file after multiple contours have been configured. This example creates a frequency contour and a line-to-line voltage magnitude contour.

| Name | Date modified | Type | Size |
|---|---|---|---|
| FrequencyColors.csv | 7/7/2020 3:05 PM | Microsoft Excel C... | 1 KB |
| FrequencyInformation.csv | 7/7/2020 9:43 PM | Microsoft Excel C... | 1 KB |
| FrequencyMeasurementPoints.csv | 7/7/2020 3:28 PM | Microsoft Excel C... | 1 KB |
| VoltageColors.csv | 7/7/2020 3:34 PM | Microsoft Excel C... | 1 KB |
| VoltageInformation.csv | 7/7/2020 3:09 PM | Microsoft Excel C... | 1 KB |
| VoltageMeasurementPoints.csv | 7/7/2020 3:27 PM | Microsoft Excel C... | 1 KB |

**Figure 4.112 Example Renamed Contour Layer Configuration Files**

Open the applicable Information.csv file. Two cells must be configured:

- **Title.** The display name of the contour. This can be any string of characters.
- **DataType.** The data type of the contour. This must exactly match a valid data type as configured with the IEEE C37.118 Reader or STTP Reader.

| | A | B |
|---|---|---|
| 1 | Title | DataType |
| 2 | Frequency Contour | Frequency |

| | A | B |
|---|---|---|
| 1 | Title | DataType |
| 2 | Voltage Contour | LL.Voltage.Magnitude |

**Figure 4.113 Example Information.csv Files**

Save and close the file.

Open the applicable MeasurementPoints.csv file. For each measurement point on the contour, two cells must be configured:

- **MeasurementPoint.** The name of the measurement point as configured in the IEEE C37.118 Reader or STTP Reader. Only one measurement point per station should be used.
- **NominalValue.** The nominal value of the measurement point. The contour layer divides the observed value by the nominal value to get a per-unit measurement, which is used to determine coloring. This is especially useful when creating voltage contours where nominal values vary between measurement points. Setting Nominal Value to 1 avoids the per-unit conversion.

| | A | B |
|---|---|---|
| 1 | MeasurementPoint | NominalValue |
| 2 | BE.BUS230 | 1 |
| 3 | CE.BUS230 | 1 |
| 4 | CF.BUS500 | 1 |
| 5 | CJ.BUS230 | 1 |
| 6 | EL.BUS230 | 1 |
| 7 | EV.BUS230 | 1 |
| 8 | GC.BUS230 | 1 |
| 9 | GO.BUS230 | 1 |
| 10 | LG.BUS230 | 1 |
| 11 | LM.BUS500 | 1 |
| 12 | SE.BUS230 | 1 |
| 13 | SP.BUS230 | 1 |
| 14 | SS.BUS230 | 1 |
| 15 | TA.BUS230 | 1 |
| 16 | TC.BUS500 | 1 |

| | A | B |
|---|---|---|
| 1 | MeasurementPoint | NominalValue |
| 2 | BE.BUS230 | 230000 |
| 3 | CE.BUS230 | 230000 |
| 4 | CF.BUS500 | 500000 |
| 5 | CJ.BUS230 | 230000 |
| 6 | EL.BUS230 | 230000 |
| 7 | EV.BUS230 | 230000 |
| 8 | GC.BUS230 | 230000 |
| 9 | GO.BUS230 | 230000 |
| 10 | LG.BUS230 | 230000 |
| 11 | LM.BUS500 | 500000 |
| 12 | SE.BUS230 | 230000 |
| 13 | SP.BUS230 | 230000 |
| 14 | SS.BUS230 | 230000 |
| 15 | TA.BUS230 | 230000 |
| 16 | TC.BUS500 | 500000 |

**Figure 4.114 Example MeasurementPoints.csv Files**

Save and close the file.

Open the applicable Color.csv file. There are four columns in this file:

- **Value.** The per-unit value to be associated with a color
- **Red.** The red component of the color (0 to 255)
- **Green.** The green component of the color (0 to 255)
- **Blue.** The blue component of the color (0 to 255)

This example contours are blue at low-frequency, red at high-frequency, and green at nominal frequency. More complicated color configurations are possible. As many as 30 rows can be used. Per-unit values outside of the range provided are ignored when creating the contour.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Value | Red | Green | Blue |
| 2 | 59.5 | 0 | 0 | 255 |
| 3 | 60 | 0 | 255 | 0 |
| 4 | 60.5 | 255 | 0 | 0 |

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Value | Red | Green | Blue |
| 2 | 0.95 | 0 | 0 | 255 |
| 3 | 1 | 0 | 255 | 0 |
| 4 | 1.05 | 255 | 0 | 0 |

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Value | Red | Green | Blue |
| 2 | 0.9 | 0 | 0 | 255 |
| 3 | 0.95 | 0 | 123 | 255 |
| 4 | 0.96 | 31 | 146 | 240 |
| 5 | 0.97 | 14 | 228 | 240 |
| 6 | 0.98 | 67 | 156 | 132 |
| 7 | 0.99 | 43 | 173 | 67 |
| 8 | 1.01 | 43 | 173 | 67 |
| 9 | 1.02 | 160 | 189 | 83 |
| 10 | 1.03 | 241 | 252 | 38 |
| 11 | 1.04 | 255 | 119 | 0 |
| 12 | 1.05 | 255 | 55 | 0 |
| 13 | 1.1 | 255 | 0 | 0 |

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Value | Red | Green | Blue |
| 2 | 0.9 | 0 | 15 | 255 |
| 3 | 0.95 | 0 | 15 | 255 |
| 4 | 0.95 | 0 | 175 | 255 |
| 5 | 0.97 | 0 | 175 | 255 |
| 6 | 0.97 | 142 | 235 | 236 |
| 7 | 0.99 | 142 | 235 | 236 |
| 8 | 0.99 | 43 | 173 | 67 |
| 9 | 1.01 | 43 | 173 | 67 |
| 10 | 1.01 | 255 | 255 | 0 |
| 11 | 1.03 | 255 | 255 | 0 |
| 12 | 1.03 | 248 | 116 | 49 |
| 13 | 1.05 | 248 | 116 | 49 |
| 14 | 1.05 | 255 | 0 | 0 |
| 15 | 1.1 | 255 | 0 | 0 |

**Figure 4.115 Example Color.csv Files**

Save and close the file.

Zip all configuration files together. Import the file back into Synchrowave. A success message appears.

The ESRI Map Application restarts. Navigate to Synchrowave Operations and refresh the page. The configuration is now complete.

## Adding Contour Layers to a Map Panel

Adding contour layers to the map panel is the same as adding any other type of layer to the map. Refer to *Adding and Removing Map Layers on page 134* for details.

## Contour Layers on Maps Outside the United States

Contour layers include a mask to prevent the contours from appearing over water. The default mask covers all land and water outside the United States. Therefore, if a contour layer is configured for locations outside the United States, the map will be completely covered by the mask.

To configure a custom mask, create a .geojson file containing polygons that define the desired mask (https://geojson.io is a free online tool that works well). Save the file with the name MaskLayer.geojson, include it in the ContourLayers.zip file, and upload the .zip file from the Application Manager.

# One-Line Diagram Panel Application

The One-Line Diagram Panel provides visualization of scalable vector graphics (SVG) drawings. SVG objects and data values can update based on real-time or historical data.

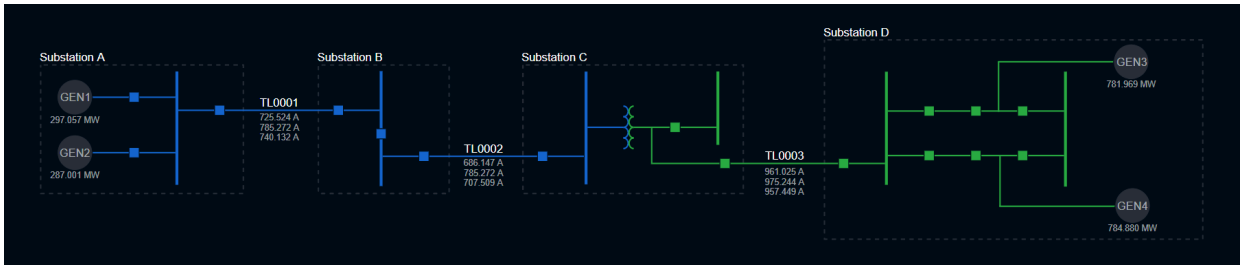



**Figure 4.116 One-Line Diagram Panel Overview**

## Navigating the One-Line Diagram Panel

### Panning

Pan the displayed diagram by selecting the diagram and dragging the cursor across the One-Line Diagram Panel.

### Zooming

Zoom in and out on the displayed diagram with the mouse wheel.

Set the default zoom level for the One-Line Diagram Panel by zooming to the desired zoom level, then select **Set** from the pop-up menu in the lower right corner of the diagram. Select **Restore** to return to the default zoom level. Select **Clear** to return the default zoom level to the original value.

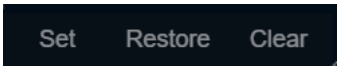



**Figure 4.117 Set the One-Line Diagram Panel Default Zoom**

### Panning Through Time

In real-time mode, the One-Line Diagram Panel updates to display the most recent values and state of an object. If you pan through historic data with the time-series trend or timeline, the One-Line Diagram Panel automatically updates to display historical values and object(s) state.

### Dashboard Navigation

Use the One-Line Diagram to quickly navigate to additional information and dashboards for power system assets displayed on the One-Line Diagram. Automatically navigate to any dashboard created for the selected power system asset by holding the **<Ctrl>** key and selecting an object in the diagram that represents a power system asset (line, substation). See *Dashboard Navigation on page 52* for additional information in configuring dashboards for power system assets.

### Selection

Use the One-Line Diagram to add measurement points to other panels on the selected dashboard. To do this, select an object (data value) on the One-Line Diagram that has an associated measurement point. Selecting a measurement point in any panel highlights and adds the selected measurement point to all panels (if Display Measurement Point Selection is enabled in panel settings).

## Uploading SVG Diagrams

To upload an SVG diagram(s) to the Synchrowave Platform, navigate to the Application Manager and select the **One-Line Diagram** application.

Use the **Import** button in the Configuration tab to load SVG diagrams. You must import and export all SVG diagram files in one ZIP file. You can select uploaded SVG diagrams during the configuration of a One-Line Diagram Panel for a dashboard. The ZIP file upload size is limited to 250 KB.

See *Appendix C: Creating SVG Diagrams* for more information on creating SVG diagrams and mapping SVG objects to measurements.

## Configuring the One-Line Diagram Panel

### Opening Edit Menu

To configure the diagram displayed in the One-Line Diagram Panel, select the + in the top right corner of the panel.

## Selecting A Diagram

Use the **One-Line Diagram File** dropdown menu to select an available SVG diagram. You can only select one SVG diagram per One-Line Diagram Panel.

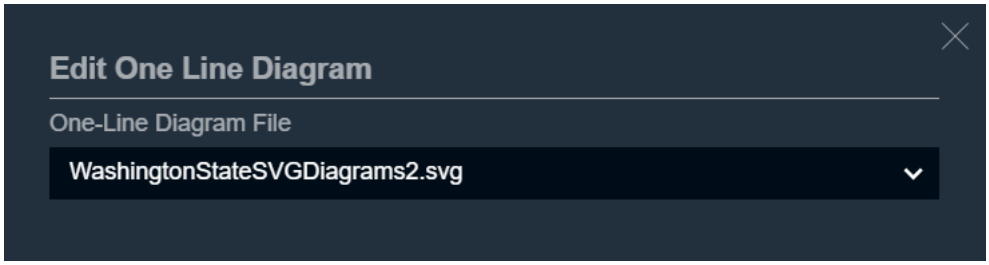



**Figure 4.118 Selecting SVG Diagram for One-Line Diagram Panel**

# Data and Storage Applications

## Introduction

The Synchrowave Platform is designed to archive and process time-series data and supports a variety of time-series data applications. Data Reader applications connect to time-series data sources, gather their data, and publish those data to the Signals application. The Signals application then publishes the data to various consumers such as the power system applications and dashboard visualization. The Time-Series Historian archives data that are published to the Signals application. The platform is designed with extensibility in mind, so that new data reader, data archive, and data consumer applications can be quickly added as use cases as needs evolve over time.

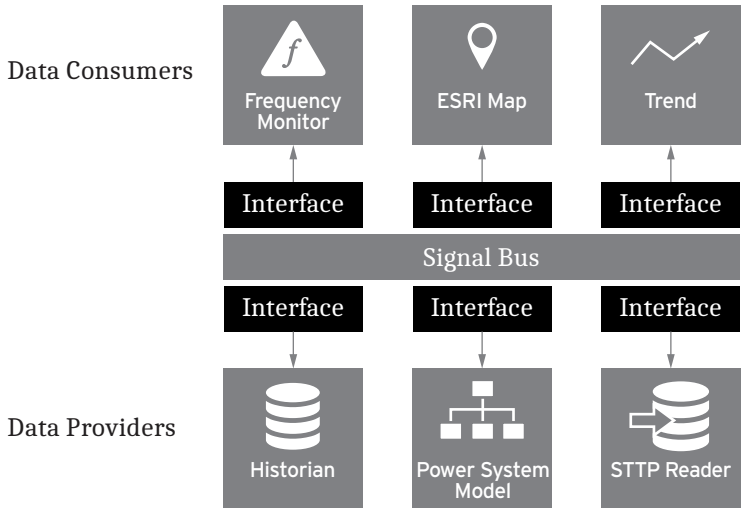



**Figure 4.119 Data and Storage Architecture**

### NOTE

For Linux installations, the files stored in application data directories have a user id (UID) and group id (GID) set to 100000. If data is copied into the directory from an external source, ensure that the files have UID and GID of 100000 or have permissions set such that UID 100000 can read (and write, if needed) the files.

# Time-Series Historian Application

The high-performance Time-Series Historian application supports data rates as few as at 1 message per day. The maximum rate is determined by computing resources. Message rates as fast as 10,000 messages per second are supported. The database serves two purposes; to archive all signals published to the signal bus and to serve those archived data when requested by applications.

## Historian Features

### Data Retention

For deployments where archive storage availability may be limited, a data retention period can be configured. The Historian application deletes archived data as it becomes older than the retention setting.

For example, if the data retention setting is set to 7 days, on the 8th day, the first day of archived data will be deleted to make space for the next day of data to be archived.

### Data Indexing

The Historian also creates minimum/maximum indexes of data archived in the Historian application to accelerate the visualization of large amounts of data for engineers and operators.

Data are archived at a rate that is typically impractical to display on a computer monitor or dashboard trend panel. For example, at a data rate of 60 messages per second, 10 minutes of archived data includes 36,000 data points. The number of data points must be reduced to a manageable number while still retaining the important details for trend display. Rather than downsampling the data points, which could result in important transient features being missed, the data indexer determines maximum and minimum data values within segments of the period of interest and provides those data points to trend panels for display. This way, even with the display zoomed out to cover hours, outliers are always visible on the trend. As the user zooms in to smaller periods, additional data resolution is added.

The indexed data are stored in the same format as the Historian data.

### Performance Monitoring and Out of Space Prediction

The Historian produces warning logs and system notifications (shown in the upper right side of the Application Manager page and causing the alarm bell to flash orange) when it has stopped writing data for more than 1 minute. This is most likely to occur if the data source for the system, e.g., the C37.118 stream, has been lost.

The Historian predicts when it will run out of space in the current application data directory and produces warning logs and system notifications when it predicts that it has 8 weeks or less of space remaining. An example of the system notification is shown below.

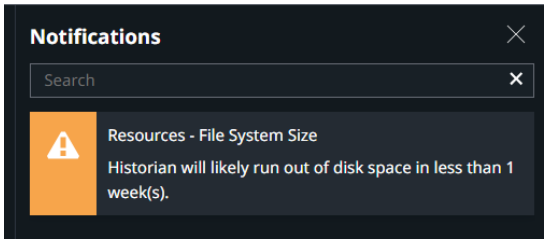



**Figure 4.120 Synchrowave Historian System Notification**

# Historian Format

## Format

The Time-Series Historian application uses folder directories and files for storage. The folder and file format provides simple and efficient management of the archived data. System administrators can use the same file-based management and backup tools that they use for all types of files. The folder and file format used is defined as follows:

sel-historian/history/

[MeasurementPoint]/

[Quantity]/

[Year]/

[Month]/

[Date],[Time],[MessageRate],[ValueType].signal

The indexed data are stored with the same directory and file structure, except under the sel-historian/index/ directory.

## Example

The following example shows the folder and file name for measurement point PullmanWA.North, Quantity Phase 1 voltage magnitude, for February 1, 2019, starting at 10:35:15.016666666 UTC, having 60 messages per second of Float32 data.

sel-historian/history/

PullmanWA.North/

Phase1.Voltage.Mag/

2019

02

20190201,103515.016666666,60,Float32.signal

## Historian Field Definitions

**NOTE**
To rename an existing measurement point or quantity (data type), the update must be in the Historian and Histogram (if used) applications.

The fields are defined as follows:

- **[MeasurementPoint].** Measurement point name. For example, SA.TL23180.
- **[Quantity].** Quantity name. For example, Phase1.Voltage.Magnitude.
- **[Year].** The year of data archived. The format is *YYYY*, where *YYYY* is year.
- **[Month].** The month of data archived. The format is *MM*, where *MM* is month.
- **[Date].** The date of the first data value in the file. The format is *YYYYMMDD*, where *YYYY* is year, *MM* is the month, and *DD* is the day.
- **[Time].** The time of the first data value in the file. The format is *hhmmss.ffffffffff*, where *hh* is the hour (24 hour), *mm* is the minute, *ss* is the second, and *ffffffffff* is the fractional seconds, with nanosecond resolution. The Date and Time must be set to a valid time stamp, as defined in *Timestamps*.
- **[MessageRate].** The file message rate. If a positive value, the rate is messages/second. If a negative value, the rate is seconds per message.
- **[ValueType].** The type of the data in the buffer. The type determines the size of each value. See *Standard Data Types*.

**NOTE**
Additional information regarding the time-series historian format can be provided upon request.

# Historian Application Configuration

## Configuring the Archive Data Directory

The Historian application creates an sel-historian folder (with history and index subfolders) at the Archive Data Directory location. See *View and Set the Application Data Directory on page 210* for instructions to set the directory. The Archive Data Directory location also stores application configuration and other files used across the system. If using a cluster configuration, this location should be a network file share drive, where each server in the cluster has access to the drive. The current Application Data Directory can be viewed from the Platform Services application page in the Application Manager.

## Configuring Data Retention and Performance

The Historian data retention and performance are configured in the Application Manager. The Retention Period Days field sets the number of days for which data are retained. A value of 0 means all data are kept.

The Flush Seconds field sets the maximum amount of data that would be lost in the event of a hardware failure. Setting the value to a lower number will impact file system performance for larger systems.

The Save Time field sets the number of seconds between writes to disk. The default value is 5 seconds.

The Signals Per Thread field sets the maximum number of signals saved on a single thread. Lower values (more threads) decrease save times but increase CPU usage while saving.

The Keep Files Open toggle either keeps all files being written to open or closes files after each round of saving. It should be kept in the on (default) state. Contact SEL if you believe you need to change it.

The Max Rate of Signals to Save field sets the maximum sampling rate for signals to be saved. Signals with sampling rates above this value will not be saved. A value of 0 configures the Historian to save all signals, regardless of sample rate.

Turning on the Serve Data Only toggle stops the Historian from saving data, but it will still serve previously written data.

Turning on the Detect Added Files Automatically toggle allows for signal data to be manually added to the Historian data directory (rather than written by the Historian itself). It has a negative performance impact when the Historian is serving data and should only be turned on when necessary.

Once desired changes are made, select **Apply**. An optional text box next to the Apply button allows you to enter a comment describing the changes. Once **Apply** has been selected, the comment will be stored in the configuration history of the config.json file.

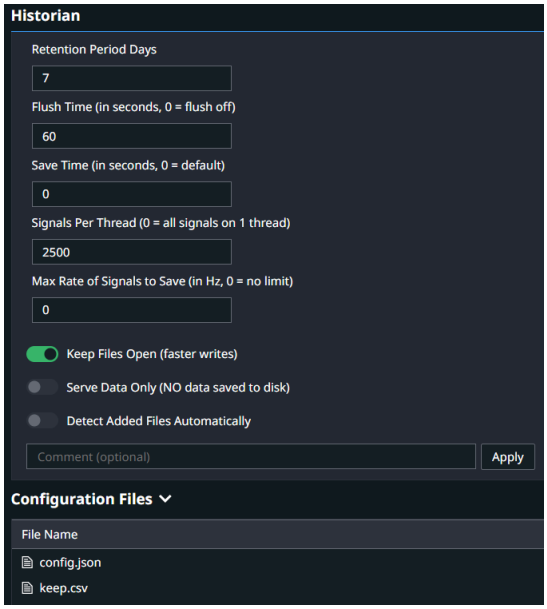



**Figure 4.121 Synchrowave Historian Data Retention Configuration**

The keep.csv file allows the user to specify MeasurementPoint and Quantity combinations to be exempt from deletion. Any configured signals will be saved indefinitely until they are removed from the keep.csv file.

| | A | B |
|---|---|---|
| 1 | MeasurementPoint | Quantity |
| 2 | StationA | Frequency |

**Figure 4.122 Synchrowave Historian Deletion Exemption Configuration**

# Calculations Application

The Calculations application allows you to configure and execute user-defined calculations related to streaming power system data.

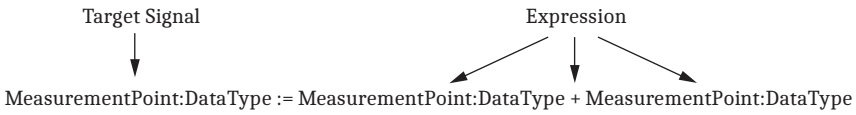



**Figure 4.123 Calculations Overview**

## Overview

### Accessing the Calculations Application

To access the Calculations user interface, use the Synchrowave Platform Navigation menu and select **Calculations**.

### Calculations Help

To access the Calculations help page from within the software, select the help icon on the calculations page, as shown in *Figure 4.124*.

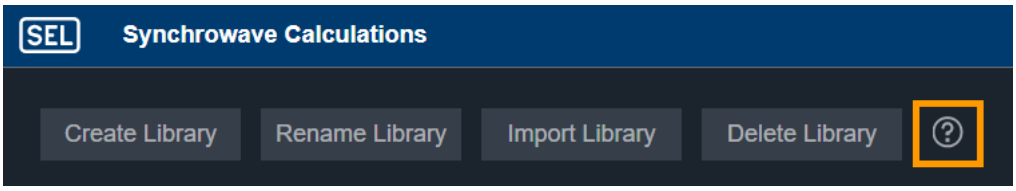



**Figure 4.124 Accessing Calculations Help Menu**

The Calculations help page provides an overview of the Calculations application and information about functions that can be used in expressions.

**Figure 4.125 Calculations Help Menu**

# Calculation Libraries

A Calculation library is a space where multiple calculations can be grouped together to achieve a common purpose. To enter or view calculations in a calculation library, select the library in the Calculation Libraries menu. Libraries can be created, renamed, imported, and deleted from the Calculations application page.

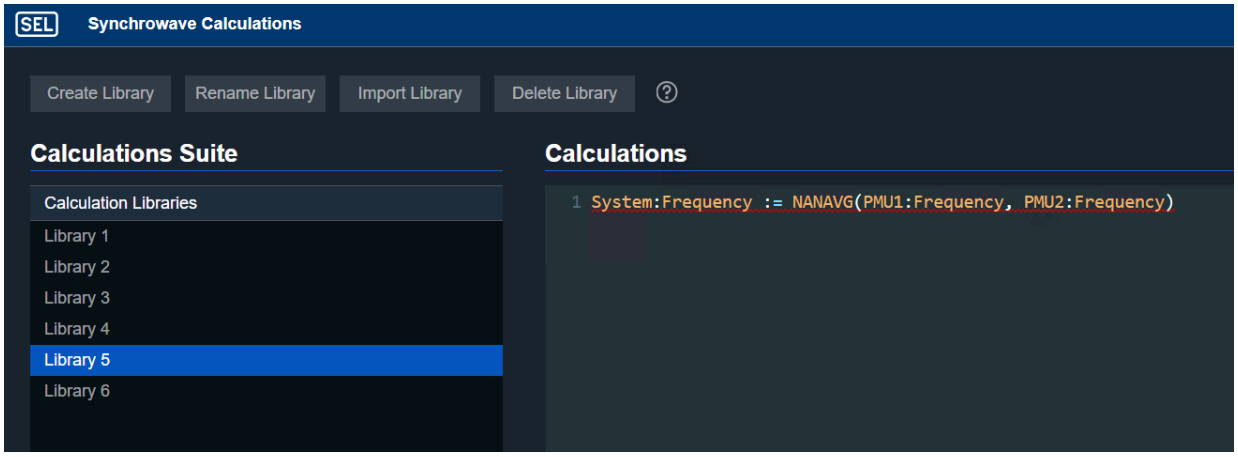



**Figure 4.126 Calculations Libraries**

# Calculations

All calculations use the following syntax:

TARGET := EXPRESSION

where:

TARGET is the target variable or signal name

EXPRESSION is the description of the calculation

**NOTE**
You cannot use spaces in any signal or variable name.

A TARGET (formatted as MeasurementPoint:Quantity) gets published to the signal bus for archiving in the Historian display in dashboards and monitoring with power system monitors. You can compose EXPRESSIONs with a combination of signals, variables, constants, and functions (see the Calculations help menu in the software for more information).

# Event Store Application

The Event Store application stores event data and serves it to consumers.

## Event Store Features

The Event Store stores event files in an unfiltered format on disk and allows for specifying the persistence period in days.

## Event Store Configuration

To configure the Event Store, use the **Query and Download** button to the MeasurementPointMappings.csv file, set the **SourceID**, **Name**, **Substation**, and **MeasurementPoint**.

### Set Retention Period

Set how long events will be stored in days. For indefinite storage, set the Retention Period to 0.

### Mapping Incoming Events

Use the Query and Download button to retrieve the MeasurementPointMappings.csv file. It contains four columns: SourceID, Name, Substation, and MeasurementPoint. Events received by the Event Store provide the SourceID, Name, and Substation fields, and these fields will be automatically populated for all events currently stored. Each of the SourceIDs must be mapped to a measurement point for the events to be associated with the assets in the power system model, differentiated on the Device Events panel, and queried by applications on the Synchrowave Platform.

# SWave Server Application

The SWave Server application reads historical .swave files and publishes their signal data for other applications to use. This server works in conjunction with the Historian application to ensure that historical data are available for applications requesting archived data. This application makes historical data from Synchrowave Central available for display in Synchrowave Operations.

# Loading SWave Data

To use the SWave Server, SWave data must be available for reading in the **[*Application Data Directory*]/sel-swaveserver/SwaveData/** folder. This can be accomplished in two ways:

1. Copy the **Historian/** and **Index/** folders from a Synchrowave Central SWave Database manually to the **[*Application Data Directory*]/ selswaveserver/** folder.
2. Use the Linux file system mounting (**/etc/fstab**) to mount another system's SWave Database folder to the **[*Application Data Directory*]/ sel-swaveserver/** folder. The remote system folder must contain the **Historian/** and **Index/** folders.

Note that *[Application Data Directory]* refers to the directory configured in the SEL.Platform application.

# Configuring the SWave Server

To configure the SWave Server, download the SignalMappings.csv file for the SWave Server, edit it as necessary (see details below), and import it back into Synchrowave.

## Configuring the CSV file

Open the CSV file with any text editor or spreadsheet application. This file includes four columns: DeviceAcronym, Description, MeasurementPoint, and Quantity. Please refer to the IEEE C37.118 Reader SignalMappings.csv file for help populating these columns. *Figure 4.127* shows an example configuration file.

**NOTE**
Measurement points, quantity (data type) and asset names can include the following characters: letters, numbers, periods, and underscores.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | DeviceAcronym | Description | MeasurementPoint | Quantity |
| 2 | SubstationA_PMU1 | TL1_VA_Magnitude | SubstationA.TransmissionLine1 | PhaseA.Voltage.Magnitude |
| 3 | SubstationA_PMU1 | TL1_VA_Angle | SubstationA.TransmissionLine1 | PhaseA.Voltage.Angle |
| 4 | SubstationA_PMU2 | TL1_VB_Magnitude | SubstationA.TransmissionLine1 | PhaseB.Voltage.Magnitude |
| 5 | SubstationA_PMU2 | TL1_VB_Angle | SubstationA.TransmissionLine1 | PhaseB.Voltage.Angle |

**Figure 4.127 Example SWave Server CSV Mapping File**

## Stop Displaying SWave Data at Some Time

If the Historian application is configured to delete data after a certain amount of time, it can be helpful to not display SWave data at a future point in time. Consider this scenario:

A utility installs Synchrowave Monitoring in late 2020. The Historian application is configured to delete archived data after six years. For the first six years of operation, archived SWave and Historian data are available for all applications on the Synchrowave Platform.

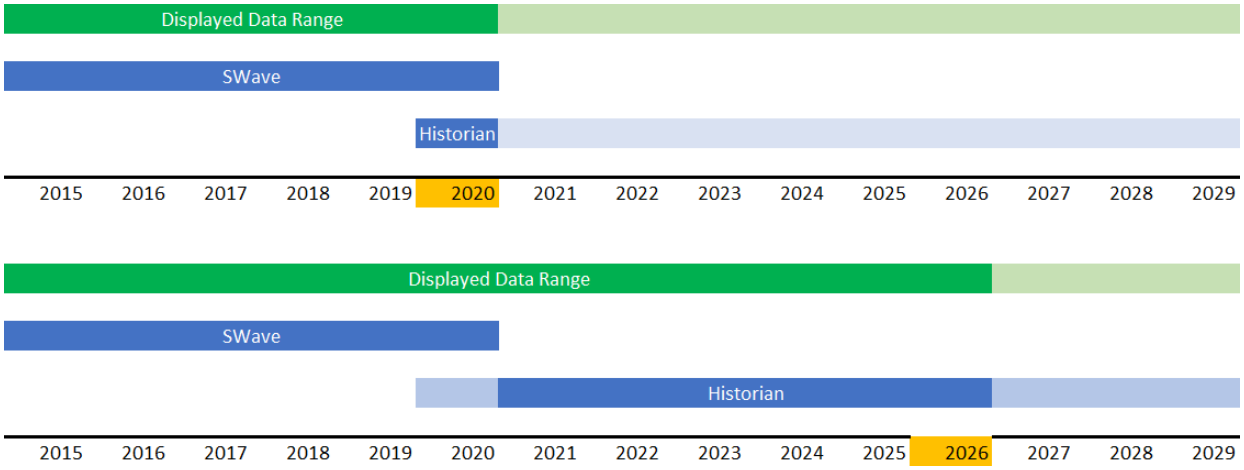



**Figure 4.128 SWave Server Initially Functioning Correctly**

One year later, some Historian data are automatically deleted. However, the SWave Server continues to make historical data available for other applications. This leads to a gap in time for data available on the platform.

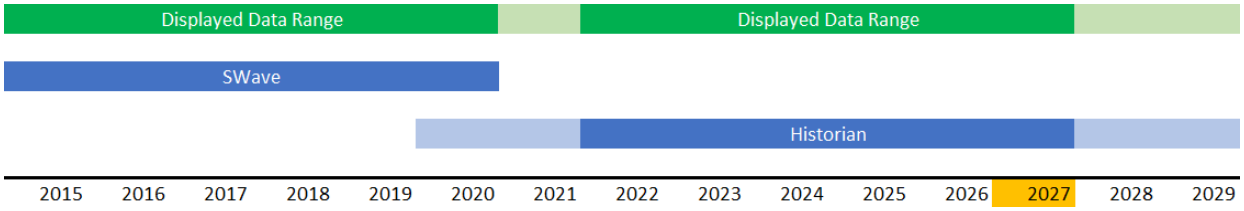



**Figure 4.129 Incorrectly Configured SWave Server**

Instead, the SWave Server should be configured to not display data once this time is reached.

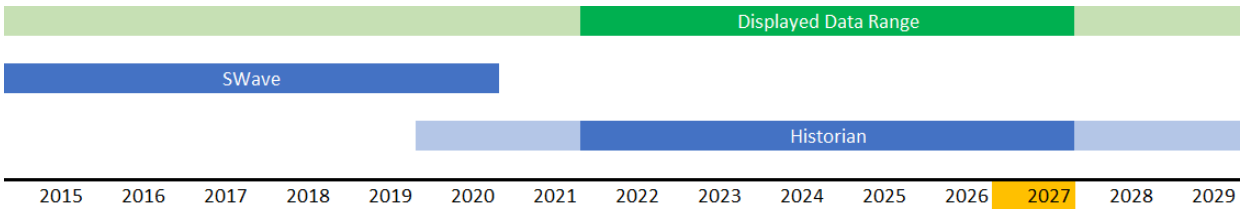



**Figure 4.130 Correctly Configured SWave Server**

To do this, a date time must be set for when the SWave Server should stop serving data. Note that the SWave data will not be deleted; instead, the data will just not be displayed by other applications.

The format for the end-of-life date time is yyyy/mm/dd HH:MM:SS.SSS. Type the date time into the box and select **Apply** to save changes. An optional text box next to the Apply button allows you to enter a comment describing the changes. Once **Apply** has been selected, the comment will be stored in the configuration history of the config.json file.

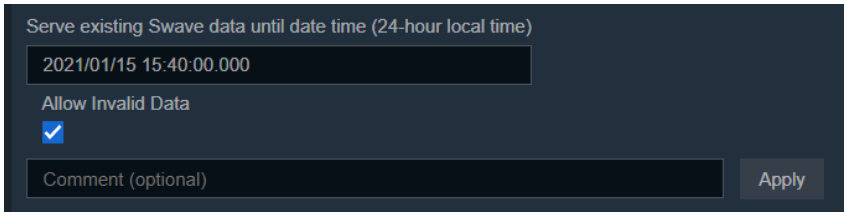



**Figure 4.131 Disable SWave Server After Set Time**

# OSI PI Reader Application

The OSI PI Reader Application enables data access from an OSIsoft PI System Historian.

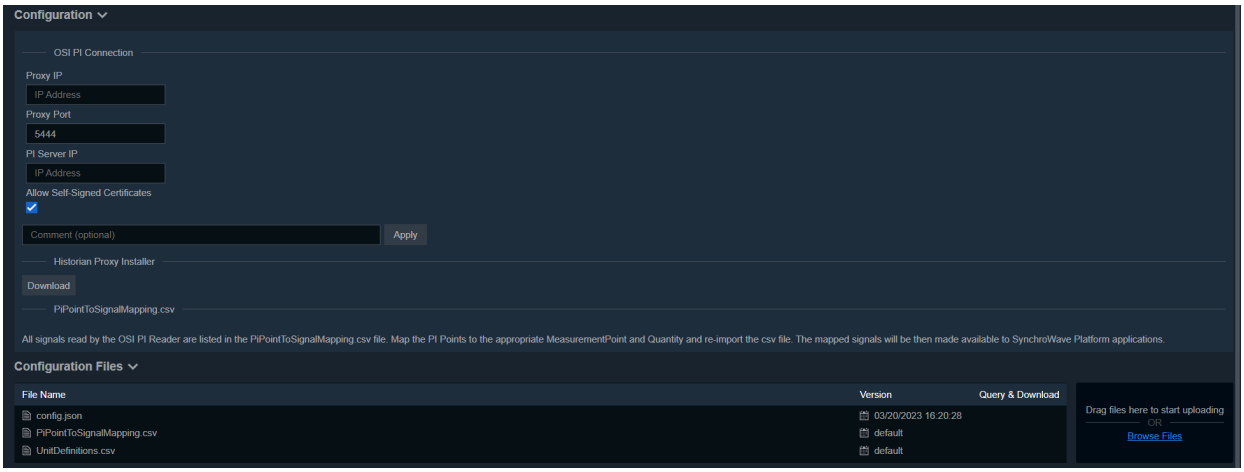



**Figure 4.132 OSI PI Reader Configuration**

## Dependencies

The Historian Proxy is an intermediary between the OSI PI Historian Reader Application and the PI Server. It is necessary because the OSIsoft PI SDK only runs on Windows machines. To run the Historian Proxy, follow these steps:

Step 1. Choose a Windows machine for the Historian Proxy. *Step 2–Step 5* are done on that machine.

Step 2. Install the PI SDK. Download this from my.osisoft.com (requires login).

Step 3. Install the PI AF Client. Download this from the site in *Step 2*.

Step 4. Go to the OSI PI Reader configuration page in the Application Manager. Select the **Download** button for the Historian Proxy installer. Move this file to the Windows machine.

Step 5. Run the installer.

Step 6. On the PI server, add the Synchrowave Operations machine IP to the Trusted sources on the PI Server. The application name is SEL.HistorianProxy.exe.

Step 7. Go to the OSI PI Reader configuration page in the Application Manager. Enter the IP of the Historian Proxy machine (the windows machine), and the IP for the PI Server. Ensure **Allow Self-Signed Certificates** is selected and select **Apply**. An optional text box next to the Apply button allows you to enter a comment describing the changes. Once **Apply** has been selected, the comment will be stored in the configuration history of the config.json file.

# Configuring the OSI PI Reader

## Signal Mapping

Incoming signals from the OSI PI Reader must be mapped to Measurement Points and Quantities. Download the PiPointToSignalMapping.csv mapping file.

**NOTE**
Measurement points, quantity (data type) and asset names can include the following characters: letters, numbers, periods, and underscores.

Open the file in any text editor or spreadsheet application. This file has three columns: PointTag, MeasurementPoint, and Quantity. The PointTag is the tag name from the OSI PI Historian. An example configuration is shown below.

| | A | B | C |
|---|---|---|---|
| 1 | PointTag | MeasurementPoint | Quantity |
| 2 | **TVA_TESTDEVICE:ABBVM** | CJ.BUS230 | Phase1.Voltage.Magnitude |
| 3 | **TVA_TESTDEVICE:ABBRK* | CJ.BUS230 | BreakerStatus |

**Figure 4.133 Example OSI PI Signal Mapping**

Save the file and import back into Synchrowave. The OSI PI Reader Application restarts.

## Unit Mapping (Optional)

All standard IEEE units are automatically recognized and decoded. Non-standard engineering units in the PI system should be mapped to base units or declared as their own base unit. SEL recommends skipping this step during initial configuration. Any units that could not be mapped will appear in the Diagnostics logs for the OSI PI Reader Application in the Application Manager.

To configure unit mapping, download the UnitDefinitions.csv mapping file. Open the file in any text editor or spreadsheet application. This file has three columns:

- **BaseUnit.** Unit abbreviation displayed in Synchrowave Operations.
- **EngineeringUnit.** The unit used in OSI PI.
- **Multiplier.** Scalar multiplier.

In *Figure 4.134*, the second row maps a non-standard IEEE unit such as centimeters to meters. The third row declares a furlong as a valid unit in Synchrowave Operations. Any OSI PI signal with the EngineeringUnit **furlong** can be displayed on panels.

| | A | B | C |
|---|---|---|---|
| 1 | BaseUnit | EngineeringUnit | Multiplier |
| 2 | m | centimeter | 0.01 |
| 3 | furlong | | |

**Figure 4.134 Example OSI PI Unit Mapping**

Save the file and import back into Synchrowave. The OSI PI Reader Application restarts.

### Signals Are Available

After successful mapping and PI server connection, the mapped signals should be available for display in Synchrowave Operations.

# IEEE P2664 STTP Reader Application

The IEEE P2664 STTP Reader application connects to STTP sources and publishes signals to the Synchrowave Platform signal bus.

**NOTE**
During a node failure, data are dropped while the IEEE P2664 STTP Reader reconnects.

## IEEE P2664 STTP Reader Features

### Signal Data Quality Processing

A poor-quality signal is published to the data bus as a NAN value. Poor signal quality includes the following values: PMU Error, Time-Synchronization Error, and No Data.

### Signal Availability

All PMUs read by the IEEE P2664 STTP Reader have a corresponding availability data type that describes the percent availability of the PMU per second. This is helpful during system installation, adding or removing a PMU, and general troubleshooting. You can display the Availability data type in any panel application by selecting **Availability** as the data type.

## IEEE P2664 STTP Reader Configuration

To configure the IEEE P2664 STTP Reader, first download the Connections.csv file, edit as necessary (see details below), and import back into Synchrowave. Then use the Download and Query option for the SignalMappings.csv file, edit as necessary (see details below), and import back into Synchrowave.

### Connecting to an STTP Source

To connect the IEEE P2664 STTP Reader to an STTP source, open the Connections.csv file and enter the IP address and port of the source (see *Figure 4.135*).

| | A | B | C | D |
|---|---|---|---|---|
| 1 | IPAddress | Port | ID | |
| 2 | 10.202.50.243 | 7000 | 0 | |
| 3 | | | | |
| 4 | | | | |

**Figure 4.135 Connecting to an STTP Source**

## Mapping Incoming STTP Signals

Signals received by the IEEE P2664 STTP Reader provide Station and Tag fields. You must map each of the new signals to a measurement point for the signals to be associated with the model and intelligently displayed and queried by applications on the Synchrowave Platform.

The SignalMapping.csv file includes four columns: DeviceAcronym, Description, MeasurementPoint, and Quantity. The Station and Tag columns are automatically populated by the IEEE P2664 STTP Reader with the signal information from the STTP data stream. During the initial configuration, the MeasurementPoint and Quantity fields are empty. The administrator uses the information in the DeviceAcronym and Description fields to complete the MeasurementPoint and Quantity fields. The MeasurementPoint describes the location in which the measurement takes place. The Quantity describes the type of measurement and type of signals that are being displayed. See *Standard Quantities on page 24* for a table of standard quantities.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **DeviceAcronym** | **Description** | **MeasurementPoint** | **Quantity** |
| 2 | SubstationA_PMU1 | TL1_VA_Magnitude | | |
| 3 | | | | |
| 4 | | | | |

**Figure 4.136 IEEE P2664 STTP Reader CSV Mapping File Format**

## Example

MeasurementPoint = SubstationA.TransmissionLine1

Quantity = PhaseA.Voltage.Magnitude

Signal = SubstationA.TransmissionLine1.PhaseA.Voltage.Magnitude

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **DeviceAcronym** | **Description** | **MeasurementPoint** | **Quantity** |
| 2 | SubstationA_PMU1 | TL1_VA_Magnitude | | |
| 3 | | | | |
| 4 | | | | |

**Figure 4.137 Completed IEEE P2664 STTP Reader CSV Mapping File**

Signals are only published to the Synchrowave Platform signal bus if both the MeasurementPoint and Quantity fields are completed. You can import a file without all fields completed. Those signals are ignored by the IEEE P2664 STTP Reader.

Upon completing the signal mapping, import the file back into Synchrowave. Signals are immediately available for display in dashboards and for use in other platform applications.

If new signals are added to the incoming STTP stream after initial import of the signal mapping file, use the Query and Download option to download the SignalMappings.csv file. The new signals are added to the end of the file. Complete the MeasurementPoint and Quantity fields for the new signals and import the file back into Synchrowave.

If previously configured signals are no longer present in the data stream (usually the result of a lost connection or a changed tag name) when the Query and Download option is used, those signals will appear at the bottom of the file after a space. These inactive signal rows should be removed before import if they are no longer needed.

## Managing Changed Data Rates

The IEEE P2664 STTP Reader does not support changing data rates for PMU data. If the real-time data rate on any PMU changes, the Synchrowave Platform must be restarted. See *Run the Synchrowave Command Line Interface on page 210* for more details. Note that Synchrowave Operations functions as normal when viewing historic data at different data rates. No action is required in this case.

# IEEE C37.118 Reader Application

The IEEE C37.118 Reader application connects to IEEE C37.118 sources and publishes signals to the Synchrowave Platform signal bus.

**NOTE**
During a node failure, data will be dropped while the IEEE C37.118 Reader reconnects.

## IEEE C37.118 Reader Features

### Signal Data Quality Processing

A poor-quality signal is published to the data bus as a NaN value unless the AllowInvalidData column in the Connections.csv is set to true for a particular data stream. Poor signal quality includes the following values: PMU Error, Time-Synchronization Error, and No Data.

### Signal Availability

All PMUs read by the IEEE C37.118 Reader have a corresponding availability data type that describes the percent availability of the PMU per second. This is helpful during system installation, adding or removing a PMU, and general troubleshooting.

The Availability data type can be displayed in any panel application by selecting **Availability** as the data type.

# IEEE C37.118 Reader Configuration

To configure the IEEE C37.118 Reader, first download the Connections.csv file, edit it as necessary (see details below), and import it back into Synchrowave. Then use the Download and Query option for the SignalMappings.csv file, edit that file as necessary (see details below), and import it back into Synchrowave.

**NOTE**
Measurement points, quantity (data type), and asset names can include the following characters: letters, numbers, periods, and underscores. Measurement points **must begin with a letter**.

## Connecting to an IEEE C37.118 Source

To connect the IEEE C37.118 Reader to an IEEE C37.118 source, open the Connections.csv file and enter the IP address, port, and PDC ID of the source in the Connection.csv file.

To view data with an invalid data quality flag or time sync error(s), set the value in the **AllowInvalidData** column to **TRUE**.

If the time on the Synchrowave server is not synchronized within 2 seconds of the PMUs, the reader may alternatively use the time stamp in the PMU stream to provide data alignment. This is accomplished by setting the value in the **OverrideAsSystemTimeSource** column to **TRUE**. The most recent time stamp for any source marked **TRUE** is used.

A blank entry for either **AllowInvalidData** or **OverrideAsSystemTimeSource** is interpreted as **FALSE**.

To establish a TCP connection, set the value in the Udp column to **FALSE**, and the UDPClientPort column will be ignored. To read a one-way UDP_S stream, set the Udp column to **TRUE** and enter the client port number in UDPClientPort.

**NOTE**
If UDP functionality is needed on a Linux installation, please contact Schweitzer Engineering Laboratories.

Then import the file back into Synchrowave.

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | IPAddress | Port | ID | AllowInvalidData | OverrideAsSystemTimeSource | Udp | UdpClientPort |
| 2 | 10.202.50.234 | 7000 | 0 | FALSE | FALSE | FALSE | |

**Figure 4.138 Connecting to an IEEE C37.118 Source**

## Mapping Incoming IEEE C37.118 Signals

Signals received by the IEEE C37.118 Reader provide Station and Tag fields. Each of the new signals must be mapped to a measurement point for the signals to be associated with the model and intelligently displayed and queried by applications on the Synchrowave Platform.

The SignalMapping.csv file includes four columns; Station Name, Tag, MeasurementPoint, and Quantity. The Station and Tag columns are automatically populated by the IEEE C37.118 Reader with the signal information from the IEEE C37.118 data stream.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | StationName | Tag | MeasurementPoint | Quantity |
| 2 | PMU1 | Frequency | | |
| 3 | PMU1 | Frequency Delta | | |
| 4 | PMU1 | I1X | | |
| 5 | PMU1 | IAX | | |
| 6 | PMU1 | IBX | | |
| 7 | PMU1 | ICX | | |
| 8 | PMU1 | V1Y | | |
| 9 | PMU1 | VAY | | |
| 10 | PMU1 | VBY | | |
| 11 | PMU1 | VCY | | |
| 12 | PMU1 | VS | | |

**Figure 4.139 IEEE C37.118 Reader CSV Mapping File Format**

During the initial configuration, the MeasurementPoint and Quantity fields are empty. The administrator uses the information in the DeviceAcronym and Description fields to complete the MeasurementPoint and Quantity fields. The MeasurementPoint describes the location in which the measurement takes place and is displayed in the legend of different dashboard panels to help users differentiate the signal from other signals displayed. The Quantity describes the type of measurement and type of signals that are being displayed.

## Example

MeasurementPoint = SubstationA.TransmissionLine1

Quantity = PhaseA.Voltage.Magnitude

Signal = SubstationA.TransmissionLine1.PhaseA.Voltage.Magnitude

Signals are only published to the Synchrowave Platform Signal Bus if both the MeasurementPoint and Quantity fields are completed. You can import a file without all fields completed. Those signals are ignored by the IEEE C37.118 Reader.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | StationName | Tag | MeasurementPoint | Quantity |
| 2 | PMU1 | Frequency | Station1.Bus | Frequency |
| 3 | PMU1 | Frequency Delta | Station1.Bus | Frequency.DxDt |
| 4 | PMU1 | I1X | Station1.Line1 | Phase1.Voltage |
| 5 | PMU1 | IAX | Station1.Line1 | PhaseA.Current |
| 6 | PMU1 | IBX | Station1.Line1 | PhaseB.Current |
| 7 | PMU1 | ICX | Station1.Line1 | PhaseC.Current |
| 8 | PMU1 | V1Y | Station1.Bus | Phase1.Voltage |
| 9 | PMU1 | VAY | Station1.Bus | PhaseA.Voltage |
| 10 | PMU1 | VBY | Station1.Bus | PhaseB.Voltage |
| 11 | PMU1 | VCY | Station1.Bus | PhaseC.Voltage |
| 12 | PMU1 | VS | Station1.Line1 | PhaseS.Voltage |

**Figure 4.140 Completed IEEE C37.118 Reader CSV Mapping File**

Upon completing the signal mapping, save the file and import it back into Synchrowave. Signals are immediately available for display in dashboards and for use in other platform applications.

If new signals are added to the incoming IEEE C37.118 stream after initial import of the signal mapping file, use the Query and Download option to download the SignalMappings.csv file. The new signals are added to the end of the file. Complete the MeasurementPoint and Quantity fields for the new signals and import the file back into Synchrowave.

If previously configured signals are no longer present in the data stream (usually the result of a lost connection or a changed tag name) when the Query and Download option is used, those signals will appear at the bottom of the file after a space. These inactive signal rows should be removed before import if they are no longer needed.

### Managing Changed Data Rates

The IEEE C37.118 Reader does not support changing data rates for PMU data. If the real-time data rate on any PMU changes, the Synchrowave Platform must be restarted via the Services tab in Windows Task Manager. Note that Synchrowave Monitoring will function as normal when viewing historic data at different data rates. No action is required in this case.

# Continuous Waveform Streaming Receiver Application

Continuous Waveform Streaming (CWS) protocol is used by the SEL-735 Power Quality and Revenue Meter to stream continuous waveform data at 3000 samples per second. The Synchrowave Platform receives CWS protocol using the CWS Receiver application. The Virtual Meters and Load Profile applications can also be configured to consume CWS data. The data received are archived and visualized in the same manner as other streaming data in Synchrowave.

## CWS Receiver Configuration

To configure the CWS Receiver application, first configure the streaming device to stream to port 4073 on the Synchrowave server.

You can use the config.json file to change the data receiving behavior of the CWS Receiver application. The ContinuousWaveformPort setting defines what port CWS Receiver listens to for UDP streams. The EnablePlugAndPlay setting determines whether new devices are automatically mapped and enabled. By default, EnablePlugAndPlay is set to false to prevent unwanted streams from inadvertently using drive space and processing capacity to record unnecessary data.

Next, download the mappings.csv file by selecting the **Query and Download** button.

During the initial configuration, all of the fields for each row are filled with the default values of all the devices currently streaming to the CWS Receiver application. The MeasurementPoint contains the Terminal ID (TID) of the streaming device. The administrator may modify the MeasurementPoint field to rename the signals corresponding to the device.

**NOTE**
Measurement points, quantity (data type), and asset names can include the following characters: letters, numbers, periods, and underscores. Measurement points **must begin with a letter**. Incorrect measurement point names will automatically be corrected.

If the name automatically generated for the measurement point is a duplicate, the CWS Receiver application will append "_dup*x*" to the TID, where *x* is the duplicate number for that name.

To enable signal publishing for a measurement point, enter TRUE in the Enable field. Only measurement points that have TRUE in the Enable field will be published.

Upon completing the mapping, save the file and import it back into Synchrowave. Enabled measurement points are immediately available for display in dashboards and for use in other platform applications.

If new streaming sources begin streaming to the CWS Receiver application, use the **Query and Download** button to download the updated mappings.csv file. The new sources will be added to the end of the file. Populate the MeasurementPoint field for the new streaming sources and then import the file back into Synchrowave.

If previously configured signals are no longer present in the data stream when you select **Query and Download** (usually the result of a lost connection or a changed tag name), those signals will appear at the bottom of the file after a space. These inactive signal rows should be removed before import if they are no longer needed.

For each streaming source, the CWS Receiver application provides the signals shown in *Table 4.1*.

**Table 4.1 CWS Receiver Quantities**

| Name | Description | Units |
|---|---|---|
| Phase[p].Voltage[a] | Instantaneous voltage | Volts |
| Phase[p].Current.Magnitude[a] | Instantaneous current | Amperes |
| Packets | Count of packets received since application startup | Unitless |
| Drops | Count of dropped packets since application startup | Unitless |
| Errors | Count of packets with an error since application startup | Unitless |

[a] Where [p] = A, B, or C for phase-to-neutral, or AB, BC, or CA for phase-to-phase values.

# Setting Up Meter Calculations

Meter Calculations provides a place to configure all applications that perform meter calculations using a simple graphical interface. Meter Calculations applies saved changes to each application's configuration files, allowing users to change application configurations manually or through Meter Calculations. When first navigating to Meter Calculations, the list of available calculation services appears on the left sidebar. Navigate to the list item corresponding to the desired calculation service and select the **New Configuration** button (*Figure 4.141*).

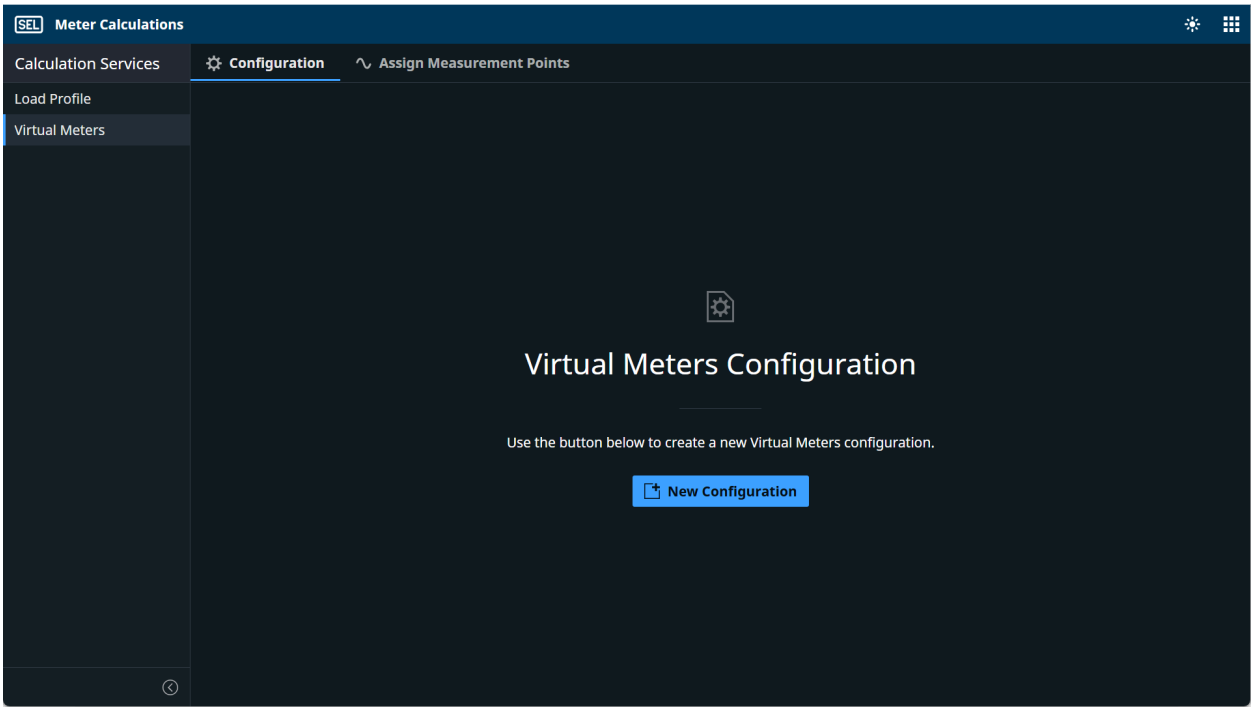



**Figure 4.141 Meter Calculations With No Configurations**

Fill in the settings on the Configuration tab, as shown in *Figure 4.142*. The settings available depend on the calculation service.

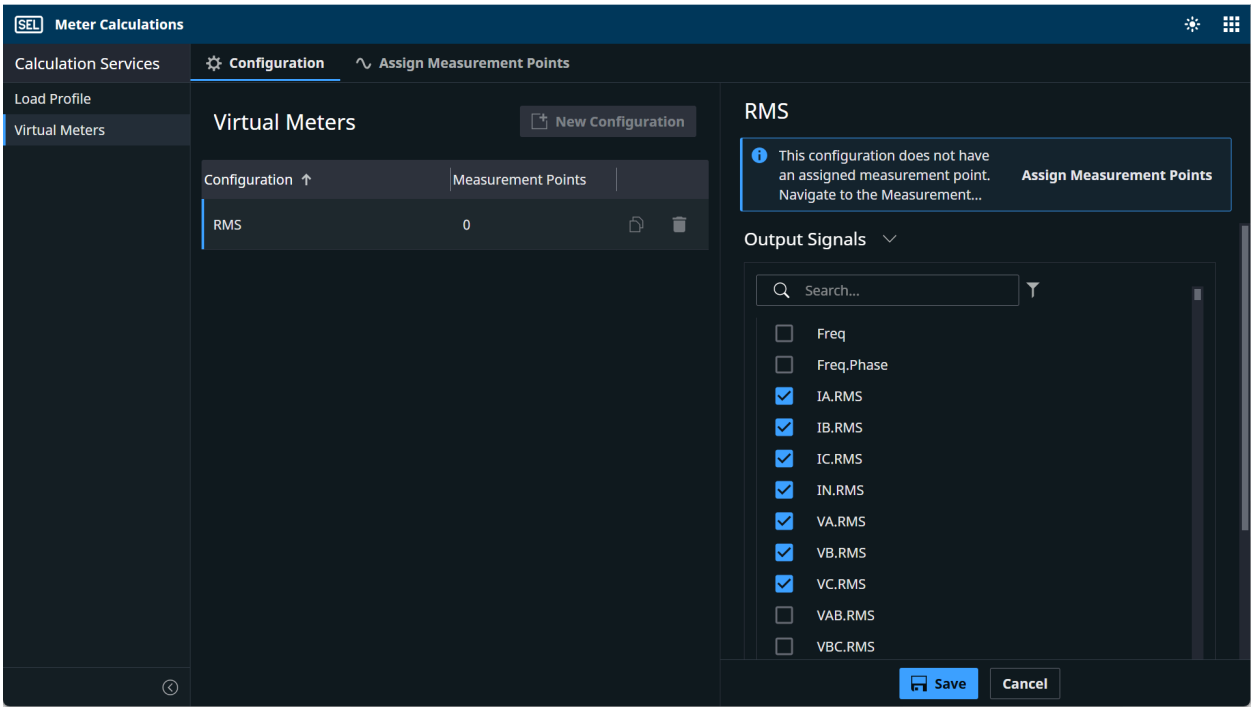



**Figure 4.142 Meter Calculations Configuration**

Assign measurement points to the configuration, as shown in *Figure 4.143*. The calculation service also supplies the list of available measurement points for assignment. Select the Play (▶) button to start the configuration and the Stop (■) button to stop a running one.

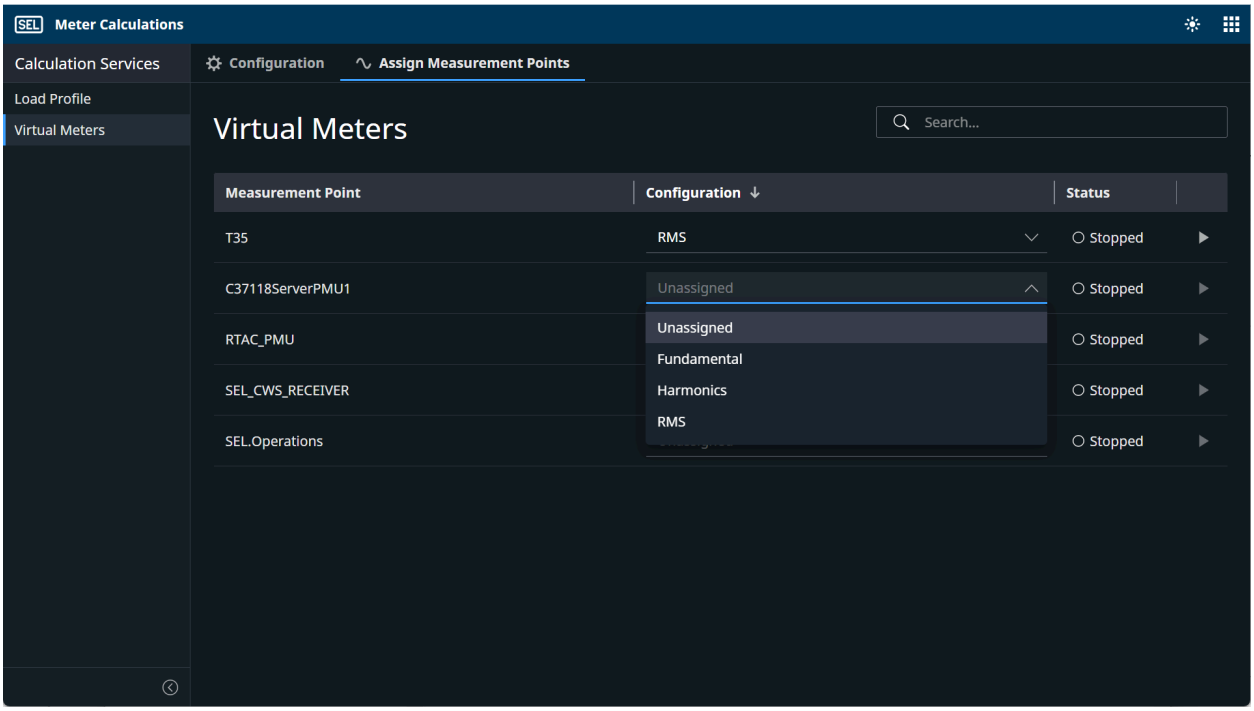



**Figure 4.143 Meter Calculations Assign Measurement Points**

# Virtual Meters Application

The Virtual Meters application consumes continuous waveform signals and calculates meter analogs that are useful for reporting and monitoring. Virtual Meters generates outputs at a rate of 160 samples per second.

## Setup

Configure the Virtual Meters application with Meter Calculations or through its configuration files. See *Setting Up Meter Calculations on page 165* for more information about Meter Calculations.

### Setting Application Configuration

1. Download the Config.csv file.
2. Set the NominalFrequency setting to either 60 for a 60 Hz system or 50 for a 50 Hz system.
3. When you are finished, upload the Config.csv file to the Synchrowave Platform.

## Creating Templates

In the Virtual Meters application, a template defines a set of calculations that you can apply to input signals. Configuration rows that share the same name are part of the same template. The Quantity field defines the calculation(s) to be performed. To add a new template to the application, follow these steps:

1. Download the Templates.csv file.
2. In the downloaded file, add a line for each desired quantity and fill out the Quantity field. Refer to *Meter Quantity List on page 170* for a list of the available quantities.
3. Set the Enabled field to **TRUE** for every quantity that should be enabled.
4. Add the same name to the Name field for all of the quantities.
5. Upload the Templates.csv file to the Synchrowave Platform.

See *Figure 4.144* for an example of a completed Templates.csv file.

| | A | B | C |
|---|---|---|---|
| 1 | Name | Quantity | Enabled |
| 2 | RMS | Freq | TRUE |
| 3 | RMS | Freq.Phase | TRUE |
| 4 | RMS | IA.RMS | TRUE |
| 5 | RMS | IB.RMS | TRUE |
| 6 | RMS | IC.RMS | TRUE |
| 7 | RMS | IN.RMS | TRUE |
| 8 | RMS | VA.RMS | TRUE |
| 9 | RMS | VB.RMS | TRUE |
| 10 | RMS | VC.RMS | TRUE |
| 11 | Power | Freq | TRUE |
| 12 | Power | Freq.Phase | TRUE |
| 13 | Power | PA | TRUE |
| 14 | Power | PB | TRUE |
| 15 | Power | PC | TRUE |
| 16 | Power | QA | TRUE |
| 17 | Power | QB | TRUE |
| 18 | Power | QC | TRUE |
| 19 | Power | SA | TRUE |
| 20 | Power | SB | TRUE |
| 21 | Power | SC | TRUE |
| 22 | Power | P3 | TRUE |
| 23 | Power | Q3 | TRUE |
| 24 | Power | S3 | TRUE |
| 25 | Fundamental | Freq | TRUE |
| 26 | Fundamental | Freq.Phase | TRUE |
| 27 | Fundamental | IA.Fund | TRUE |
| 28 | Fundamental | IB.Fund | TRUE |
| 29 | Fundamental | IC.Fund | TRUE |
| 30 | Fundamental | IN.Fund | TRUE |
| 31 | Fundamental | VA.Fund | TRUE |
| 32 | Fundamental | VB.Fund | TRUE |
| 33 | Fundamental | VC.Fund | TRUE |
| 34 | Fundamental | IA.Ang | TRUE |
| 35 | Fundamental | IB.Ang | TRUE |
| 36 | Fundamental | IC.Ang | TRUE |
| 37 | Fundamental | IN.Ang | TRUE |
| 38 | Fundamental | VA.Ang | TRUE |
| 39 | Fundamental | VB.Ang | TRUE |
| 40 | Fundamental | VC.Ang | TRUE |
| 41 | Harmonics | IA.1CYC.HRM01.Mag | TRUE |
| 42 | Harmonics | IA.1CYC.HRM02.Mag | TRUE |
| 43 | Harmonics | IA.1CYC.HRM03.Mag | TRUE |
| 44 | Harmonics | IA.1CYC.HRM04.Mag | TRUE |
| 45 | Harmonics | IA.1CYC.HRM05.Mag | TRUE |
| 46 | Harmonics | IA.1CYC.HRM06.Mag | TRUE |

**Figure 4.144 Configured Templates File**

## Configuring Measurement Points

Once one or more templates have been created, map the measurement point to templates by using the following steps:

1. Download the MeasurementPointMappings.csv file by using the Query & Download button.
2. The Virtual Meters application automatically creates a line in the file for each usable measurement point. Add the desired template name in the Config field.
3. Set the Enabled field to **TRUE** to turn on calculations and publishing for the measurement point.
4. Upload the MeasurementPointMappings.csv file to the Synchrowave Platform.

See *Figure 4.145* for an example of a completed MeasurementPointMappings.csv file.

| | A | B | C |
|---|---|---|---|
| 1 | MeasurementPoint | Config | Enabled |
| 2 | Stackland_AxionWave | Fundamentals | FALSE |
| 3 | Conklin_SEL_T35 | Fundamentals | TRUE |
| 4 | Meyers_SEL_735 | RMS Quantities | TRUE |
| 5 | | | |

**Figure 4.145 Configured MeasurementPointMappings File**

# Meter Quantity List

The analog quantities listed in *Table 4.2* can be calculated by the Virtual Meters application and are available to use within templates.

**Table 4.2 Meter Quantities**

| Name | Description | Units | Update Rate |
|---|---|---|---|
| Current | | | |
| I[A, B, C, N, 3].RMS | A, B, C, N, or three-phase rms current | A | 1/2 cycle |
| I[A, B, C, N, 3].Fund | A, B, C, N, or three-phase fundamental current | A | 1/2 cycle |
| I[A, B, C, N, 3].Ang | A, B, C, N, or three-phase fundamental current angle | A | 1/2 cycle |
| Voltage | | | |
| V[A, B, C, LN3].RMS | A, B, C, N, or three-phase rms line-to-neutral voltage | V | 1/2 cycle |
| V[A, B, C, LN3].Fund | A, B, C, N, or three-phase fundamental line-to-neutral voltage | V | 1/2 cycle |
| V[A, B, C, LN3].Ang | A, B, C, N, or three-phase fundamental line-to-neutral voltage angle | V | 1/2 cycle |
| V[AB, BC, CA, LL3].Rms | Phase A-B, B-C, C-A, or LL3 rms line-to-line voltage | V | 1/2 cycle |
| V[AB, BC, CA, LL3].Ang | Phase A-B, B-C, C-A, or LL3 fundamental line-to-line voltage angle | V | 1/2 cycle |

| Name | Description | Units | Update Rate |
|---|---|---|---|
| **Power** | | | |
| P[A, B, C, 3] | A, B, C, or three-phase rms watts | W | 1/2 cycle |
| Q[A, B, C, 3] | A, B, C, or three-phase rms VARs | VAR | 1/2 cycle |
| S[A, B, C, 3] | A, B, C, or three-phase rms VA | VA | 1/2 cycle |
| PF[A, B, C, 3] | A, B, C, or three-phase rms fundamental power factor | Unitless | 1/2 cycle |
| P[A, B, C, 3].Fund | A, B, C, or three-phase rms fundamental W | W | 1/2 cycle |
| Q[A, B, C, 3].Fund | A, B, C, or three-phase rms fundamental VARS | VAR | 1/2 cycle |
| S[A, B, C, 3].Fund | A, B, C, or three-phase rms fundamental VA | VA | 1/2 cycle |
| PF[A, B, C, 3].Fund | A, B, C, or three-phase rms fundamental Power Factor | Unitless | 1/2 cycle |
| **Harmonics** | | | |
| V[A, B, C].1CYC.HRM[X].Mag[a] | A, B, or C one-cycle harmonic voltage magnitude | V | 1 cycle |
| V[A, B, C].1CYC.HRM[X].Ang[a] | A, B, or C one-cycle harmonic voltage angle | ° | 1 cycle |
| V[AB, BC, CA].1CYC.HRM[X].Mag[a] | AB, BC, or CA line-to-line one-cycle harmonic voltage magnitude | V | 1 cycle |
| V[AB, BC, CA].1CYC.HRM[X].Ang[a] | AB, BC, or CA line-to-line one-cycle harmonic voltage angle | ° | 1 cycle |
| I[A, B, C, N].1CYC.HRM[X].Mag[a] | A, B, C, or N one-cycle harmonic current Magnitude | A | 1 cycle |
| I[A, B, C, N].1CYC.HRM[X].Ang[a] | A, B, C, or N one-cycle harmonic current angle | ° | 1 cycle |
| P[A, B, C].HRM[X].1CYC[a] | A, B, or C one-cycle harmonic active power | W | 1 cycle |
| V[A, B, C].1CYC.THD | A, B, or C one-cycle voltage total harmonic distortion | % | 1 cycle |
| V[AB, BC, CA].1CYC.THD | AB, BC, or CA line-to-line one-cycle voltage total harmonic distortion | % | 1 cycle |
| I[A, B, C, N].1CYC.THD | A, B, C, or N one-cycle current total harmonic distortion | % | 1 cycle |
| **Symmetrical Components** | | | |
| I0 | Zero-sequence current | A | 1 cycle |
| I1 | Positive-sequence current | A | 1 cycle |
| I2 | Negative-sequence current | A | 1 cycle |
| V0 | Zero-sequence voltage | V | 1 cycle |
| V1 | Positive-sequence voltage | V | 1 cycle |
| V2 | Negative-sequence voltage | V | 1 cycle |
| **Other** | | | |
| Freq | System frequency | Hz | 1/2 cycle |
| Freq.Phase | Indicator for which phase is used for frequency tracking (0 = A, 1 = B, 2 = C) | Unitless | 1/2 cycle |

[a]X represents the harmonic order from 02 to the maximum, which is 20 for 3000 samples-per-second streams and 100 for 14400 samples-per-second streams.

# Voltage, Current, and Power Calculations

The following information details the meter quantity calculations performed by the Virtual Meters application. The application calculates all meter values from instantaneous waveforms sampled at 3 ksps.

## Voltage Delta/Wye Waveform Calculations

The Virtual Meters application calculates either line-to-neutral or line-to-line voltages (whichever is not provided) from the raw waveform.

### Delta-to-Wye Calculation

If the raw voltage waveforms are a line-to-line voltage, the line-to-neutral voltage waveforms are calculated as follows.

$$VA = (VAB - VCA)/3$$

$$VB = (VBC - VAB)/3$$

$$VC = (VCA - VBC)/3$$

### Wye-to-Delta Calculation

If the raw voltage waveforms are a line-to-neutral voltage, the line-to-line voltage waveforms are calculated as follows.

$$VAB = VA - VB$$

$$VBC = VB - VC$$

$$VCA = VC - VA$$

## Neutral Current Waveform

The Virtual Meters application uses the sum of the three-phase currents to calculate the neutral current IN, as shown in the following equation.

$$IN = IA + IB + IC$$

## Voltage and Current RMS Magnitudes

The Virtual Meters application calculates voltage and current magnitudes. The values are recalculated every half cycle in a 1-cycle window.

The meter calculates rms voltage in accordance with the following equation.

$$Vx = \sqrt{\frac{\sum_{0}^{N-1}[s(n)]^2}{N}}$$

The meter calculates rms current in accordance with the following equation.

$$Ix = \sqrt{\frac{\sum_{0}^{N-1}[s(n)]^2}{N}}$$

where:
N = total number of samples
x = A, B, or C for line-to-neutral voltages, A, B, C or N for line-to-neutral currents, or AB, BC, or CA for line-to-line voltages and currents
n = index number
s(n) = array of *v* or *i* samples corresponding to X

## Average Voltage and Current

The average voltage and current are calculated from the voltage and current magnitudes as follows.

$$VLN3 = (VA + VB + VC) / 3$$

$$VLL3 = (VAB + VBC + VCA) / 3$$

$$I3 = (IA + IB + IC) / 3$$

## Half-Cycle Power Calculations

Active power (Px), reactive power (Qx), and apparent power (Sx) calculations use unfiltered 1 ksps or greater voltage and current samples as source data.

Active per-phase power is calculated as follows.

$$Px = \frac{1}{N} \sum_{n=0}^{N-1} (Vxn \bullet Ixn)$$

where:
x = A, B, C
Vxn, Ixn = discrete samples
N = the total number of samples in a 1-cycle period

Active three-phase power is calculated as the sum of per-phase quantities.

$$P3 = PA + PB + PC$$

Apparent per-phase power is calculated using per-phase rms quantities.

$$Sx = Ix \bullet Vx$$

where:
Ix, Vx = the respective phase rms quantities

Apparent three-phase power is calculated as the sum of per-phase quantities.

$$S3 = SA + SB + SC$$

Reactive per-phase power is calculated using per-phase power quantities.

$$Qx = \sqrt{Sx^2 - Px^2}$$

where:
x = A, B, C, or 3

## Power Factor

The Virtual Meters application calculates three-phase and per-phase true power factor updated every half cycle.

$$PFx = \frac{Px}{Sx}$$

where:
x = A, B, C, or 3

# Load Profile Application

The Load Profile application allows users to calculate load profile signals similar to the Load Profile functionality in the SEL-735 Power Quality and Revenue Meter. The application provides a variety of functions to aggregate high rate signals into lower rate ones.

Load Profile creates new signal names by using the combination of the input signal name, the function, and the acquisition rate. The output signal's name includes the input signal measurement point and the output quantity, the latter of which is constructed by combining the LDP prefix, the input signal's name, the function name, and the acquisition rate (e.g., *LDP.[input signal].[function name].[acquisition rate]*).

The acquisition rate determines the length of the aggregation interval. The available acquisition rates are as follows:

- Subsecond: 0.05, 0.1, 0.2, 0.25, and 0.5 (aligned to the top of the second).
- Seconds: 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, and 30 (aligned to the top of the minute).
- Seconds: 60, 120, 180, 240, 300, 360, 600, 720, 900, 1200, 1800, and 3600 (aligned to the top of the hour).
- Seconds: 7200 (aligned to the top of an even hour).

**NOTE**
Top of hour and even hours are based on UTC time.

When the acquisition rate is part of a signal name, subsecond rates are converted to milliseconds and appended with *ms.* For example, an acquisition rate of 0.25 results in a signal named *LDP*.[*input signal].[function name].250ms*.

**Table 4.3 Load Profile Functions**

| Function Name | Description | Units |
|---|---|---|
| MIN | Minimum value of values in the interval | Same as input signal |
| MAX | Maximum value of values in the interval | Same as input signal |
| AVG | Average of values in interval | Same as input signal |
| COI | Change over interval, which is the difference between the last value in the interval and the first | Same as input signal |

| Function Name | Description | Units |
|---|---|---|
| EOI | End of interval, which is the last value in the interval | Same as input signal |
| COUNT | Number of values in the interval. Useful for verifying data integrity. | Unitless |
| SUM | Sum of the values in the interval | Same as input signal |
| RMS | RMS of the values in the interval | Same as input signal |

# Setup

## Creating Templates

Configure the Load Profile application with Meter Calculations or through its configuration files. See *Setting Up Meter Calculations on page 165* for more information about Meter Calculations.

In the Load Profile application, configuration rows that share the same name are part of the same template. To add a new template to the application, follow these steps:

1. Download the Templates.csv file.
2. In the downloaded file, add a line for each desired quantity and fill out the Quantity field. The available list of quantities can be found in the Virtual Meters application. For more information, see *Meter Quantity List on page 170*. If no Virtual Meters template is creating the input quantity, Load Profile will not create an output quantity until Virtual Meters publishes a sufficient quantity for the input. If Load Profile outputs a quantity from a saved template, that quantity may be used as an input quantity.
3. Add a function from the list in *Table 4.3* to the Function field.
4. Add a valid acquisition rate to the AcquisitionRate (s) field.
5. Set the Enabled field to **TRUE** for every quantity that should be enabled.
6. Add the same name to the Name field for all of the quantities.
7. Upload the Templates.csv file to the Synchrowave Platform.

See *Figure 4.144* for an example of a completed Templates.csv.

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Name | Function | Quantity | AcquisitionRate (s) | Enabled |
| 2 | Maxandmin | MAX | VA.RMS | 3 | TRUE |
| 3 | Maxandmin | MAX | VB.RMS | 3 | TRUE |
| 4 | Maxandmin | MAX | VC.RMS | 3 | TRUE |
| 5 | Maxandmin | MAX | VLL3.RMS | 3 | TRUE |
| 6 | Maxandmin | MAX | IA.RMS | 3 | TRUE |
| 7 | Maxandmin | MAX | IB.RMS | 3 | TRUE |
| 8 | Maxandmin | MAX | IC.RMS | 3 | TRUE |
| 9 | Maxandmin | MAX | IN.RMS | 3 | TRUE |
| 10 | Maxandmin | MIN | VA.RMS | 3 | TRUE |
| 11 | Maxandmin | MIN | VB.RMS | 3 | TRUE |
| 12 | Maxandmin | MIN | VC.RMS | 3 | TRUE |
| 13 | Maxandmin | MIN | VLL3.RMS | 3 | TRUE |
| 14 | Maxandmin | MIN | IA.RMS | 3 | TRUE |
| 15 | Maxandmin | MIN | IB.RMS | 3 | TRUE |
| 16 | Maxandmin | MIN | IC.RMS | 3 | TRUE |
| 17 | Maxandmin | MIN | IN.RMS | 3 | TRUE |

**Figure 4.146 Configured Templates File**

## Configuring Measurement Points

Once one or more templates have been created, map the measurement point to templates by using the following steps:

1. Download the Mappings.csv file by using the Query & Download button.
2. The Load Profile application automatically creates a line in the file for each usable measurement point. Add the desired template name in the Config field.
3. Set the Enabled field to **TRUE** to turn on calculations and publishing for the measurement point.
4. Upload the Mappings.csv file to the Synchrowave Platform.

See *Figure 4.146* for an example of a completed Mappings.csv.

| | A | B | C |
|---|---|---|---|
| 1 | MeasurementPoint | TemplateName | Enabled |
| 2 | Stackland_AxionWave | Sums | FALSE |
| 3 | Conklin_SEL_T35 | Averages | FALSE |
| 4 | Meyers_SEL_735 | Maxandmin | TRUE |

**Figure 4.147 Configured Mappings File**

# Power System Model Application

The Power System Model application provides a framework by which measurements are associated with power equipment. It enables importation of a power system model and associated GIS data, and it provides an interface that all other applications that require power system model information can use.

# Power System Model Data

The power system data are composed of five .csv formatted files containing information describing station data, bus data, line data, line segment data, and pole data, respectively. To begin configuration, download each file.

**NOTE**
Measurement points, quantity (data type) and asset names can include the following characters: letters, numbers, periods, and underscores.

## Station Data

All station information required for the power system model is imported as a stations.csv file. *Figure 4.148* shows a snippet of the file. The first row defines the columns and must appear as follows:

- **StationId.** Enter a unique identifier for each station. The unique station identifier is used as the display name for the station. The unique identifier of a station is used as the display name for the station.
- **Latitude and Longitude.** Enter the GIS location (in degrees) of the station.
- **NominalVoltageKV.** Enter the maximum voltage level (in kV). If a station has buses at multiple voltage levels, enter the highest level.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | StationId | Latitude | Longitude | NominalVoltageKV |
| 2 | Station1 | 46.7298 | -117.1817 | 230 |
| 3 | Station2 | 46.7324 | -117.0002 | 230 |
| 4 | Station3 | 46.4004 | -117.0012 | 230 |

**Figure 4.148 stations.csv File Format**

## Bus Data

All bus information required for the power system model is imported as a buses.csv file. *Figure 4.149* shows a snippet of the file. The first row defines the columns and must appear as follows:

- **BusId.** Enter a unique identifier for each bus in a station in the BusId column. The unique identifier of a bus is used as the display name for the bus.
- **StationId.** Enter the corresponding StationId of this bus. This must exactly match a StationId of the stations.csv file.
- **NominalVoltageKV.** Enter the nominal voltage level (in kV) of the bus in the NominalVoltageKV column.
- **Adjacent BusId.** Enter the BusId for any adjacent buses. If it is adjacent to multiple buses, separate the BusIds by using semicolons (;). A bus is considered adjacent if it is electrically connected with zero impedance (or via only breakers) to other buses. If there is no measurement at the adjacent bus, ignore the adjacent bus.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | BusId | StationId | NominalVoltageKV | AdjacentBusIds |
| 2 | Station1.Bus1 | Station1 | 230 | Station1.Bus2;Station1.Bus3 |
| 3 | Station1.Bus4 | Station1 | 138 | |
| 4 | Station2.Bus1 | Station2 | 230 | Station2.Bus2 |
| 5 | Station2.Bus3 | Station2 | 138 | Station2.Bus4 |
| 6 | Station3.Bus1 | Station3 | 230 | station3.Bus2 |

**Figure 4.149 buses.csv File Format**

## Line Data

Connection information of all lines required for the power system model is imported as a lines.csv file. *Figure 4.150* shows a snippet of the file. The first row defines the columns and must appear as follows:

- **LineId.** Enter a unique identifier for each line in the LineId column. The unique identifier of a line is used as the display name for the line.
- **NominalVoltageKV.** Enter the nominal voltage level (in kV) of the line in the NominalVoltageKV column.
- **FromBusId** and **ToBusId.** Enter the unique identifier of the buses at the line terminals in the FromBusId and ToBusId columns. These identifiers must match a corresponding BusId from the buses.csv file.
- **FromTerminalMP** and **ToTerminalMP.** Enter the display name of the measurement point at the line terminals in the FromTerminalMP and ToTerminalMP columns. These measurement points are typically used for line current measurements near the buses FromBusId and ToBusId, respectively.

Each row in the file contains all required information of a two-terminal line in the power system for the Power System Model application. If a line has more than two terminals, define the line for each unique pair of terminals, such as what is shown for the three-terminal line Line230 in *Figure 4.150*. In this example, a row is not included to connect Station2.Line230 to Station3.Line230 as it is not unique and is already defined by the prior two rows.

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | LineId | FromTerminalMP | ToTerminalMP | FromBusId | ToBusId | NominalVoltageKV |
| 2 | Line138 | Station1.Line138 | Station2.Line138 | Station1.Bus4 | Station2.Bus3 | 138 |
| 3 | Line230 | Station1.Line230 | Station2.Line230 | Station1.Bus1 | Station2.Bus1 | 230 |
| 4 | Line230 | Station1.Line230 | Station3.Line230 | Station1.Bus1 | Station3.Bus1 | 230 |

**Figure 4.150 lines.csv File Format**

## Pole GIS Coordinates

The GIS coordinates of all poles of all lines specified in the segments.csv file are imported by using a poles.csv file. *Figure 4.151* shows a snippet of the file. The first row defines the columns and must appear as follows:

A line segment is drawn on the GIS map as a linear connector between two poles. Stations are considered starting or ending poles of lines. Enter stations as typical poles in the file with the same latitude and longitude defined in the stations.csv file.

- **LineId.** Enter the LineId for this line. It must match exactly with a LineId from the lines.csv file.
- **PoleId.** Enter the PoleId for this pole. A PoleId may not be used more than once for a particular line but can be redefined for another line. Note that in *Figure 4.151*, Pole1 is defined for both Line230 and Line138.
- **Latitude and Longitude.** Enter the GIS location (in degrees) of the pole or station.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | LineId | PoleId | Latitude | Longitude |
| 2 | Line230 | Station2 | 46.7324 | -117.0002 |
| 3 | Line230 | Pole1 | 46.732935 | -117.091444 |
| 4 | Line230 | station1 | 46.7298 | -117.1817 |
| 5 | Line230 | Pole2 | 46.564093 | -117.128966 |
| 6 | Line230 | Station3 | 46.4004 | -117.0012 |
| 7 | Line138 | Station1 | 46.7298 | -117.1817 |
| 8 | Line138 | Pole1 | 46.732395 | -117.09155 |
| 9 | Line138 | Station2 | 46.7324 | -117.0002 |
| 10 | | | | |

**Figure 4.151 poles.csv File Format**

## Line Segments Data

GIS segments information of the lines defined in the lines.csv are imported by using a segments.csv file. A snippet of the file is shown in *Figure 4.152*. The first row defines the columns and must appear as follows:

- **LineId.** Enter the LineId for this line. It must match exactly with a LineId from the lines.csv file.
- **FromPoleId** and **ToPoleId.** Enter the PoleIds for this line segment. They must match exactly with the PoleIds defined in poles.csv.

Segments of a line must start and end with corresponding station identifiers and the identifiers must match the corresponding StationId in the stations.csv file. The line segments do not have to be in order.

| | A | B | C |
|---|---|---|---|
| 1 | LineId | FromPoleId | ToPoleId |
| 2 | Line230 | Station2 | Pole1 |
| 3 | Line230 | Pole1 | Station1 |
| 4 | Line230 | station1 | Pole2 |
| 5 | Line230 | Pole2 | Station3 |
| 6 | Line138 | Station1 | Pole1 |
| 7 | Line138 | Pole1 | Station2 |
| 8 | | | |

**Figure 4.152 segments.csv File Format**

The four line segments shown in *Figure 4.152* might represent a line, as shown in *Figure 4.153*. Line230 connects Station2 and Station3, with Station1 as a midline tap.

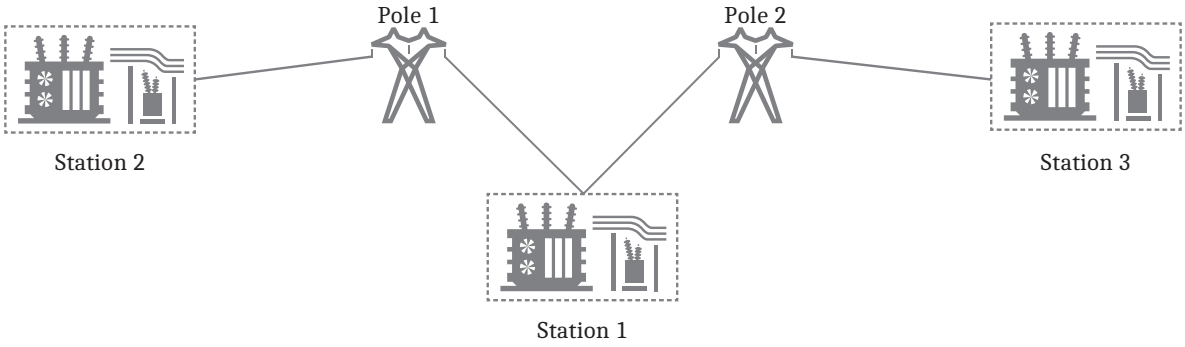



**Figure 4.153 Example Line**

## Importing Power System Model Data

Once the files are edited as necessary, import them back into Synchrowave.

# ACSELERATOR Database Reader Application

The ACSELERATOR Database Reader application connects to an ACSELERATOR Database and publishes event report information to the Synchrowave Platform signal bus.

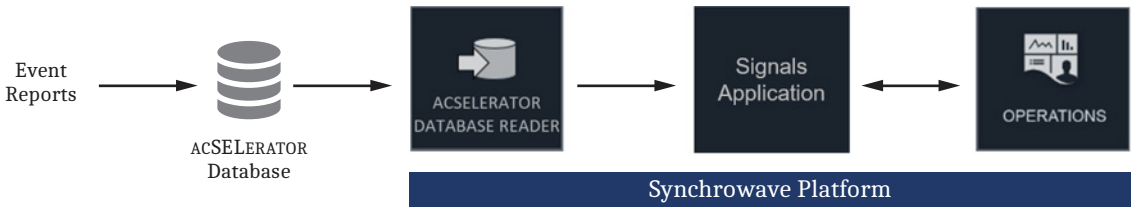



**Figure 4.154 ACSELERATOR Database Reader Overview**

## ACSELERATOR Database Reader Features

The ACSELERATOR Database Reader:

- Securely connects to an ACSELERATOR Database
- Publishes protective relay event reports to Synchrowave Platform
- Maps protective relay devices to measurement points

## ACSELERATOR Database Reader Configuration

### Generate an ACSELERATOR Database Connection Key

To generate an ACSELERATOR Database Connection Key, complete the following steps:

Step 1. Open ACSELERATOR QuickSet SEL-5030 Software on the computer where the ACSELERATOR Database is located.

Step 2. Select **File > Database Manager**.

Step 3. Select the ACSELERATOR **Database** tab.

Step 4. Select the **Allow Remote Databases** check box.

Step 5. Select **Create Connection Key**.

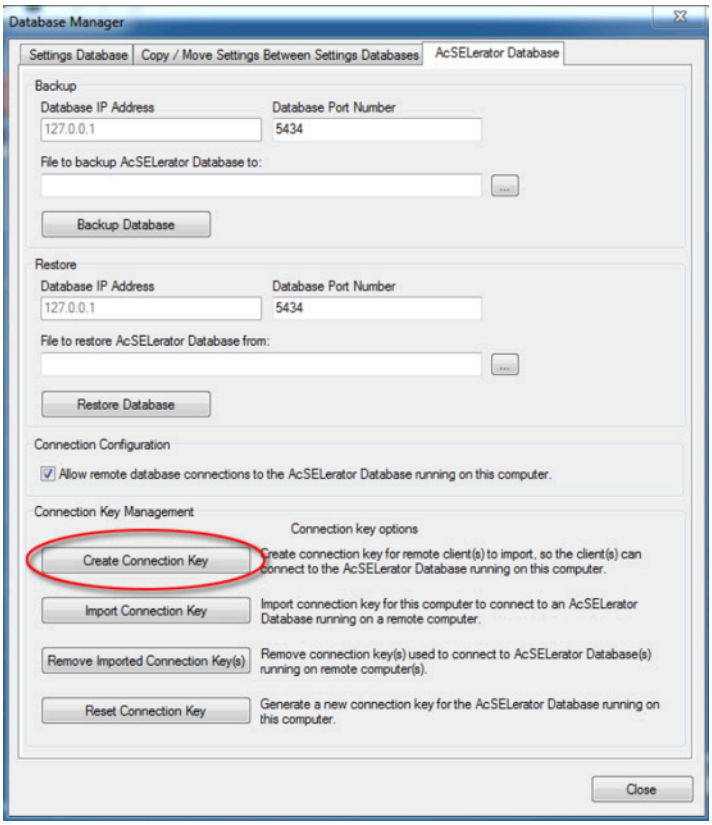



**Figure 4.155 ACSELERATOR Database Manager**

Step 6. When prompted, enter your desired password and select **Submit**. Make note of the password.

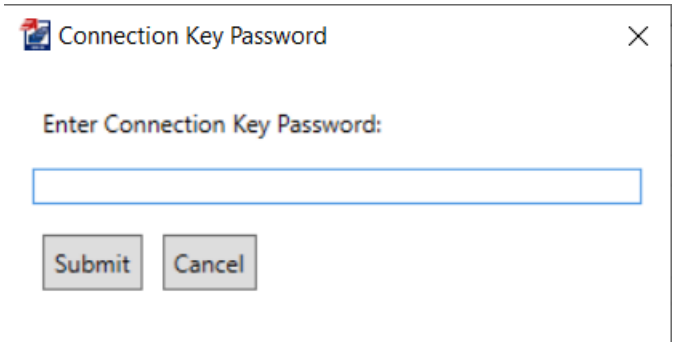



**Figure 4.156 ACSELERATOR Database Connection Key Password Prompt**

## Connect to an ACSELERATOR Database

To connect to an ACSELERATOR Database, complete the following steps:

Step 1. Open Synchrowave Application Manager in a web browser.

Step 2. Add the ACSELERATOR Database Reader application, if not already installed.

Step 3. Select the ACSELERATOR Database Reader application from the Application List.

Step 4. Select **Select Connection Key** and load the previously generated Connection Key.

Step 5. Enter the same password as when you created the Connection Key and select **Import**.

Step 6. Select **Test Connection** and verify successful connection to the ACSELERATOR Database.

Step 7. Select the time zone of the events in the ACSELERATOR Database.

Step 8. Select **Apply**.

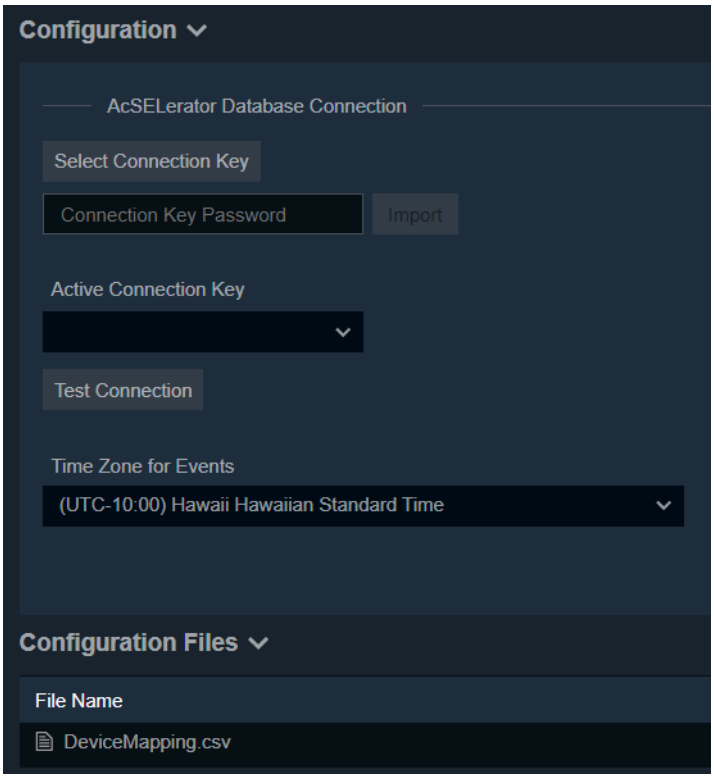



**Figure 4.157 ACSELERATOR Database Reader Configuration**

## Mapping Devices to Measurement Points

Event reports are generated by protective relay devices. These devices are listed in the ACSELERATOR Database. Each device must then be mapped to a measurement point for the event reports to be associated with the model and intelligently displayed and queried by applications on the Synchrowave Platform.

The device mapping for the ACSELERATOR Database Reader is accomplished via the DeviceMapping.csv file. Use the Download and Query option to download it.

The file includes three columns: Device, MeasurementPoint and Comment. The Device column is automatically populated by the ACSELERATOR Database Reader with the device path.

| | A | B | C |
|---|---|---|---|
| 1 | Device | MeasurementPoint | Comment |
| 2 | Substation A:Transmission Line 1:SEL-411L | SubstationA.TransmissionLine1 | |
| 3 | Substation A:Transmission Line 1:SEL-T400L | SubstationA.TransmissionLine1 | |
| 4 | Substation A:Transmission Line 2:SEL-411L | SubstationA.TransmissionLine2 | |
| 5 | Substation A:Transmission Line 2:SEL-T400L | SubstationA.TransmissionLine2 | |
| 6 | Substation B:Transmission Line 1:SEL-411L | SubstationB.TransmissionLine1 | |
| 7 | Substation B:Transmission Line 1:SEL-T400L | SubstationB.TransmissionLine1 | |
| 8 | Substation B:Transmission Line 2:SEL-411L | SubstationB.TransmissionLine2 | |
| 9 | Substation B:Transmission Line 2:SEL-T400L | SubstationB.TransmissionLine2 | |
| 10 | | | |
| 11 | | | |

**Figure 4.158 ACSELERATOR Database Device CSV Mapping File Format**

During the initial configuration, the MeasurementPoint field will be empty. Using the information in the Device field, the administrator can complete the MeasurementPoint field. The MeasurementPoint describes the location in which the measurement took place and will be displayed in the legend of different dashboard panels to help users differentiate the device from other devices displayed.

Event reports will only be visible to Synchrowave applications if the MeasurementPoint field is completed. You can import a file without all fields completed; event reports from those devices will be ignored by the ACSELERATOR Database Reader.

Upon completing the device mapping, save the file and import it back into Synchrowave. Event reports will be immediately available for display in Dashboards, and for use in other platform applications.

If new devices are added to the ACSELERATOR Database, after initial import of the device mapping file, download the DeviceMapping.csv file again via the Download and Query option. The new devices will be added to the end of the file. Complete the MeasurementPoint field for the new devices and import the file back into Synchrowave.

# DMA Receiver Application

The DMA Receiver application accepts data from SEL Blueframe® Data Management and Automation (DMA).

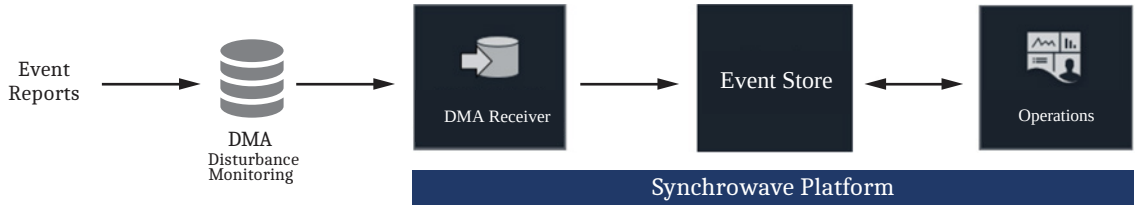



**Figure 4.159 DMA Receiver Overview**

## DMA Receiver Features

DMA Receiver receives oscillography event data from DMA and passes it on to other Synchrowave applications.

# DMA Configuration

## Set Up Resources in Resource Management

In the SEL Blueframe Portal, open Resource Management (*Figure 4.160*).

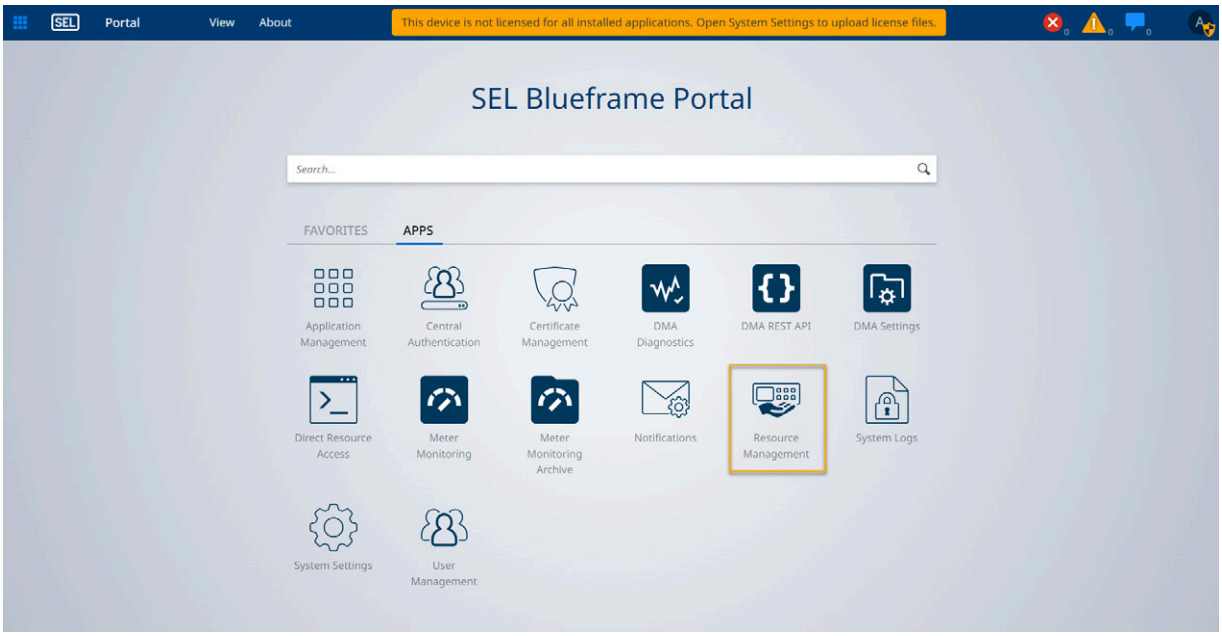



**Figure 4.160 Resource Management**

Step 1. Create a folder for Synchrowave connections.

Step 2. Open the folder and create a new **Resource** (*Figure 4.161*).

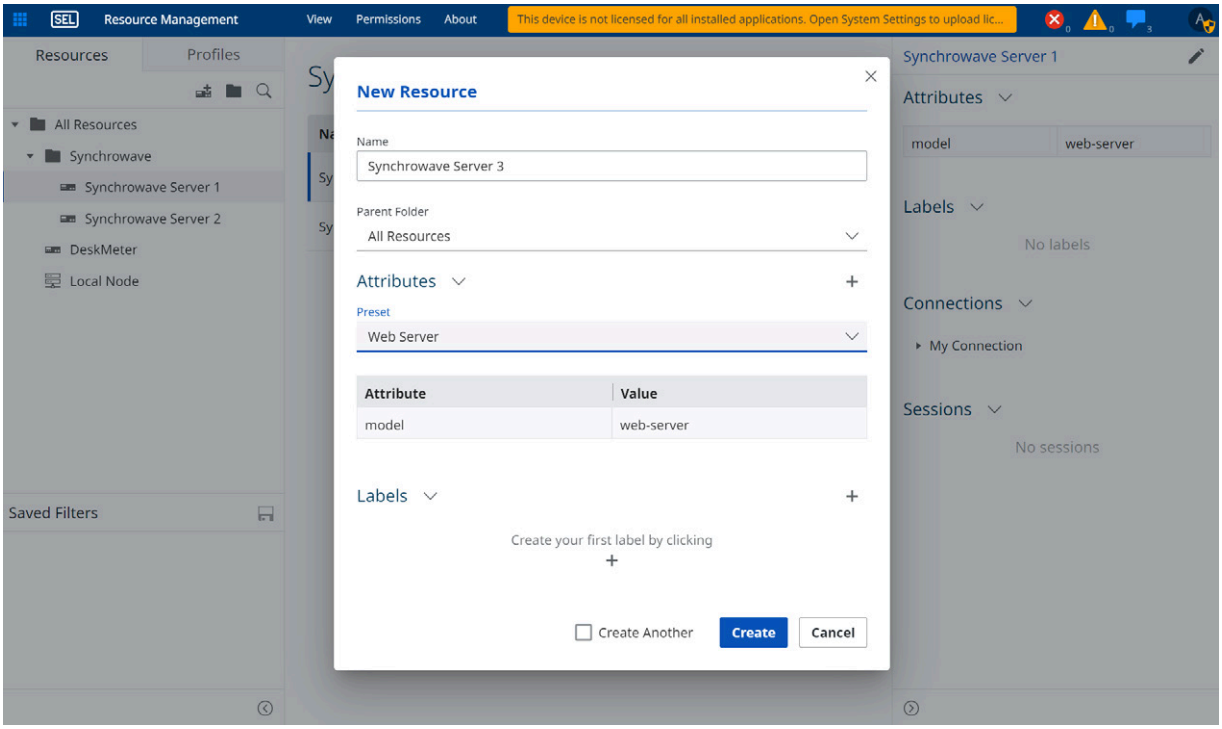



**Figure 4.161 Create a New Web Server Resource**

Step 3. Name the resource.

Step 4. Choose **Web Server** from the preset list.

Step 5. Select **Create Another** if you intend to connect the Blueframe machine to multiple Synchrowave servers.

Step 6. Select **Create**.

Step 7. For each Synchrowave connection, double-click on the new resource in the table to configure the connection to the resource.

Step 8. Select the **Connections** tab.

Step 9. Create a **New Connection** (*Figure 4.162*).

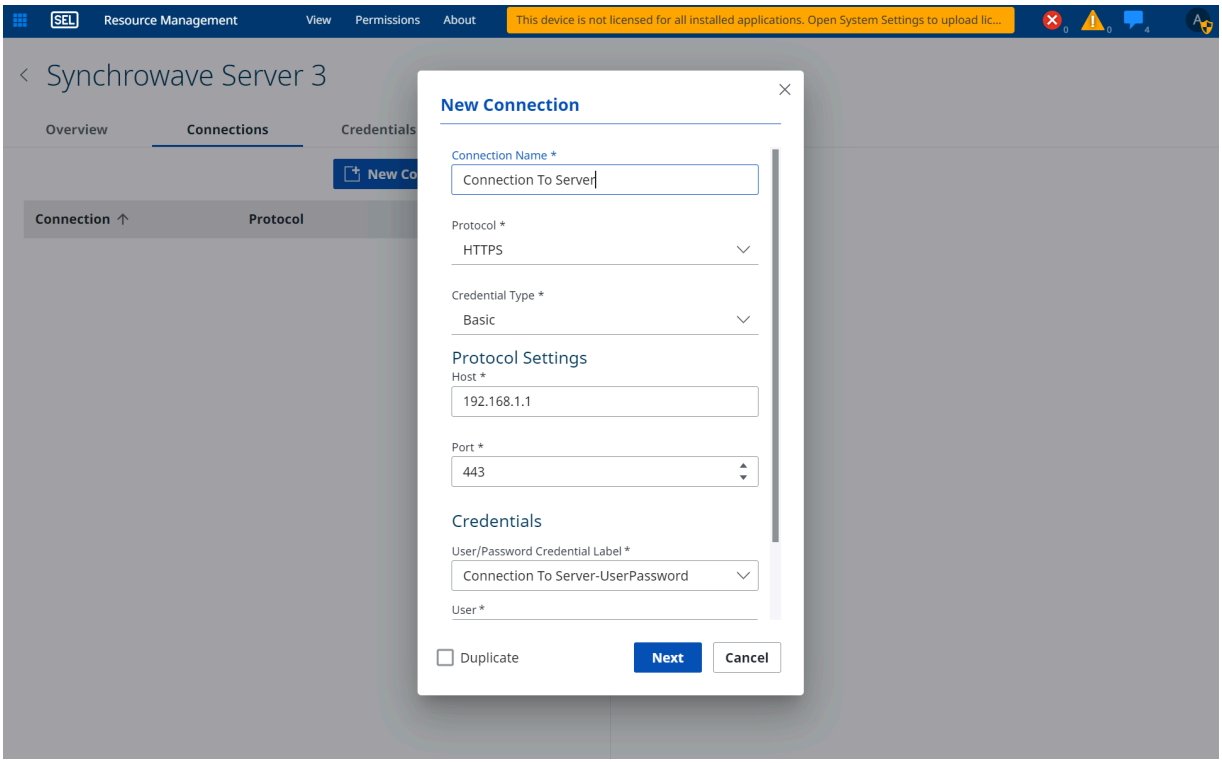



**Figure 4.162 Add a Connection to the Web Server**

Step 10. Name the connection.

Step 11. Under Protocol, select **HTTPS**.

Step 12. Under Credential Type, select **Basic**.

Step 13. Enter the IP address of the Synchrowave server.

Step 14. Enter a valid username and password for an LDAP user with one of these roles: System Admin, Operations Admin, or Engineer. See *Configuration of Authentication on page 19* for more information about setting up LDAP authentication in the Synchrowave Platform.

Step 15. Select **Create**.

Step 16. Create folders for your SEL relays and meters.

Step 17. Add a new asset using the **Direct Resource Asset** preset (*Figure 4.163*).

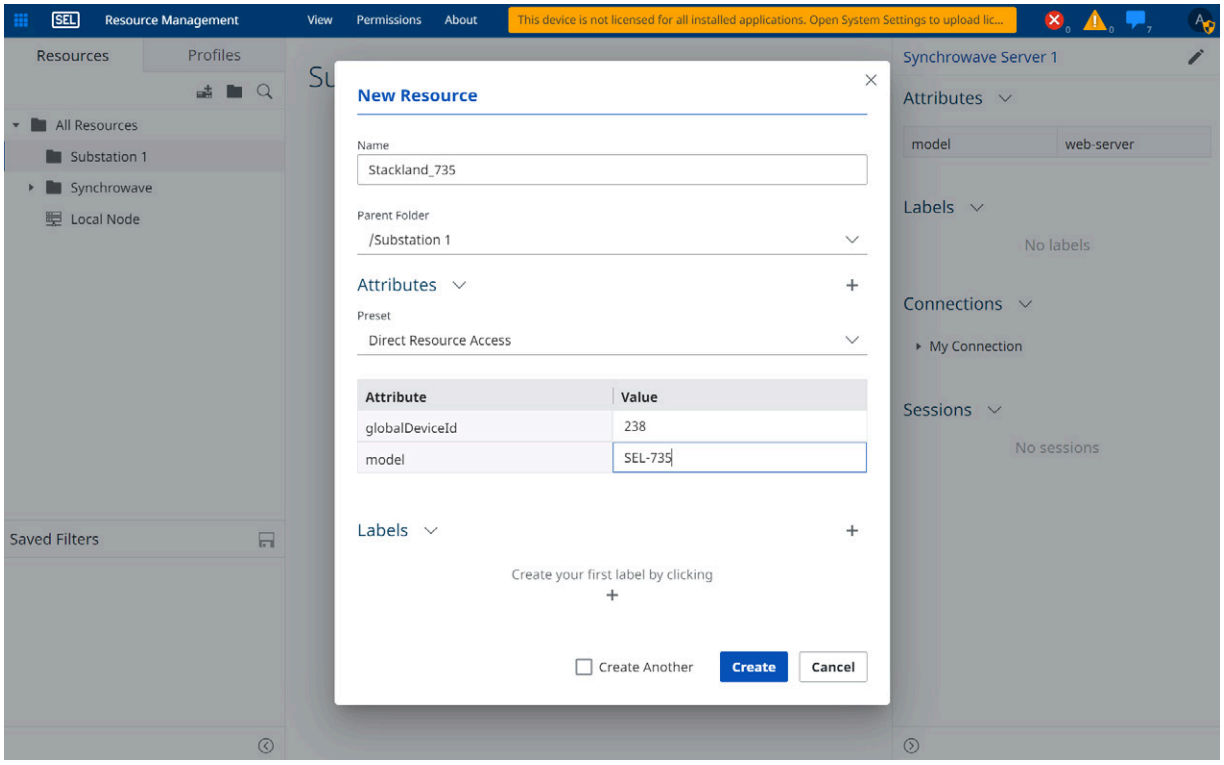



**Figure 4.163 Create a New Direct Resource Access**

Step 18. Double-click on the new resource.

Step 19. Select the **Connections** tab.

Step 20. Create a **New Connection** (*Figure 4.164*).

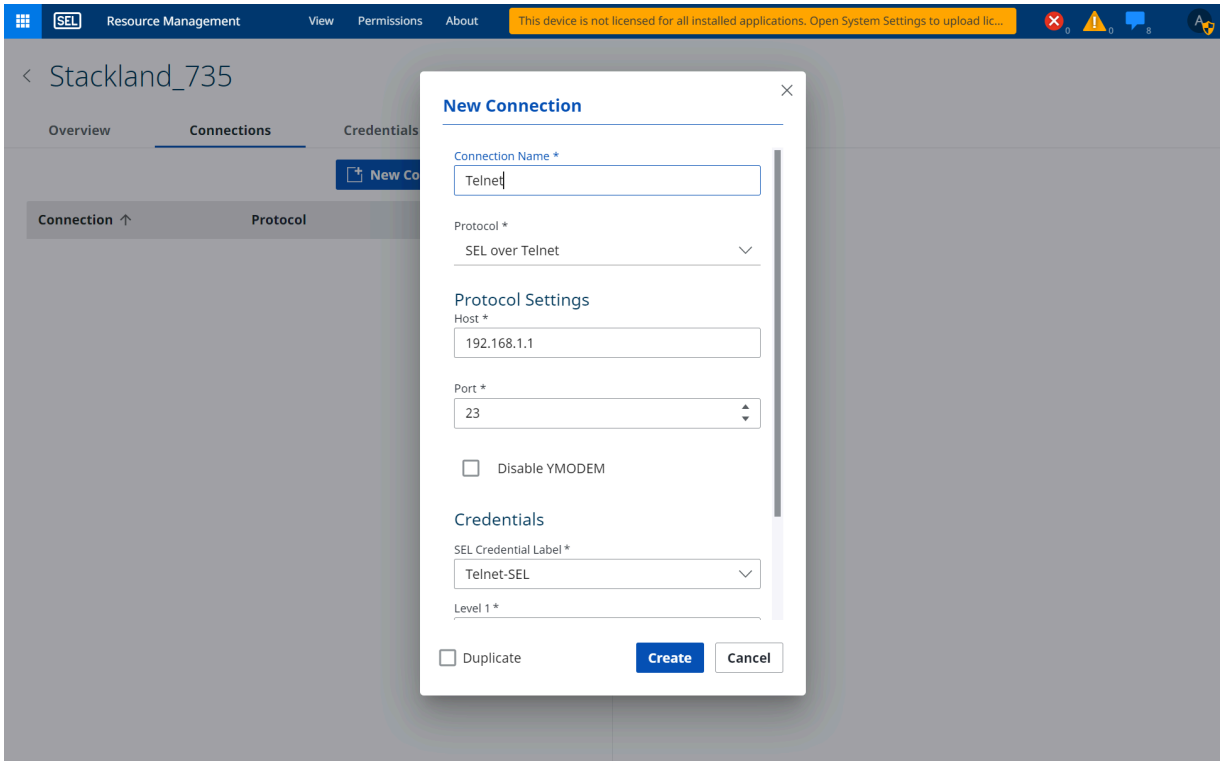



**Figure 4.164 Add a Connection to the Direct Resource Access**

Step 21. Name the connection.

Step 22. Under Protocol, select **HTTPS** for networked devices or **SEL Client Serial** for serial-connected devices.

Step 23. For Telnet, set the Host, Port, and Credentials. For Serial, set the Protocol Settings and Credentials.

Step 24. Select **Create**.

Step 25. Repeat *Step 17* through *Step 24* for each device you would like to add.

## Set Up Oscillography Disturbance Monitoring

Use the application menu in Blueframe (⠿) to navigate to Disturbance Monitoring.

Step 1. From the Collection tab, select **New Plan** (*Figure 4.165*).

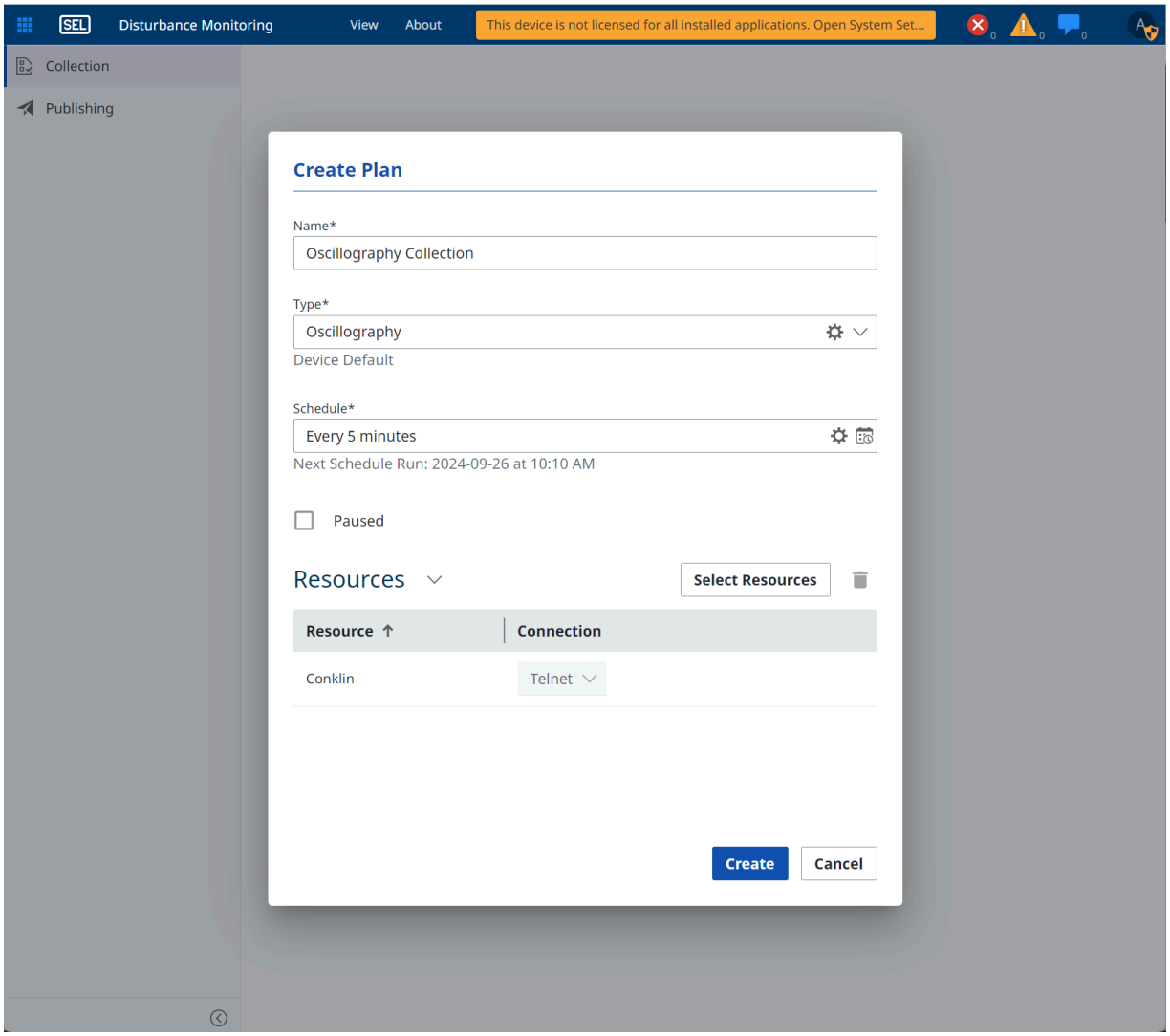



**Figure 4.165 Create a Collection Plan**

Step 2. Name the plan.

Step 3. Choose **Oscillography** as the Type. Synchrowave cannot currently receive Sequence-of-Events (SOE) data.

Step 4. Set the Schedule to a rate between one minute and one day.

Step 5. Add Resources to the plan.

Step 6. Select **Create**.

## Set Up Publishing in Disturbance Monitoring

Step 1. On the left sidebar, select **Publishing**, and then select **New Publisher** (*Figure 4.166*).

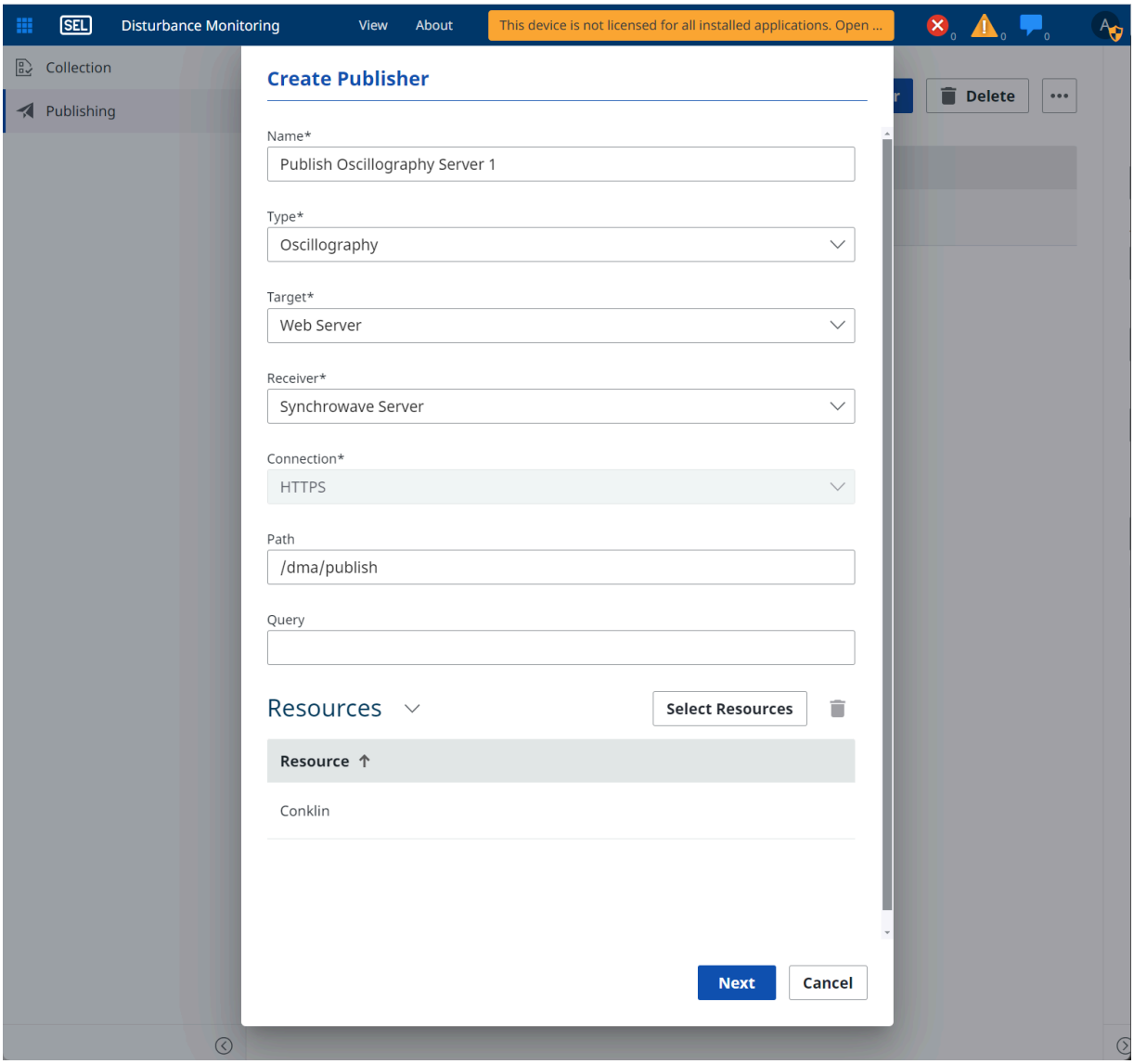



**Figure 4.166 Create a New Publishing Plan**

Step 2. Select **Oscillography** as the Type.

Step 3. Select **Web Server** as the Target.

Step 4. Select one of the Synchrowave servers.

Step 5. Select the Connection to use if there is more than one option.

Step 6. Set the **Path** to */dma/publish*.

Step 7. Select all the Resources you want to be a part of this Publish job.

Step 8. Select **Create**.

## Verify Successful Publishing

Step 1. Use the application menu in Blueframe to navigate to DMA Diagnostics.

Step 2. Verify that the Publish Data Result column shows **Success**.

Any oscillography events sent to Synchrowave are now stored in the Event Store.

# Synchrowave Event Express

Synchrowave Event Express provides web-client based oscillography analysis for event reports in the Device Events panel.

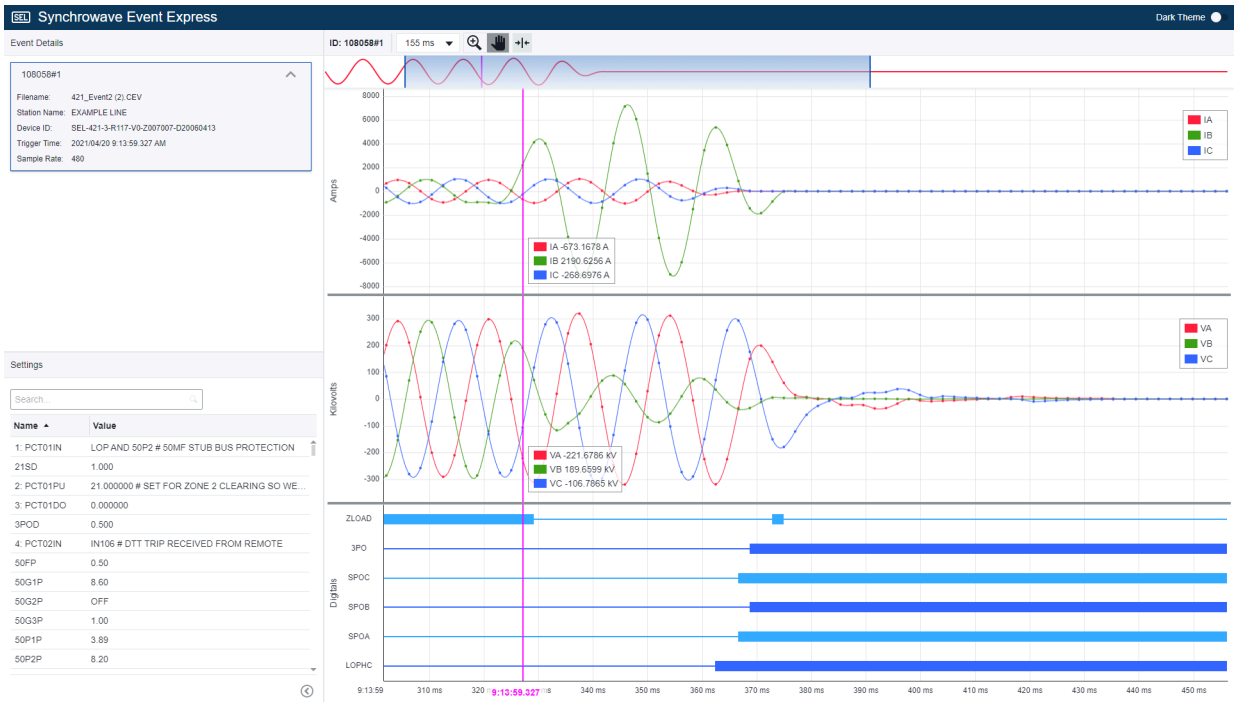



**Figure 4.167 Synchrowave Event Express Overview**

# Navigating Synchrowave Event Express

## Accessing Synchrowave Event Express

From the Device Events panel, select an event icon and then select the waveform icon in the top right corner of the panel.

**Figure 4.168 Opening an Event in Synchrowave Event Express**

# Event Details

Summary information regarding the displayed event report is shown in the Event Details section of Synchrowave Event Express.

**Figure 4.169 Event Details Information**

# Relay Settings

Search through relay settings as set in the device at the time of the event.

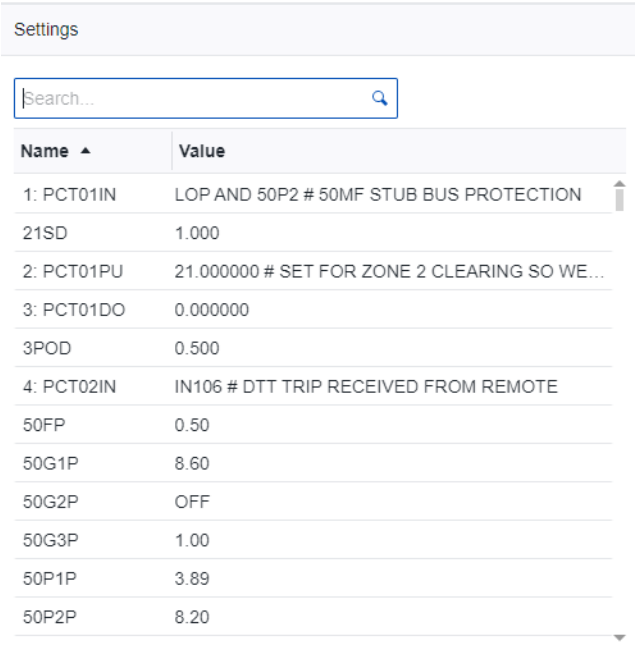



**Figure 4.170 Relay Settings From Event Report**

# Analog Chart

The analog displays current oscillography, voltage oscillography and other analog values included in the selected event report. Three-phase current and voltage are displayed on charts by default. To see a specific value at a point in time, use the time-cursor.

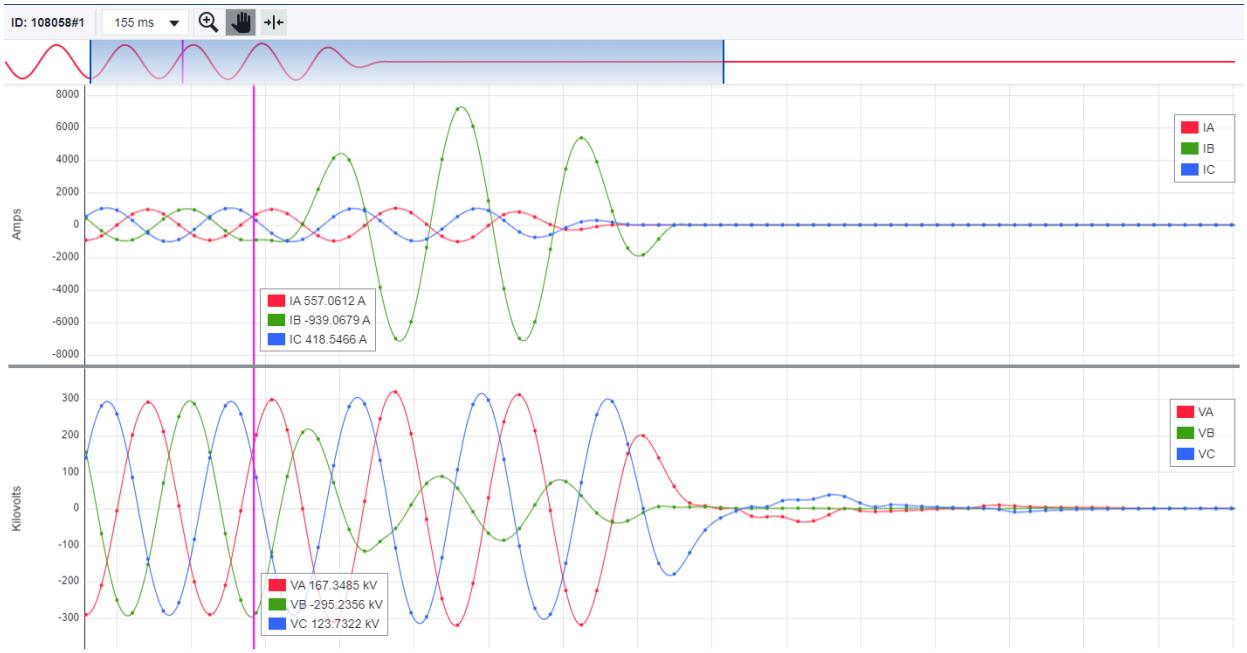



**Figure 4.171 Default Analog Charts Displaying Current and Voltage Oscillography**

## Digital Chart

The Digital chart displays Relay Word bits from the event report to help engineers understand root cause of an event.

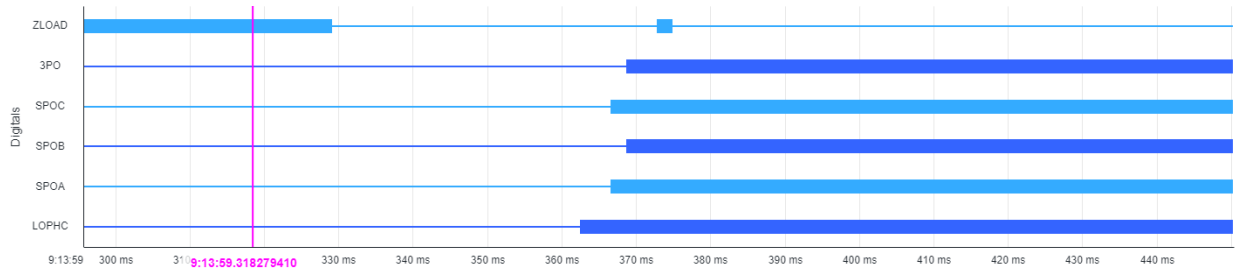



**Figure 4.172 Default Digital Chart Displaying Relay Word Bits**

## Chart Navigation

Users zoom and pan through data on analog and digital charts. All charts are synchronized in time. Users can toggle between zoom and pan control by holding the **<Ctrl>** key or selecting the zoom/pan buttons.

**Figure 4.173 Toggle Between Zoom and Pan**

# Data Export Application

The Data Export application allows time-series data to be quickly exported for further analysis. On a trend chart panel, select the (Export Data) button to open the Data Export Application in a new tab. Alternatively, use the (Synchrowave Platform Navigation) button to open the Data Export application page.

The time range, measurement points, and data type are prepopulated based on the trend panel settings.

## Configuring Data Export

### Export Format

Two types of files are supported for export.

- Zipped COMTRADE (.EVZIP)
- Comma-separated values (.CSV)

**NOTE**
For COMTRADE data exports, the time stamp precision is dependent on the duration of the selected time period being exported. For durations less than 71.5 minutes ($2^{32}$ microseconds), time stamps are reported with microsecond precision. For longer durations, divide the duration in microseconds by $2^{32}$ and round up to the nearest 1, 2, or 5 times an integer power of ten. For example, an 8-hour export would be (8*3600*1000000) / ($2^{32}$) = 6.7, which would then be rounded up to 10-microsecond precision time stamps.

The .EVZIP format is a ZIP file containing the .CFG and .DAT COMTRADE files in COMTRADE-2013 FLOAT32 format. The raw files may be accessed directly by changing the file extension from .EVZIP to .ZIP and extracting.

### Start and End Date/Time

Use the calendar selectors to select the start and end dates. Type the start and end times in the format HH:MM:DD.SSS.

### Line Frequency (Hz) (COMTRADE Only)

Select the line (nominal) frequency to be written to the COMTRADE .CFG file.

### Sample Rate

Optionally provide an alternate output sample rate. Sample Rate can be specified in units of either samples per second or seconds per sample and must be a positive integer. If Sample Rate is greater than the native data rate, data are exported at the native rate. If Sample Rate is less than the native rate, data are averaged and downsampled to the specified rate before exporting.

### Write Local Timestamps

Toggle the Write Local Timestamps button to green to export data with time stamps from the local (client) machine. Otherwise, time stamps are UTC.

### Export Name

Optionally provide a filename for the exported data.

### Include Start Time in File Name

Toggle the Include Start Time in File Name button to green to export with a file name that appends the start time to the Export Name. Otherwise, only the Export Name is included in the file name.

### Adding/Removing Measurement Points

Measurement Points in the right-hand column will be exported. To add measurement points, search for the desired measurement point or select the measurement point name. Remove measurement points by selecting a previously added measurement point and selecting **Remove**.

### Adding Data Types

Data Types in the right-hand column will be exported. Select data types in the left-hand column to add them to the right-hand column. Select data types in the right-hand column to move them back to the left-hand column. The filter tool can be used to search for data types.

## Exporting Data

Select the **Export** button to download the data. If the format was COMTRADE, double-clicking the downloaded file opens the event in Synchrowave Event if installed on the client computer.

### Export Templates

Frequently exported sets of Measurement Points and Data Types can be saved using the Export Templates panel. Select the desired Measurement Points, Data Types, and Export Name and select **Save**. Name the Export Template and then select **Ok**. The saved template will be available any time the Data Export application is opened.

# One-Line Manager Application

The One-Line Manager provides a user interface to associate signals, measurement points, and assets on the Synchrowave Platform with SVG objects in diagrams.

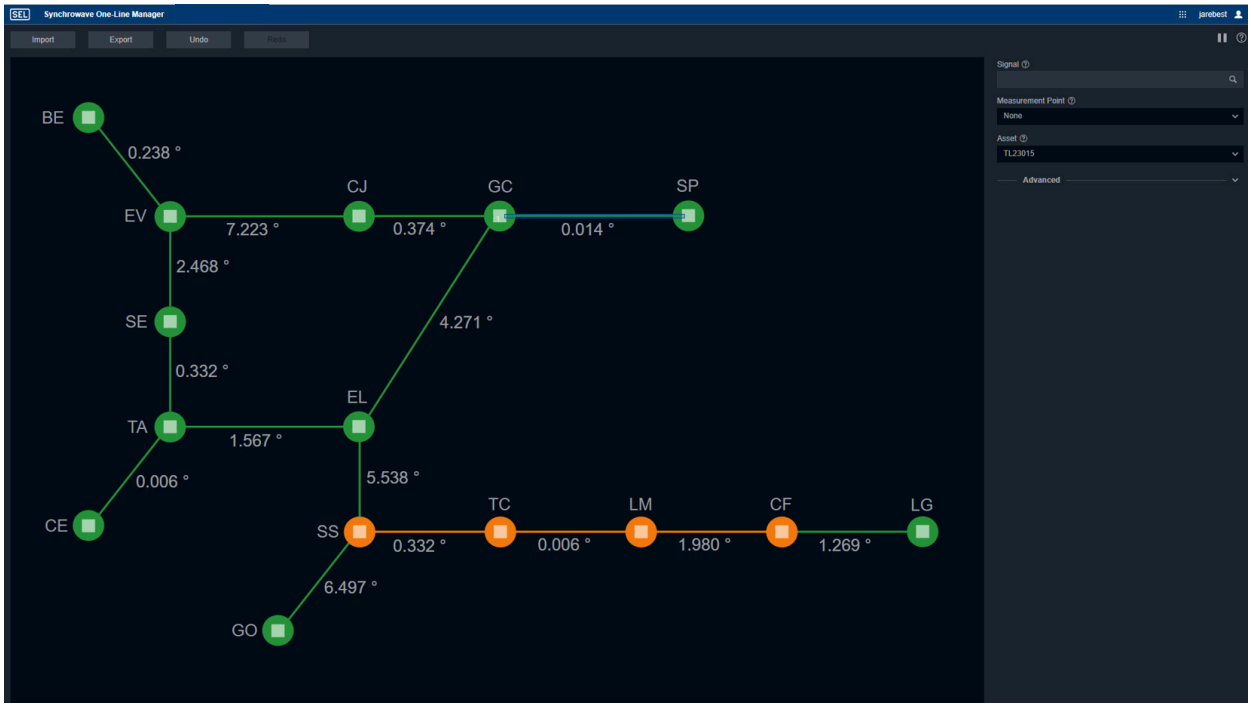



**Figure 4.174 One-Line Manager Application Overview**

# Importing and Exporting SVG Diagrams

## Import

Load an SVG diagram by selecting **Import**. For information on creating an SVG diagram, see *Appendix C: Creating SVG Diagrams*.

## Export

After associating assets and measurements points, form the Synchrowave Platform with objects in the SVG diagram. Click **Export** to download the updated SVG diagram. To see the updated SVG diagram in Synchrowave Operations, navigate to the Application Manager and select the One-Line Diagram application to import the updated diagram.

# Navigating One-Line Manager Application

## Panning

Pan the displayed diagram by selecting the diagram and dragging the cursor.

## Zooming

Zoom in and out on the diagram with the mouse wheel. Hold the **<Ctrl>** key while using the mouse wheel to zoom with more granular steps. Press the **<Z>** key to reset zoom.

### Selection

- Click on an SVG object to select object.
- **<Shift>+click** to select multiple objects.
- **<Ctrl>+click** to select grouped objects.

### Real-Time State

By selecting the play button in the top right corner of the One-Line Manager, the software will issue data requests to the Synchrowave Platform for signals configured in the diagram. The real-time state feature helps users validate signal, measurement points, and asset mappings.

## Associating Signals, Measurement Points, and Assets With SVG Objects

During SVG diagram creation (*Appendix C: Creating SVG Diagrams*), attributes such as value, color, and navigation are added to SVG objects in the diagram. The One-Line Manager makes it easy to associate assets and measurement points to the SVG objects.

### Line (or Station) Object Configuration

Adding an asset to a line object allows a user in Synchrowave Operations to **<Ctrl>+click** the line and navigate to the associated asset. To associate an asset with a line object, select the line object in the diagram. Search for the desired asset in the Asset dropdown menu, where assets in the power system model are available. (Requires appropriate attributes to be added to line object. See *Appendix C: Creating SVG Diagrams*.)

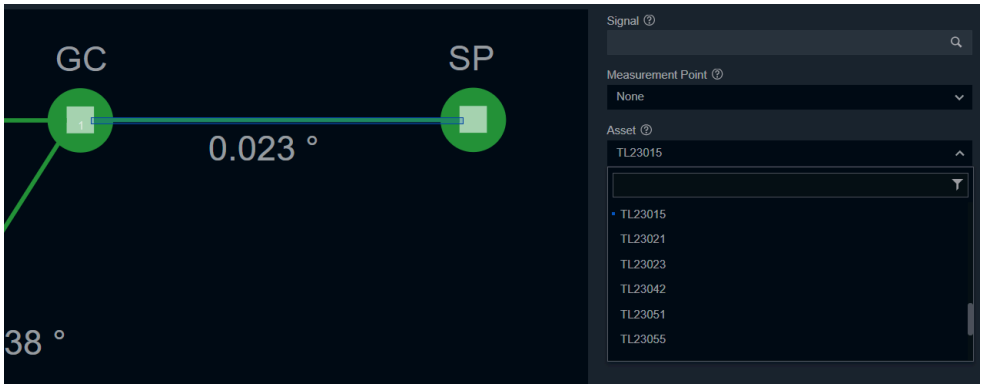



**Figure 4.175 Line Object Configuration Example**

### Text Object With Selection and Threshold Indication Configuration

Applying a signal to a text object results in the value of the signal being displayed. It can also be helpful to add SVG objects around the text object to show a selection state when selected. Adding a Measurement Point to an object will enable selection within Synchrowave Operations. To change the background behind the text when a threshold is exceeded, associate an Asset with an object. To simplify configuration, select multiple related objects and add Signal, Measurement Point, and Asset fields at one time. (Requires appropriate attributes to be added to objects. See *Appendix C: Creating SVG Diagrams*.)

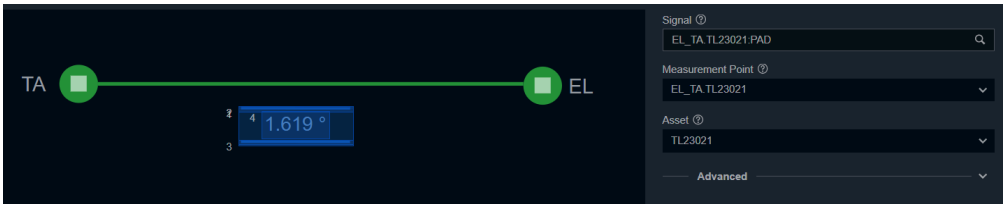



**Figure 4.176 Text Object Configuration Example**

## Advanced Object Configuration

Opening the advanced menu option when selecting an SVG object in the One-Line Manager provides access to the attribute configuration described in *Appendix C: Creating SVG Diagrams*. The advanced menu can be used to make modifications to the attribute configuration for an object without leaving the One-Line Manager.

This page intentionally left blank

SECTION 5

# Installation and Hardware Requirements

## Introduction

This section describes installation features and installation requirements for the Synchrowave Platform and Synchrowave Operations.

Consider the following when installing the Synchrowave Platform and Synchrowave Operations:


- *Deployment Network Architecture on page 199*
- *Server and Client Requirements and Specifications on page 201*
- *Data Storage Requirements on page 205*
- *Linux Software Installation on page 206*
- *Run the Synchrowave Command Line Interface on page 210*
- *Synchrowave Platform Backup Procedure on page 213*
- *Windows Software Installation on page 215*


## Deployment Network Architecture

### Secure Network Deployment

When using the Synchrowave Platform for real-time operations decision making, SEL recommends installing the Synchrowave Platform on servers in the secure control center network.

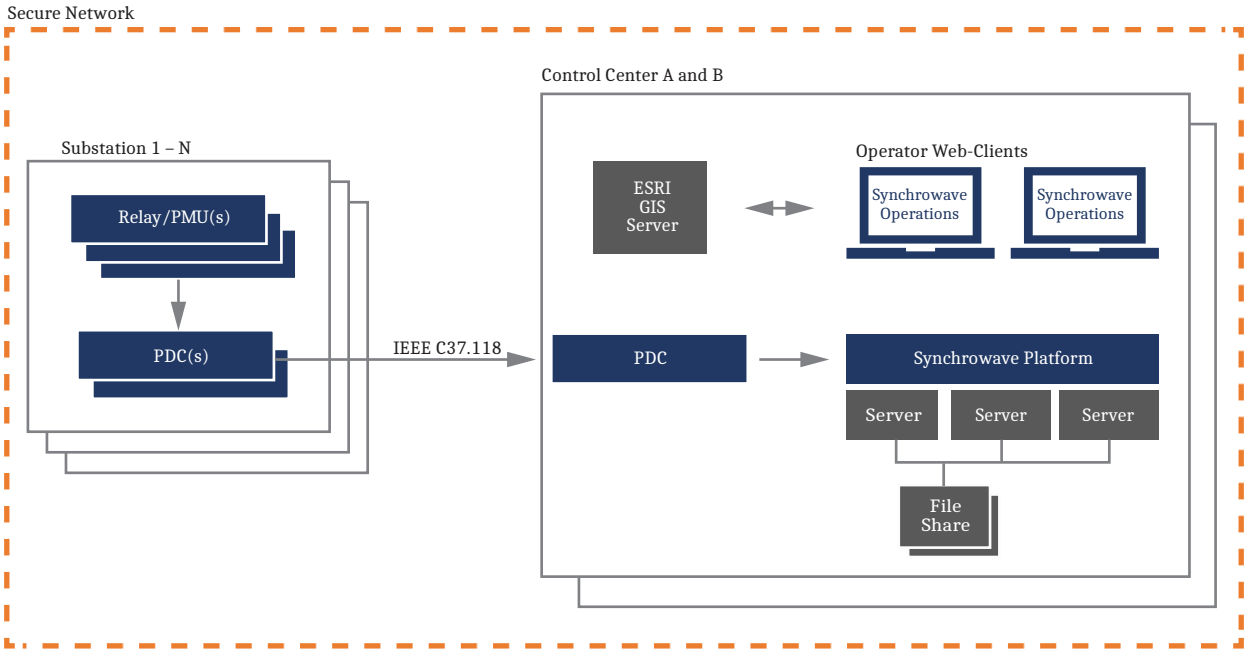



**Figure 5.1 Secure Network Deployment Architecture**

SEL recommends never connecting critical infrastructure to the internet.

For GIS capability, the Synchrowave Platform integrates with ESRI ArcGIS Server. SEL recommends installing an offline ESRI ArcGIS Server in the secure network to serve GIS data.

Any additional applications that are integrated with the Synchrowave Platform should also be installed and run from within the secure network.

## Corporate Network Deployment

The Synchrowave Platform provides significant value to engineering and planning teams for near real-time and post-event analysis. In this case, to provide efficient access to the Synchrowave Platform, deploying the software on servers located on the corporate network may be justified. SEL recommends using a one-directional protocol like UDP_S in combination with a one-way stream of data from the secure network to the corporate network.

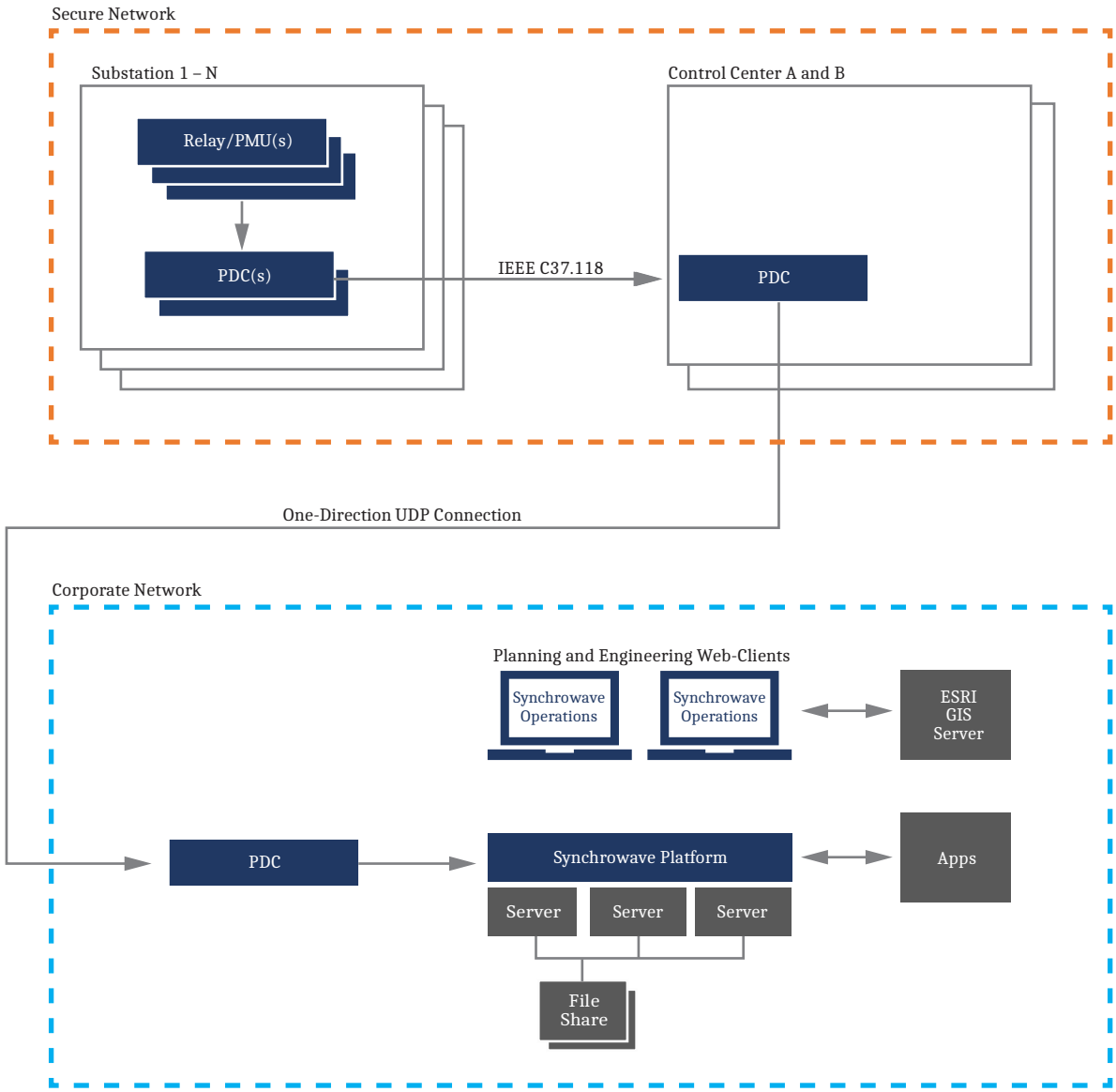



**Figure 5.2 Corporate Network Deployment Architecture**

For GIS capability, the Synchrowave Platform integrates with ESRI ArcGIS Server. SEL recommends connecting to a local ESRI ArcGIS Server within the Corporate network to serve GIS data. The software can also connect to the ESRI ArcGIS Online secure portal.

Any additional applications that are to be integrated with the Synchrowave Platform should also reside within the corporate network.

# Server and Client Requirements and Specifications

## Cluster or Single Server Configuration

### Cluster

The Synchrowave Platform includes software container technology. Container technology enables applications to be automatically deployed and managed across a server cluster. A cluster is defined as multiple servers synchronized together. As a result of deploying the Synchrowave Platform on a cluster, reliability and resiliency are built into the platform.

A minimum of *three nodes* is required to form a cluster. See *Hardware Server Requirements on page 201* for the servers to be used in the cluster.

### Single Server

In addition to the recommended cluster deployment, the Synchrowave Platform supports installation on a single server. When deployed on a single server, failover and redundancy are not possible. A single server deployment can be a cost-effective way to deploy the Synchrowave Platform for testing, engineering, and other environments that do not require the performance and resiliency that utility operations require in a production system.

## Hardware Server Requirements

### Minimum Server Requirements

Not all performance timing responses will be met with the minimum system.

- 2.1 GHz Quad Core
- 16 GB RAM
- 1 GE Network Card
- 240 GB SSD (see *Data Storage Requirements on page 205* for data archive requirements)

### Recommended Server Requirements

- 2.1 GHz Processor with 16+ Cores
- 32 GB RAM
- 10 GE Network Card (2X)
- 240 GB SSD (see *Data Storage Requirements on page 205* for data archive requirements)

### High-Performance Server Requirements

- 2.5 GHz Intel Xeon Gold Processor with 20+ Cores (Dell R740/R640 Class)
- 32 GB RAM
- 10 GE Network Card (4X)
- 240 GB SSD (see *Data Storage Requirements on page 205* for data archive requirements)

### Physical Server Versus Virtual Machine

For cluster deployments, SEL recommends using physical servers with 10 GE network connection for server-to-server communication.

A virtual machine can be used for single server deployments.

## Software Server Requirements

### Supported Operating Systems

The Synchrowave Platform runs on a Linux or Windows operating system. The following versions of Linux are supported:

- Ubuntu Server version 20.0.4 (recommended)
- Redhat Enterprise Linux version 8

The following versions of Windows are supported:

- Windows 10 (version 1909 or later, Enterprise Edition)
- Windows 11
- Windows Server 2016 Standard
- Windows Server 2019 Standard
- Windows Server 2022 Standard

### Server Time Synchronization

All nodes within a cluster must be time-synchronized within 200 ms of GPS time.

### Web Server Load Balancing

For cluster deployments, SEL recommends configuring a web-client load balancer for the servers in the cluster. Load balancers monitor the traffic connecting to a server and help ensure it is balanced across servers. They can also detect when a server is no longer active and can switch a user to an active server.

**SECURITY NOTE**

The load balancer must be configured to forward HTTPS traffic to the Synchrowave cluster (i.e., configured as a Layer 4 Load Balancer). The HTTPS certificate installed on the Synchrowave cluster then encrypts traffic all the way from the Synchrowave nodes to the client computers. There is no need to install an HTTPS certificate on the load balancer, and it will see and pass encrypted traffic only.

If a load balancer is not feasible, SEL recommends configuring a round robin DNS and associating all nodes in the cluster with a single domain name. This ensures that when a new web session is opened or the browser is refreshed that the user is directed to an active server. The round robin configuration does not guarantee that the client will automatically fail over to a healthy web-client during a failure.

### Other Applications

Running applications other than Synchrowave Operations on the server may degrade the performance and cybersecurity of Synchrowave Operations.

## Client Requirements

### Supported Web-Client

- Google Chrome Web Browser—Version 84.0 or higher
- Microsoft Edge Web Browser—Version 84.0 or higher

### Client Screen Resolution

Synchrowave Platform applications are designed for optimal performance with a screen resolution of 1920 x 1280 on 24-inch monitors.

### Minimum Client Network Connection Requirement

100 Mbps Network

**NOTE**
Not all performance timing responses will be met with the minimum system.

### Recommended Client Network Connection Requirement

1 Gbps Network

## Network Requirements

### Port and Protocol Requirements

The following section lists the ports used by the Synchrowave Platform and Operations applications. For Synchrowave to operate correctly, these ports must be opened on all firewalls between the nodes as specified in the table.

**NOTE**
When the table indicates **Platform node(s)**, the port(s) must be open to all nodes that are part of the cluster.

**NOTE**
When the table indicates **Clients**, the port(s) must be open to allow connections from all desired client network addresses. Note that if a load balancer is used, the port(s) need to be open only to/from the load balancer.

## Platform

The ports used by the platform are a function of whether it is configured as a single node or a cluster, as follows. These ports must be opened on each node and on the network connecting all nodes in the cluster.

**Table 5.1 Single-Node System**

| Direction | Protocol | Port | From | To | Description |
|---|---|---|---|---|---|
| Inbound | TCP/HTTP | 80 | Clients | Platform node | Web-gateway traffic. Port 80 is used only to redirect HTTP requests to HTTPS, Port 443. |
| Inbound | TCP/HTTPS | 443 | Clients | Platform node | Web-gateway traffic. |
| Outbound | TCP/LDAP | As Configured (Default: 389; use 636 for LDAPS) | Platform node | LDAP Server | User authentication with LDAP server. |
| Outbound | **Protocol Specific** | | Platform node | File server | Network file system access ports are protocol specific. Consult your file system vendor documentation for details. |

**Table 5.2 Cluster**

| Direction | Protocol | Port | From | To | Description |
|---|---|---|---|---|---|
| Inbound | TCP/HTTP | 80 | Clients | Platform nodes | Web-Gateway traffic. Port 80 is used only to redirect HTTP requests to HTTPS, Port 443. |
| Inbound | TCP/HTTPS | 443 | Clients | Platform nodes | Web-Gateway traffic. |
| Outbound | TCP/LDAP | As Configured (Default: 389; use 636 for LDAPS) | Platform nodes | LDAP Server | User authentication with LDAP server. |
| Outbound | **Protocol Specific** | | Platform nodes | File server | Network file system access ports are protocol specific. Consult your file system vendor documentation for details. |
| Bidirectional | TCP | 6443 | Platform nodes | Platform nodes | Kubernetes API Server |
| Bidirectional | TCP | 2379, 2380 | Platform nodes | Platform nodes | Embedded Etcd |
| Bidirectional | UDP | 51820 | Platform nodes | Platform nodes | WireGuard protected cluster communications. |

## Operations Applications

*Table 5.3* lists the required ports for each application that is part of the Operations system.

**Table 5.3 Operations Applications**

| Application | Direction | Protocol | Port | From | To | Description |
|---|---|---|---|---|---|---|
| ACSELERATOR Database Reader | Outbound | TCP | As Configured (Default: 5434) | Platform nodes | ACSELERATOR Database Server | Connection to database |
| IEEE C37.118 Reader | Outbound | TCP | As Configured (Default: 4712) | Platform nodes | C37.118 Phasor Data Concentrator(s) | Synchrophasor data |

| Application | Direction | Protocol | Port | From | To | Description |
|---|---|---|---|---|---|---|
| Esri Map | Outbound | TCP/HTTPS | 443 | Clients | ESRI Map Server(s) | ESRI map data |
| STTP Reader | Outbound | TCP | As Configured (Default: 7170) | Platform nodes | Synchrophasor Gateway | Synchrophasor data |
| OSI PI Reader | Outbound | TCP/HTTPS | As Configured (Default: 5444) | Platform nodes | Node running PI Historian Proxy Service | SCADA data |
| Continuous Waveform Streaming Receiver | Inbound | UDP | As Configured (Default: 4703) | External device | Continuous Waveform Streaming Receiver application | Continuous waveform data |

These applications require no network access beyond that provided by the Synchrowave platform: Dashboards, Data Export, Event Panel, Frequency Monitor, Historian, Notifications, Operations, Panels, Phase Angle Monitor, Platform Services, Power Monitor, Power System Model, Search, Signals, Timeline, and Voltage Monitor.

# Data Storage Requirements

## Storage Space Requirements

The amount of storage required for the Synchrowave Platform varies widely and is dependent upon several factors:

- Number of PMUs and signals/PMU.
- How long the data are to be stored.
- The applications installed on the platform. Some applications may generate additional storage requirements.

All historian data, application configuration, and logs are stored in a common storage location.

Experience shows that allocating 125 GB of storage per year for each PMU is a reasonable initial amount. Contact SEL for additional information regarding choosing the correct archiving strategy and to receive an archive sizing calculator spreadsheet.

## Storage Type Requirements

### Cluster Server Deployments

For cluster deployments, SEL recommends using an external network file system for storage. The file system must be shared across all nodes in the cluster. SEL recommends that the network file system be redundant to guard against a network file system failure. The following network file system types are supported:

- NFS Version 3
- SMB Version 3.1.1 or newer

When configuring the NFS mount on a clustered system, refer to guidance in *Linux Pre-Installation checklist*.

**SECURITY NOTE**
The data access permissions of the external network file system folder must be limited to system administrators only. Application configuration and executables are stored on the file system for sharing between Synchrowave nodes.

Alternatively, a local drive on one of the nodes can be used for storage. However, if the cluster node with the drive fails, data will be unavailable until the server is restored.

### Single Server Deployments

For single server deployments, a local drive or external network file system is used for storage.

# Linux Software Installation

## Pre-Installation Checklist

Complete the following items prior to software installation:

- Install operating system on each server.
- Configure IP Address for each server to be included in cluster.
- Set the time zone of the servers.
- Configure time server network time protocol (NTP) for each server.
- If Synchrowave will be installed on a cluster of servers, ensure that at least three servers are available.
- Set up shared file system and mount it to each server. Observe the following:

  **SECURITY NOTE**
  The data access permissions of the external network file system folder must be limited to system administrators only. Application configuration and executables are stored on the file system for sharing between Synchrowave nodes.

  - NFS v3 is the recommended network protocol.
  - UID/GID 100000 is used by Synchrowave Applications. The NFS server should not squash this UID/GID.
  - The NFS server may either squash root to UID/GID 100000 (root_squash, anonuid=100000, anongid=100000), or use the no_root_squash option.
  - If multi-protocol access or extended ACLs are necessary, ensure that UID/GID 100000 and root UID/GID 0 (if using no_root_squash) do not get blocked.

- When configuring the NFS mount on a clustered system, specify that the lookupcache = none.
- Firewalls between the nodes and the file system must be configured for NFS traffic to pass.

- On Linux installations, Synchrowave uses WireGuard to encrypt communications between nodes in the cluster. WireGuard must be installed *before* k3s and the Synchrowave Platform. Install WireGuard by following the operating system dependent instructions at https://www.wireguard.com/install/.

# Install Synchrowave Platform

See *Appendix D: Installation Checklist* for an installation checklist. This may help when troubleshooting the installation process.

## Initial Installation Instructions

The Synchrowave Platform relies on a lightweight version of Kubernetes called K3s. To set up a cluster, first install K3s on each node and join the nodes into a cluster, using the following steps:

Step 1. Copy the k3s-install-<version>.run file to the server.

Step 2. Modify installer permissions using the following command:

**sudo chmod 005 ./k3s-install-<version>.run**

Step 3. Run the installer on the first server with the following command:

**sudo ./k3s-install-<version>.run**

The installer will verify pre-installation requirements and exit if there are operating system changes needed.

Step 4. View the license agreement, then enter **2** to accept the license and create a new cluster (see *Figure 5.3*).

- The installer will automatically configure CoreDNS forwarding. If it detects an external DNS server, CoreDNS forwarding is enabled. Otherwise, it is disabled.
- The installer will attempt to automatically detect appropriate network settings. If successful, the settings are shown. Either accept the default settings or enter them manually. If unsuccessful, a prompt will appear to enter them manually.

```
K3S INSTALLER

 1. View K3s License Agreement
 2. Accept License and Create Cluster
 3. Accept License and Join Cluster
 4. Upgrade
 5. Cancel

Select menu option (1-5): 2
```

**Figure 5.3 Review and Accept K3s License Agreement**

## Join Additional Nodes to Cluster

This section applies to multinode clusters only. If installing on a single node, skip to *Install Synchrowave in the Cluster on page 209*.

Repeat the following steps on each additional node (a minimum of two more are required) being joined to the cluster.

Step 1. Repeat *Step 1* through *Step 3* from *Initial Installation Instructions on page 207*.

Step 2. Enter **3** in the installer to accept the license and join this node into the cluster, as shown in *Figure 5.4*.

```
K3S INSTALLER

 1. View K3s License Agreement
 2. Accept License and Create Cluster
 3. Accept License and Join Cluster
 4. Upgrade
 5. Cancel

Select menu option (1-5): 3
```

**Figure 5.4 Join Cluster**

Step 3. Enter the IP address of one of the existing nodes in the cluster.

Step 4. From one of the existing nodes in the cluster, run the following command to retrieve the join token of the cluster:

**sudo cat /var/lib/rancher/k3s/server/node-token**

Step 5. Copy the output string and enter it into the installer prompt, as shown in *Figure 5.5*.

```
K3S INSTALLER

 1. View K3s License Agreement
 2. Accept License and Create Cluster
 3. Accept License and Join Cluster
 4. Cancel

Select menu option (1-4): 3
Enter the IP address of an existing node: 1.1.1.1
Enter the token from an existing node (/var/lib/rancher/k3s/server/node-token):
0123456789abcdef0123456789abcdef0123456789abcdef0123456789abcdef012::server:0123
456789abcdef0123456789abcdef
```

**Figure 5.5 Enter Output String Into Installer Prompt**

Step 6. When all nodes have been joined, verify the cluster is complete by running the following command:

**sudo kubectl get nodes**

Once Synchrowave is installed, the Synchrowave command line interface is the preferred method to examine node status.

## Install Synchrowave in the Cluster

These steps need to be run on only one node in the cluster.

Step 1. Copy the synchrowave-<version>.run file to one of the server nodes.

Step 2. Modify installer permissions using the following command:

**sudo chmod 005 ./synchrowave-<version>.run**

Step 3. Run the installer with the following command:

**sudo ./synchrowave-<version>.run**

Step 4. View the license agreement, then enter **2** to accept the license and install.

Step 5. On multi-node systems, when prompted, enter the path to the Application Directory to be used by Synchrowave for application configuration and data:

```
SYNCHROWAVE PLATFORM INSTALLER

 1. View SEL License Agreement
 2. Accept License and Install
 3. Cancel

Select menu option (1-3): 2
Running installation dependency checks.
Please enter a path for the app directory:
```

**Figure 5.6 Application Directory Path**

The Application Directory needs to point to a location where an external shared file system is mounted. Note that the file system must be mounted to each node in the cluster at the same path. See *Storage Type Requirements on page 205* for requirements of the file system.

Step 6. Navigate to the client web page by entering the following URL into a web browser:

**https://<IP or name>/**

<IP or name> is the IP address or node name of one of the nodes in the cluster.

Software configuration continues using the Application Manager page.

## Install Remaining Synchrowave Applications

The remaining Synchrowave Applications are installed via the web client. From the Application Manager page, select the **Add Application** button, navigate to where the application package is stored, and select **SEL.Operations.WASA-xxx.zip**.

# Run the Synchrowave Command Line Interface

The Synchrowave command line interface (CLI) is available on each node in the cluster and provides low level configuration for Synchrowave platform parameters. The first time the CLI is run on a node, the full path to the CLI must be specified, as follows:

**/usr/local/synchrowave/cli.sh**

The CLI creates a link to the /usr/local/bin folder so that it can be run subsequently with just its name:

**synchrowave**

Because the CLI makes administration level changes, it needs to have super-user privileges. It can either be run under a root account, or by a user that is in the sudo list on the server. On startup, the CLI attempts to elevate to root privilege (using sudo) before running the requested commands. Thus, the user running the CLI must have sudo access. The CLI will prompt for the user's password if needed.

If run with no parameters, the CLI lists the available commands, as shown in *Figure 5.7*.

```
A command line interface for the Synchrowave Platform.

-------------------------------------------------------------------------------
Command [PARAM]                    Description
-------------------------------------------------------------------------------

app ls                             List all app IDs and statuses.
app install FILE-PATH              Install an application package.
app rm APP-ID                      Remove an application.
app restart APP-ID                 Restart an application.
app enable APP-ID                  Enable an application.
app disable APP-ID                 Disable an application.

config ls APP-ID                   List config versions for the specified app.
config get CONFIG-NAME FILE        Save config to a file.
config load CONFIG-NAME            Load application configuration.

system nodes                       List nodes and node status.
system restart                     Restarts all applications.
system uninstall                   Removes Synchrowave (preserves the cluster).

app-dir get                        Get the application directory.
app-dir set                        Set the application directory.

dev-key ls                         List all development keys.
dev-key add PUB-KEY-PATH           Upload a development key.
dev-key rm KEY-NAME                Delete a development key.

tls-cert ls                        List all loaded TLS certificates.
tls-cert add CERT-FILEPATH         Upload a TLS certificate.
tls-cert rm CERT-FILENAME          Delete a TLS certificate.

-------------------------------------------------------------------------------
```

**Figure 5.7 Synchrowave Command Line Interface Directory**

## View and Set the Application Data Directory

The Application Data Directory is the folder where Synchrowave stores all application data (such as dashboards and historian data). Synchrowave creates a subfolder for each application under the Application Data Directory.

For clustered systems, the Application Data Directory is required to be set to an external network file system that is accessible from all nodes in the cluster.

The location of the Application Data Directory can be viewed using app-dir get:

**synchrowave app-dir get**

The location can be changed using app-dir set:

**synchrowave app-dir set**

When prompted, enter the path to the desired folder. With external file systems, this is set to the mount location of the file system (as defined in /etc/fstab). See *Pre-Installation Checklist on page 206* for details on setting up a network file system.

# Restart All Synchrowave Applications

The following command run from an active node in the cluster will restart all Synchrowave applications on all nodes:

**synchrowave system restart**

# Node Management

## List Nodes in a Cluster

The system nodes command lists the nodes in the cluster and their current status, K3s version, IP address, OS version and kernel, and container runtime:

**synchrowave system nodes**

## Add Nodes to a Cluster

Nodes are added using the k3s installer provided with Synchrowave (see *Join Additional Nodes to Cluster on page 208*).

## Remove a Node From a Cluster

The node removal process is as follows:

Step 1. If the node being removed is still functional, log in to that node and uninstall k3s as follows:

**k3s-uninstall.sh**

Step 2. On another node in the cluster, run the **k3s-remove-node.sh** command:

**k3s-remove-node.sh**

Select the node to remove from the list, then select "y" to remove the node:

```
horizon@horizon-test-ubuntu1:~$ k3s-remove-node.sh
NODES:
1. horizon-test-ubuntu2
2. horizon-test-ubuntu3

Select the node to remove: 1

If the node to remove is functional, uninstall k3s before continuing (run "k3s-uninstall.sh" on the node to remove).
If it is not possible to uninstall k3s or otherwise reset the node to remove, then ensure that it is permanently shutdown.

Remove "horizon-test-ubuntu2" [y/n]
```

**Figure 5.8 Remove Node From List**

## Change the Hostname of a Node in a Cluster

The hostname changing process is as follows:

Step 1. Follow the steps in *Remove a Node From a Cluster on page 211* to remove the node that you will rename.

Step 2. Change the hostname of the removed node:

**hostnamectl set-hostname <New Hostname>**

Step 3. Restart the node to ensure the changes are persisted.

Step 4. Reattach the node to the cluster by following the steps in *Join Additional Nodes to Cluster on page 208*.

# Restore to Previous Application Configuration

The Config. History tab in the Application Manager is the primary way to restore an application's configuration. For cases when the Web-Gateway application has failed or been misconfigured, a previous version of an application's configuration can be loaded by running the following steps from one of the nodes in the cluster.

Step 1. Log in to one of the server nodes.

Step 2. Run the following command:

**synchrowave config ls sel-webgateway**

Step 3. Identify the configuration version for the application that you want to roll back to from the list of configurations. The configuration versions are named by the UTC date and time that the configuration was created.

Step 4. Run the following command:

**synchrowave config load <config version>**

<config version> is the full name of the configuration to load.

```
horizon@horizon1:~$ synchrowave config ls sel-webgateway
sel-webgateway_20211013,190305.4775019
sel-webgateway_20211013,190327.3809173
sel-webgateway_default
horizon@horizon1:~$ synchrowave config load sel-webgateway_20211013,190327.3809173
Application config loaded.
horizon@horizon1:~$
```

**Figure 5.9 Restore to Previous Application Version**

## Uninstall Synchrowave From the Cluster

To completely uninstall Synchrowave from the cluster, using the system uninstall command:

**synchrowave system uninstall**

This command must be run on every node in the system to fully remove Synchrowave.

Note that this will leave the K3s cluster installed. To fully remove K3s, run the following command on each node in the cluster:

**k3s-uninstall.sh**

# Allow Installation of Third-Party Applications

## Add Development Signature Key

The Synchrowave Platform only allows installation of signed applications. To install a development application on the Synchrowave Platform, add the development public key.

To add the public key, run the following command:

**sudo synchrowave dev-key add <path to public key>**

Development public keys are provided by the application developer.

# Synchrowave Platform Backup Procedure

A Synchrowave Platform system should be backed up to ensure resiliency in case of server or file system failure. There are two sets of data that may need to be backed up: the data on a local node and the data stored in the network file system. The backup and restore procedure is dependent on the Synchrowave setup as described in this section.

## Node Local File System Backup

For cluster installations, backing up the local file system is not required. There is no state stored on a single node that is not replicated on the other node's file systems. If backup is desired because of concerns of losing all nodes, follow the process for single node installations. Note that the backup process need only be done on one node in the cluster.

For single node installations, follow this process:

Step 1. Stop the platform to avoid changes during the backup:

**k3s-killall.sh**

Step 2. Backup all local file systems on the node.

Step 3. Restart the platform:

**sudo systemctl start k3s**

# Node Local File System Restore

For cluster installations, restore a single failed node's local file system as follows:

Step 1. Remove the failed node from the cluster. Connect to a terminal of a different node in the cluster. Use the synchrowave node **cli** command to find the failing node id, and remove it with **kubectl**:

**synchrowave system nodes**

**sudo kubectl delete node [NODE-NAME]**

Step 2. Resolve the problem that caused the node failure. A fresh operating system installation is a good option.

Step 3. Ensure the shared network file system is mounted on the node (via **/etc/fstab** and mount).

Step 4. Run the Synchrowave Platform installer (the same version as the other nodes in the cluster) and select **Join Existing Cluster**. Follow the steps to join the node into the cluster.

Step 5. Once the node is joined in, all necessary files will automatically be transferred to the node.

For singe-node installations, or to restore all nodes in a cluster from backup, follow this process:

Step 1. Resolve the problem that caused the node failure.

Step 2. Restore the (first) node's file system from backup.

Step 3. Start the Synchrowave Platform on the node.

**sudo systemctl start k3s**

Step 4. If this node was part of a cluster, restore the cluster making this node the leader as follows:

**sudo k3s-reset-cluster.sh**

Step 5. For all other nodes, either restore them from the same backup or start with a fresh operating system install. Then:

a. Ensure the shared network file system is mounted on the node (via **/etc/fstab** and mount).

b. Run the Synchrowave Platform installer (the same version as first node) and select **Join Existing Cluster**. Follow the steps to join the node into the cluster.

c. Once the node is joined in, all necessary files will automatically be transferred to the node.

## Network File System Backup

Step 1. Take a snapshot of the entire mounted NAS file system. Using snapshots provides:

- A synchronized view of all system state, avoiding issues related some files being backed up and significantly different times than related files.
- The ability to copy files without interfering with active modifications by the system.

Step 2. Backup the mounted file system.

Optionally, if the backups are not to include historic data, then exclude the sel-historian folder from the backup.

## Network File System Restore

Step 1. Stop the Synchrowave Platform as follows:

On each node in the cluster, connect to the terminal and execute:

**k3s-killall.sh**

Step 2. Restore the entire mounted file system from backup.

Step 3. Restart the platform as follows:

On each node in the cluster, connect to the terminal and execute:

**sudo systemctl start k3s**

# Configuring Network Settings

In some situations (e.g., the server is commissioned in an isolated environment, and then moved to a production environment), the network settings for k3s need to be reconfigured after installation. Two utility scripts are available to aid in reconfiguration:

- **k3s-configure-dns.sh**: Enable or disable CoreDNS forwarding.
- **k3s-configure-network.sh**: Manually change the node IP address and network overlay interface.

# Windows Software Installation

## Pre-Installation Checklist

Complete the following items prior to software installation:

- Configure the IP address.
- Set the time zone of the server.
- Configure the time server network time protocol (NTP).
- If applicable, set up the shared file system and mount it.
- Ensure sufficient drive space is available.

# Initial Installation Instructions

The Synchrowave Platform installer supports single server installations only.

Step 1. Run **Synchrowave Platform Setup.exe**.

Step 2. Open your web browser and set the address to "localhost".

Step 3. Select the **Add Application** button.

Step 4. Select **SEL.Operations.WASA-xxx.zip**.

Step 5. After successful installation of the server, the Application Data Directory needs to be mapped to the desired location on the file system or network drive. This step can be completed by accessing the server via a web-client and navigating to the Platform Services configuration page in the Application Manager.

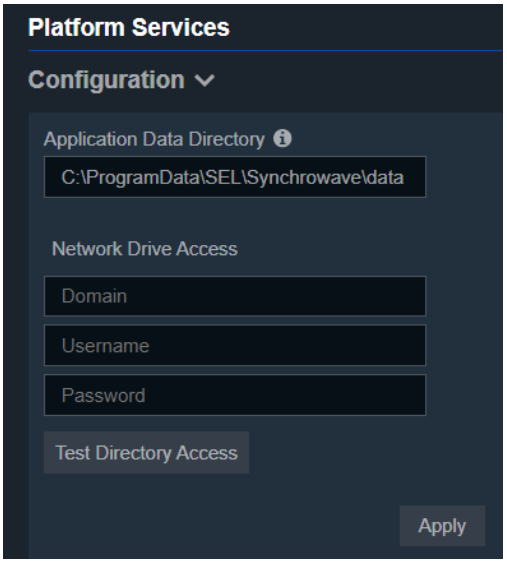



**Figure 5.10 Configuration of Application Data Directory**

APPENDIX A

# Software and Manual Versions

## Software

The software and application version information is available in the Application Manager.

*Table A.1* lists the Synchrowave Operations software versions, a description of the modifications, and the instruction manual date code that corresponds to these versions. The most recent version is listed first.

Starting with revisions published after March 1, 2022, changes that address security vulnerabilities are marked with "[Cybersecurity]". Other improvements to cybersecurity functionality that should be evaluated for potential cybersecurity importance are marked with "[Cybersecurity Enhancement]".

**Table A.1 Synchrowave Operations WASA Package Revision History**

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 2.9.1 | ➤ Added the Meter Calculations application.<br>➤ Added the Load Profile application.<br>➤ Added the Virtual Meters application.<br>➤ Improved time awareness in the CWS Receiver application.<br>➤ Improved CWS Receiver configuration file compatibility with Excel.<br>➤ Improved CWS Receiver application memory usage. | 20250221 |
| 2.9.0 | ➤ Added the Notification Inhibit Table and the ability to prevent notifications from being created for selected measurement points.<br>➤ Updated the ESRI Map application to use ArcGIS version 4.30.<br>➤ Added the Continuous Waveform Streaming Receiver application. | 20250108 |
| 2.7.3 | ➤ Improved the performance of the ACSELERATOR Database Reader application. | 20250103 |
| 2.7.2 | ➤ [Cybersecurity Enhancement] Updated the ACSELERATOR Database Reader application to use remote server identity information from the ACSELERATOR Database Connection Key to enhance X.509 connection verification when connecting to the database.<br>➤ Added the ability to map assets to objects in ESRI Map using attributes other than ObjectID.<br>➤ Improved the configuration of the C37.118 Reader for UDP_S connections.<br>➤ Improved the contour layer drawing algorithm so that contours render correctly over large regions and the contour mask works correctly.<br>➤ Added the ability to save the file name in a Data Export template.<br>➤ Added a function to the Calculations application that allows the use of a primary and one or more backup signals for calculations.<br>➤ Added the ID column to the Notification Table.<br>➤ Disallowed calculation libraries with names that begin with a digit.<br>➤ Modified Device Events so that only trip events get the trip icon.<br>➤ Improved configuration of the Digitals.csv file so that commas are not required when all states are not labeled.<br>➤ Improved the precision of the ESRI Map box zoom.<br>➤ Improved the highlighting in the cursor legend of the Time-Series Trend.<br>➤ Added the Event Store application.<br>➤ Added the DMA Receiver application. | 20241008 |

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 2.7.0 | ➤ Improved support for digital signals and added the Digital Chart application.<br>➤ Added the ability to search for published dashboards.<br>➤ Added a configurable dashboard for the main Notifications page. | 20240124 |
| 2.6.1 | ➤ [Cybersecurity] Updated Microsoft .NET third-party libraries to prevent remote code execution.<br>➤ Added notifications from Historian for when disk is nearly full and if it has stopped writing.<br>➤ Improved Historian support for manually copied signal files.<br>➤ Added ability to filter and query signals to the Calculations application.<br>➤ Addressed an issue with the Data Table not sorting correctly.<br>➤ Updated Microsoft ASP.NET Core third-party libraries for the OSI PI Reader Historian Proxy. | 20231201 |
| 2.5.0 | ➤ Added option for total power on Data Table.<br>➤ Modified STTP reader to retain and distinguish tags no longer in data stream.<br>➤ Made line thickness configurable on Time-Series Trend.<br>➤ Added Line Frequency setting for COMTRADE data export. | 20230714 |
| 2.4.0 | ➤ Improved Modal Analysis.<br>➤ Added Oscillation Monitor.<br>➤ Added Configuration History details, including support for comments.<br>➤ Added ability to apply custom styles to feature layers on ESRI map. | 20230427 |
| 2.0.0 | ➤ Added Sequence Calculator.<br>➤ Added ability to export averaged data at a rate lower than native.<br>➤ Added ability to exclude signals from deletion by the Historian. | 20220908 |
| 1.6.1 | ➤ [Cybersecurity] Improved the security of ACSELERATOR Database Reader Application by encryption using a unique key generated when the database is installed. | 20220628 |
| 1.6 | ➤ Added Generation Trip Locator.<br>➤ Added Instrument Transformer Monitor.<br>➤ Added Synchrowave Vision capability to Time Series Trend.<br>➤ Increased number and type of signals supported by Modal Analysis application. | 20220426 |
| 1.5 | ➤ Upgraded Synchrowave Platform from Docker Swarm to K3s (Kubernetes). | 20211209 |
| 1.4.4 | ➤ Added ability to copy and paste panels in dashboards.<br>➤ Added support for 50 Hz power systems to Disturbance Detector application.<br>➤ Improved performance of Device Events panel. | 20211104 |
| 1.4.3 | ➤ Added Data Export Templates.<br>➤ Added support for map contour layers outside North America. | 20210812 |
| 1.4.2 | ➤ Optimized user interface performance.<br>➤ Improved STTP Reader performance. | 20210709 |
| 1.4.1 | ➤ Added Synchrowave Event Express.<br>➤ Added support for time-enabled layers for ESRI Map.<br>➤ Added Disturbance Detector.<br>➤ Added One-Line Diagram Manager.<br>➤ Added ability to display multiple data types (same units) on several of the dashboard panel applications. | 20210618 |
| 1.3.1 | ➤ Increased the length of time supported for COMTRADE data export.<br>➤ Improved resilience of the SEL Signals application to network failures. | 20210301 |

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 1.3 | ➤ Added One-Line Diagram Panel.<br>➤ Added Histogram Panel.<br>➤ Added IEEE P2664 STTP Reader Application.<br>➤ Added Notification Comments.<br>➤ Added Signal Monitor.<br>➤ Added Calculation Application.<br>➤ Improved Bar Chart and Phasor Scope Panels.<br>➤ Improved dashboard navigation. | 20210115 |
| 1.2 | ➤ Added SWave Reader Application.<br>➤ Added OSI PI Reader Application.<br>➤ Added Playback Application.<br>➤ Added Light Theme.<br>➤ Improved data export function.<br>➤ Added XY Panel.<br>➤ Added Modal Analysis Application.<br>➤ Added ArcGIS Integration and Contour Layers to ESRI Map.<br>➤ Added Replay to Timeline.<br>➤ Added Dynamic Thresholds.<br>➤ Added Shelving Notifications.<br>➤ Improved Notification Table.<br>➤ Improved Bar Chart. | 20200731 |
| 1.1 | ➤ Added ACSELERATOR Database Reader.<br>➤ Improved Power System Monitor applications.<br>➤ Added data export function.<br>➤ Added Bar Chart, Dial, Phasor Scope, Notification Table, and Event Panel applications.<br>➤ Added user-created notifications.<br>➤ Added search function.<br>➤ Added user interface improvements. | 20200115 |
| 1.0.0 | ➤ Initial version. | 20191007 |

*Table A.2* and *Table A.3* list the Synchrowave Platform software versions, a description of the modifications, and the instruction manual date code that corresponds to these versions for the Linux and Windows platform versions, respectively. The most recent versions are listed first.

Starting with revisions published after March 1, 2022, changes that address security vulnerabilities are marked with "[Cybersecurity]". Other improvements to cybersecurity functionality that should be evaluated for potential cybersecurity importance are marked with "[Cybersecurity Enhancement]".

**Table A.2 Synchrowave Linux Platform Software Revision History**

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 2.9.0 | ➤ Improved the network configuration capability of the k3s installer and added utility scripts to assist with network configuration. | 20250108 |
| 2.7.2 | ➤ Updated to .Net Core 8.0.8. | 20241008 |
| 2.7.0 | ➤ Updated colors and fonts.<br>➤ Added support for Unicode characters. | 20240124 |
| 2.6.1 | ➤ [Cybersecurity] Updated Microsoft .NET third-party libraries to prevent remote code execution.<br>➤ [Cybersecurity] Addressed a vulnerability that allowed an Operations Admin to execute code in a different user's context.<br>➤ Improved SELinux support.<br>➤ Addressed parsing issue with FileSystemIgnore.txt configuration file for Resource Monitor. | 20231201 |

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 2.5.0 | ➤ [Cybersecurity Enhancement] Closed Port 10250 on k3s.<br>➤ Added support for LDAPS on Port 636.<br>➤ Added LDAP support for very large, nested user groups.<br>➤ Added support for special characters in usernames. | 20230714 |
| 2.0.0 | ➤ [Cybersecurity] Added node-to-node encryption using WireGuard.<br>➤ [Cybersecurity] Changed Synchrowave application containers to not run as root.<br>➤ [Cybersecurity] Added certificate-based validation of LDAP and ESRI servers.<br>➤ Added System Manager.<br>➤ Added Resource Monitor.<br>➤ Improved application configuration workflow. | 20220908 |
| 1.6 | ➤ Added ability to display a custom banner on each page.<br>➤ Added Operations Support and View Only roles. | 20220426 |
| 1.5 | ➤ Upgraded Synchrowave Linux Platform from Docker Swarm to K3s (Kubernetes). | 20211209 |
| 1.4.3 | ➤ Updated third-party libraries. | 20210812 |
| 1.2 | ➤ Improved Application Manager Diagnostic Logs. | 20200731 |
| 1.0 | ➤ Initial version. | 20191007 |

**Table A.3 Synchrowave Windows Platform Software Revision History**

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 2.7.2 | ➤ Updated to .Net Core 8.0.8. | 20241008 |
| 2.7.0 | ➤ Updated colors and fonts.<br>➤ Added support for Unicode characters. | 20240124 |
| 2.6.1 | ➤ [Cybersecurity] Updated Microsoft .NET third-party libraries to prevent remote code execution.<br>➤ [Cybersecurity] Addressed a vulnerability that allowed an Operations Admin to execute code in a different user's context.<br>➤ Addressed an issue where the SEL Synchrowave user was generating many .tmp files. | 20231201 |
| 2.5.0 | ➤ Added support for LDAPS on Port 636.<br>➤ Added LDAP support for very large, nested user groups.<br>➤ Added support for special characters in usernames. | 20230714 |
| 2.4.0 | ➤ Added support for Windows 11 and Windows Server 2022. | 20230427 |
| 2.0.0 | ➤ [Cybersecurity] Added certificate-based validation of LDAP and ESRI servers.<br>➤ Added Operations Support and View Only roles.<br>➤ Added System Manager.<br>➤ Improved application configuration workflow. | 20220908 |
| 1.6 | ➤ Added ability to display a custom banner on each page.<br>➤ Added Operations Support and View Only roles. | 20220426 |
| 1.5 | ➤ Upgraded Synchrowave Linux Platform from Docker Swarm to K3s (Kubernetes). | 20211209 |
| 1.4.3 | ➤ Updated third-party libraries. | 20210812 |
| 1.2 | ➤ Improved Application Manager Diagnostic Logs. | 20200731 |
| 1.0 | ➤ Initial version. | 20191007 |

# Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

*Table A.4* lists the product manual release dates and a description of modifications. The most recent product manual revision is listed at the top.

**Table A.4 Manual Revision History**

| Date Code | Summary of Revisions |
|---|---|
| 20250221 | **Section 4**<br>➤ Added *Setting Up Meter Calculations*, *Virtual Meters Application*, and *Load Profile Application*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 2.9.1. |
| 20250108 | **Section 3**<br>➤ Added *Inhibiting Measurement Points* to *Notification List* in *Notification Application*.<br><br>**Section 4**<br>➤ Added *Inhibit Measurement Points* to *Other Operations* in *Notification Table Application*.<br>➤ Added *Notification Inhibit Table* and *Continuous Waveform Streaming Receiver Application*.<br><br>**Section 5**<br>➤ Added Continuous Waveform Streaming Receiver to *Table 5.3: Operations Applications*.<br>➤ Updated *Install Synchrowave Platform* in *Linux Software Installation*.<br>➤ Added *Configuring Network Settings*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 2.9.0.<br>➤ Updated for Synchrowave Linux Platform software version 2.9.0. |
| 20250103 | **Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 2.7.3. |
| 20241008 | **Section 4**<br>➤ Updated *Zooming* in *Navigating the GIS Map*.<br>➤ Updated *Configuring Data Export* in *Data Export Application*.<br>➤ Updated *Configuring Asset Mapping* in *Associating Assets With Map Layers*.<br>➤ Added *DMA Receiver Application* and *Event Store Application*.<br><br>**Appendix A**<br>➤ [Cybersecurity Enhancement] Updated for Synchrowave Operations WASA package version 2.7.2.<br>➤ Updated for Synchrowave Linux Platform software version 2.7.2.<br>➤ Updated for Synchrowave Windows Platform software version 2.7.2.<br><br>**Appendix B**<br>➤ Updated *Table B.1: Symptoms*.<br><br>**Appendix C**<br>➤ Updated *SVG Templates and Components* in *Creating SVG Diagrams*.<br>➤ Updated *Changing the Color of an Object Based a Signals Value (Line, Bus, Transformer, etc.)* in *Adding Attributes to SVG Objects*.<br>➤ Updated *Figure C.3: JSON for Changing Color of Feeder Object*, *Figure C.4: JSON for Changing Color of Breaker Object*, *Figure C.5: JSON for Right Power Flow Arrow*, *Figure C.6: JSON for Left Power Flow Arrow*, *Figure C.7: JSON for Signal Values and Threshold State (Alarm State)*, *Figure C.8: JSON for Selection State—Top and Bottom Bar*, and *Figure C.9: JSON for Selection State—Threshold Region for Selection State*. |
| 20240124 | **Section 2**<br>➤ Updated *SEL Signals Diagnostic Menu and Configuration* in *SEL Signals Application*.<br><br>**Section 3**<br>➤ Updated *Searching for Dashboards* in *Dashboards Application*.<br>➤ Updated *Creating Dashboard Templates* in *Dashboards Application*. |

| Date Code | Summary of Revisions |
|---|---|
| | **Section 4**<br>➤ Added *Digital Chart Application*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 2.7.0.<br>➤ Updated for Synchrowave Linux Platform software version 2.7.0.<br>➤ Updated for Synchrowave Windows Platform software version 2.7.0. |
| 20231201 | **Section 4**<br>➤ Added *Performance Monitoring and Out of Space Prediction* in *Historian Features*.<br>➤ Updated *Configuring Data Retention and Performance* in *Historian Application Configuration*.<br>➤ Added *Contour Layers on Maps Outside the United States* in *Contour Layers*.<br><br>**Section 5**<br>➤ Added *Install Remaining Synchrowave Applications* in *Install Synchrowave Platform*.<br>➤ Updated *Add Application Signature Key* in *Allow Installation of Third-Party Applications*.<br><br>**Appendix A**<br>➤ [Cybersecurity] Updated for Synchrowave Operations WASA package version 2.6.1.<br>➤ [Cybersecurity] Updated for Synchrowave Linux Platform software version 2.6.1.<br>➤ [Cybersecurity] Updated for Synchrowave Windows Platform software version 2.6.1.<br><br>**Appendix D**<br>➤ Updated *Installation Checklist*. |
| 20230714 | **Section 1**<br>➤ Removed GEP Reader from *Table 1.5: Data Application Highlights*.<br><br>**Section 2**<br>➤ Updated *Figure 2.26: LDAP Server Connection Setup*.<br><br>**Section 3**<br>➤ Added information about deleting dashboards to *Configuring Dashboard Navigation Folders* in *Dashboard Navigation*.<br><br>**Section 4**<br>➤ Updated *Y-Axis Scaling* in *Navigating the Time-Series Trend*.<br>➤ Updated *Configuring Time-Series Trend Settings* in *Configuring the Time-Series Trend*.<br>➤ Updated *Figure 4.37: Setting Up Default Time-Series Trend*.<br>➤ Updated *Adding/Removing Data Columns* in *Configuring the Table* under *Table Panel Application*.<br>➤ Updated *Figure 4.84: Table Data Columns Options Menu*.<br>➤ Added information about previously configured signals no longer present in the data stream to *Example* in both *IEEE P2664 STTP Reader Configuration* and *IEEE C37.118 Reader Configuration*.<br>➤ Added *Line Frequency (Hz) (COMTRADE Only)* to *Configuring Data Export* in *Data Export Application*.<br><br>**Section 5**<br>➤ Updated *Table 5.1: Single-Node System* and *Table 5.2: Cluster* to specify using Port 636 for LDAPS in outbound TCP/LDAP communications from platform node(s) to an LDAP server.<br>➤ Removed GEP Reader from *Table 5.3: Operations Applications*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 2.5.0.<br>➤ Updated for Synchrowave Windows Platform software version 2.5.0.<br>➤ Updated for Synchrowave Linux Platform Software version 2.5.0.<br><br>**Appendix E**<br>➤ Updated *General Data Storage* in *Commissioning*. |

| Date Code | Summary of Revisions |
|---|---|
| 20230427 | **Section 2**<br>➤ Added information about adding a comment with a configuration change from the Import dialog box to *Application Configuration* in *Application Manager*.<br>➤ Added information about adding comments describing banner title changes to *Platform Services Application* in *Platform Applications*.<br>➤ Added information about adding comments describing authentication configuration changes to *Web Gateway Application*.<br><br>**Section 3**<br>➤ Added information about adding comments describing Auto-Acknowledge Timeout Seconds changes to *Audible Notifications* in *Notification Application*.<br>➤ Added *Importing and Exporting Dashboards* to *Dashboard Navigation* in *Dashboards Application*.<br><br>**Section 4**<br>➤ Added *Displaying Magnitude* in *Configuring the Phasor Scope Panel*.<br>➤ Added note about voltage and current signals to *Power Calculation* in *Power Monitor Application*.<br>➤ Added *Oscillation Monitor Application*.<br>➤ Added *Configuring Algorithm Parameters* to *Instrument Transformer Monitor Application*.<br>➤ Updated *Modal Analysis Application*.<br>➤ Updated *Zooming* in *Navigating the GIS Map* in *ESRI Map Panel Application*.<br>➤ Added information about adding comments describing layer additions to *Adding New ArcGIS Layers* in *ESRI Map Panel Application*.<br>➤ Updated *Configuring Data Retention and Performance* in *Historian Application Configuration*.<br>➤ Added information about adding comments describing end-of-life date time changes to *Configuring the SWave Server* in *SWave Server Application*.<br><br>**Section 5**<br>➤ Added Windows 11 and Windows Server 2022 Standard to list of supported operating systems in *Software Server Requirements*.<br>➤ Added information regarding WireGuard installation to *Linux Software Installation*.<br><br>**Appendix A**<br>➤ Changed the title of *Determining the Software Versions* to *Software* and *Determining the Manual Version* to *Instruction Manual*.<br>➤ Updated for Synchrowave Operations WASA package version 2.4.0.<br>➤ Updated for Synchrowave Windows Platform software version 2.4.0.<br>➤ Moved and/or copied applicable version 2.0.0 revision statements from *Table A.1: Synchrowave Operations WASA Package Revision History* to *Table A.2: Synchrowave Linux Platform Revision History* and *Table A.3: Synchrowave Windows Platform Revision History*. |
| 20220908 | **General**<br>➤ Added *Appendix E: Cybersecurity Features*.<br><br>**Section 2**<br>➤ Updated *Adding/Removing Users* in *Configuration of Authentication* under *Platform Applications > Web Gateway Application*.<br>➤ Added *System Manager and Resource Monitor*.<br><br>**Section 4**<br>➤ Updated *Condition Monitoring Configuration* in *Power System Applications*.<br>➤ Updated *Voltage Monitor Application*.<br>➤ Added *Figure 4.11: Grouping Parameters and Notification Type Configuration*.<br>➤ Added *Sequence Calculator Application* to *Generation Trip Locator Application*.<br>➤ Updated *Configuring the Archive Data Directory* in *Historian Application Configuration* under *Time-Series Historian Application*.<br>➤ Removed *GEP Reader Application*.<br>➤ Updated *Importing Power System Model Data* in *ACSELERATOR Database Reader Application*.<br><br>**Section 5**<br>➤ Updated Port number and Description for Bidirectional UDP cluster in *Table 5.2: Cluster*.<br>➤ Updated *Pre-Installation Checklist* in *Linux Software Installation*.<br>➤ Updated *Figure 5.8: Remove Node From List*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 2.0.0. |

| Date Code | Summary of Revisions |
|---|---|
| 20220628 | **Section 4**<br>➤ Updated *ACSELERATOR Database Reader*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.6.1. |
| 20220426 | **Section 2**<br>➤ Updated *Figure 2.17: Platform Services Configuration*.<br>➤ Added Banner Title information in *Platform Services Application*.<br><br>**Section 3**<br>➤ Updated *Adding Dashboard Panels*.<br><br>**Section 4**<br>➤ Added *Instrument Transformer Monitor Application*.<br>➤ Updated *Modal Analysis Application*.<br>➤ Added *Generation Trip Locator Application*.<br>➤ Updated *Y-Axis Scaling* options.<br>➤ Changed *Configuring the Reference Measurement Point* to *Configuring the Reference Measurement Point and Time Align Delay*.<br>➤ Updated note in *Configuring the CSV File*.<br>➤ Added note to *Connecting to an IEEE C37.118 Source*.<br>➤ Changed *GEP Reader CSV Mapping File Format* figure caption to *ACSELERATOR Database Device CSV Mapping File Format*.<br><br>**Section 5**<br>➤ Updated *Supported Operating Systems*.<br>➤ Added *Linux Software Installation* and *Windows Software Installation*.<br>➤ Updated app-dir set information in *View and Set the Application Data Directory*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.6. |
| 20211209 | **Section 2**<br>➤ Added *Platform Services Application*.<br><br>**Section 5**<br>➤ Updated *Table 5.1: Single-Node System*.<br>➤ Updated *Table 5.2: Cluster*.<br>➤ Updated *Supported Operating Systems*.<br>➤ Updated *Initial Installation Instructions*.<br>➤ Updated *Joining Additional Nodes to Cluster*.<br>➤ Updated *Synchrowave Platform Backup Procedure*.<br>➤ Added *Installing Synchrowave in the Cluster*.<br>➤ Updated *Synchrowave Command Line Interface*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.5.<br><br>**Appendix B**<br>➤ Updated *Table B.1: Symptoms*.<br>➤ Updated *Solutions*.<br><br>**Appendix D**<br>➤ Updated the *Installation Checklist*. |
| 20211104 | **Section 4**<br>➤ Updated *Panel Applications*.<br>➤ Updated *Configuring Display Range*.<br>➤ Updated *Configuring the Reference Measurement Point*.<br>➤ Updated *Configuring Data Retention and Performance*.<br>➤ Updated *Configuring Data Indexer Retention*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.4.4. |

| Date Code | Summary of Revisions |
|---|---|
| 20210812 | **Section 3**<br>➤ Updated *Configuring Dashboard Navigation*.<br>➤ Added *Figure 3.22: Creating a Dashboard Navigation Folder*.<br>➤ Updated *Dashboard Creation*.<br>➤ Updated *Publishing Dashboards*.<br><br>**Section 4**<br>➤ Updated *X-Axis Zooming* in *Device Events Panel Application*.<br>➤ Updated *IEEE C37.118 Reader Application*.<br>➤ Added *Export Templates*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.4.3.<br>➤ Updated for Synchrowave Platform software version 1.4.3. |
| 20210709 | **Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.4.2 |
| 20210618 | **Section 1**<br>➤ Updated *Table 1.3: Power System Monitoring Application Highlights* and *Table 1.5: Data Application Highlights*.<br><br>**Section 2**<br>➤ Updated *Figure 2.18: Web Browser Not Secure Warning* and *Figure 2.20: Web-Client HTTPS Status Indication*.<br>➤ Updated *SEL Signals Application*.<br><br>**Section 3**<br>➤ Updated *Dashboards Application*.<br><br>**Section 4**<br>➤ Updated *Power Monitor Application*.<br>➤ Added *Disturbance Detector Application*.<br>➤ Updated *Time-Series Trend Panel Application*.<br>➤ Updated *Bar Chart Panel Application, Changing the Data Type*.<br>➤ Updated *Dial Panel Application*.<br>➤ Updated *Phasor Scope Panel Application*.<br>➤ Added *Device Events Panel Application*.<br>➤ Updated *Numeric Panel Application*.<br>➤ Updated *ArcGIS Map Layers*.<br>➤ Updated *IEEE C37.118 Reader Application*.<br>➤ Updated *Bus Data*.<br>➤ Updated *Figure 4.141: ACSELERATOR Database Reader Configuration*.<br>➤ Added *Synchrowave Event Express*.<br>➤ Updated *Data Export Application*.<br><br>**Section 5**<br>➤ Updated *Supported Operating Systems*.<br>➤ Updated *Table 5.1: Single-Node System* and *Table 5.2: Cluster*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.4.1.<br><br>**Appendix C**<br>➤ Updated *Figure C.3: XML for Changing Color of Feeder Object*, *Figure C.4: XML for Changing Color of Breaker Object*, *Figure C.5: XML for Right Power Flow Arrow*, *Figure C.6: XML for Left Power Flow Arrow*, *Figure C.7: XML for Signal Values and Threshold State (Alarm State)*, *Figure C.8: XML for Selection State—Top and Bottom Bar*, and *Figure C.9: XML for Selection State—Threshold Region for Selection State*. |
| 20210301 | **Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.3.1. |

| Date Code | Summary of Revisions |
|---|---|
| 20210115 | **Section 1**<br>➤ Updated *Table 1.3: Power System Monitoring Application Highlights*, *Table 1.4: Panel Application Highlights*, *Table 1.5: Data Application Highlights*.<br><br>**Section 2**<br>➤ Updated *Figure 3.2: Software User Interface—Notification Summary*, *Figure 3.3: Software User Interface—Timeline Application*, *Figure 3.4: Software User Interface—Dashboards and Dashboard Navigation*, *Figure 3.6: Notification Summary Display Location*.<br>➤ Updated *Creating a User Notification* and *Notification Analysis Mode*.<br>➤ Added *Notification Comment*.<br>➤ Updated *Figure 3.20: Notification Analysis Dashboard*.<br>➤ Added *Audible Notifications*.<br>➤ Updated *Figure 3.34: System Monitoring Dashboard*, *Figure 3.35: Asset Investigation Dashboard*, *Figure 3.36: Notification Analysis Dashboard*.<br>➤ Updated *Navigation Dashboards* and *Configuring a Home Dashboard*.<br>➤ Updated *Figure 3.47: Creating a Dashboard*, *Figure 3.48: Naming a Dashboard*, *Figure 3.49: Private User Dashboard Indication*, *Figure 3.51: Adding Dashboard Panel*, *Figure 3.67: Light Theme Dashboard Display*.<br><br>**Section 4**<br>➤ Added *Signal Monitor*.<br>➤ Updated *Figure 4.15: Edit Data Type* and *Figure 4.16: Add/Remove Measurement Points From Time-Series Trend*, *Figure 4.17: Setting Up Default Y-Axis Scale*, *Figure 4.24: Edit Bar Chart Panel Data Type*, *Figure 4.25 Add/Remove Measurement Points From Bar Chart Panel*, *Figure 4.26: Configure the Bar Chart Panel Default View Range*.<br>➤ Added *Change Bar Orientation* and *Histogram Panel Application*.<br>➤ Updated *Figure 4.41: Edit Phasor Scope Panel Data Type* and *Figure 4.35: Add/Remove Measurement Points From Phasor Scope Panel*.<br>➤ Added *Configuring Angle Range*, *Setting Zero Position*, and *Calculations Application*.<br>➤ Updated *Loading SWave Data*.<br>➤ Added *IEEE P2664 STTP Reader Application* and *One-Line Diagram Application*.<br><br>**Section 5**<br>➤ Updated *Recommended Server Requirements* and *Installing Synchrowave Platform*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Operations WASA package version 1.3.<br><br>**Appendix C**<br>➤ Added *Appendix C: Associating One-Line Diagrams With Measurement Points*.<br><br>**Appendix D**<br>➤ Added *Appendix D: Installation Checklist*. |
| 20200731 | **Section 1**<br>➤ Updated *Figure 1.1: Synchrowave Operations and Platform Functional Diagram*.<br>➤ Updated *Table 1.4: Panel Application Highlights*.<br>➤ Updated *Table 1.5: Data Application Highlights*.<br><br>**Section 2**<br>➤ Updated *Application Diagnostics*.<br>➤ Updated *Adding/Removing Users*.<br><br>**Section 3**<br>➤ Updated *Figure 3.12: Notification List Details*.<br>➤ Added *Shelving Notifications*.<br>➤ Updated figures in *Timeline Application*.<br>➤ Added *Replay*.<br>➤ Updated *Configuring a Home Dashboard*.<br>➤ Updated *Dashboard Creation*.<br>➤ Added *Changing Dashboard Theme*.<br>➤ Added *Playback Application*. |

| Date Code | Summary of Revisions |
|---|---|
| | Section 4<br>➤ Added *Dynamic Thresholds*.<br>➤ Added *Modal Analysis Application*.<br>➤ Updated *Set Thresholds and Assign Time Groups*.<br>➤ Updated *Figure 4.12: Time-Series Trend Panel Overview*.<br>➤ Added *Data Export Application*.<br>➤ Updated *Figure 4.16: Bar Chart Panel Overview*.<br>➤ Updated *Navigating the Bar Chart Panel*.<br>➤ Updated *Figure 4.23: Add/Remove Measurement Points From Bar Chart Panel*.<br>➤ Added *Configuring the View Scale*.<br>➤ Added *XY Panel Application*.<br>➤ Updated *Notification Table Application*.<br>➤ Updated *Figure 4.66: Connecting to ESRI GIS Server*.<br>➤ Updated *Figure 4.68: Changing the GIS Map Base Map*.<br>➤ Updated *Figure 4.69: Add/Remove Map Layers*.<br>➤ Added *Select Visible Map Layers*.<br>➤ Added *Configuring Opacity and View Range*.<br>➤ Added *ArcGIS Map Layers*.<br>➤ Added *Associating Assets With Map Layers*.<br>➤ Added *Contour Layers*.<br>➤ Added *Panel*.<br>➤ Added *Signal Availability*.<br>➤ Added *SWave Server Application*.<br>➤ Added *Managing Changed Data Rates*.<br>➤ Added *Signal Availability*.<br>➤ Added *Managing Changed Data Rates*.<br><br>Section 5<br>➤ Updated *Network Requirements*.<br>➤ Added *Restarting the Synchrowave Platform*.<br>➤ Added *Synchrowave Platform Backup Procedure*.<br><br>Appendix A<br>➤ Updated for Synchrowave Operations WASA package version 1.2.<br>➤ Updated for Synchrowave Platform software version 1.2.<br><br>Appendix B<br>➤ Added *Appendix B: Troubleshooting*. |
| 20200115 | ➤ Replaced cover image.<br>Section 1<br>➤ Updated *Figure 1.1: Synchrowave Operations and Platform Functional Diagram*.<br>➤ Updated *Table 1.4: Panel Application Highlights*.<br>➤ Updated *Table 1.5: Data Application Highlights*.<br><br>Section 3<br>➤ Added *User-Created Notifications*.<br>➤ Updated *Figure 3.27: Dashboard Navigation Toolbar*.<br>➤ Updated *Figure 3.28: Dashboard Navigation Menu*.<br>➤ Updated *Figure 3.29: Dashboard Navigation Path*.<br>➤ Updated *Figure 3.30: Navigating to Dashboards in the Same Folder*.<br>➤ Added *Searching for Dashboards*.<br>➤ Added *Configuring a Home Dashboard*.<br>➤ Updated *Figure 3.37: Creating a Dashboard*.<br>➤ Updated *Figure 3.40: Dashboard Options Menu*. |

| Date Code | Summary of Revisions |
|---|---|
| | Section 4<br>➤ Updated *Configuring the Frequency Monitor*.<br>➤ Updated *Configuring the Voltage Monitor*.<br>➤ Updated *Power Monitor Application*.<br>➤ Added *Bar Chart Panel Application*.<br>➤ Added *Dial Panel Application*.<br>➤ Added *Phasor Scope Panel Application*.<br>➤ Added *Event Panel Application*.<br>➤ Added *Notification Table Application*.<br>➤ Updated *Figure 4.12: Add/Remove Measurement Points From Time-Series Trend*.<br>➤ Added *ACSELERATOR Database Reader Application*.<br><br>Section 5<br>➤ Added *Allow Installation of Third Party Applications*.<br><br>Appendix A<br>➤ Updated for Synchrowave Operations WASA package version 1.1.<br>➤ Updated for Synchrowave Platform software version 1.1. |
| 20191007 | ➤ Initial version. |

APPENDIX B

# Troubleshooting SEL Synchrowave Platform and Operations

## Introduction

This section outlines the most common issues with Synchrowave based on the symptoms the issue causes along with remedies to resolve the issue. To use this section, first locate the symptom in the first column of *Table B.1*, then review the possible causes in the second column. The third column describes methods to resolve the problem and/or references solutions (found after *Table B.1*) that include step-by-step instructions to resolve specific problems.

## Symptoms

**Table B.1 Symptoms**

| Symptom | Possible Causes | Remedy |
|---|---|---|
| Web Gateway login failed.<br>Web Gateway logs indicate `Unable to reach LDAP for ….` | LDAP Service Account credentials are invalid or changed. | Changing the service account credentials will cause Synchrowave to be unable to communicate with LDAP, potentially locking out users. If admin users are unable to log in to resolve this, follow *A. Restoring Access to Synchrowave When Locked Out on page 231*. |
| | LDAP/Active Directory is down. | Resolve LDAP/Active Directory issues. |
| | Network access problems between Synchrowave and LDAP/Active Directory. | Verify and correct network, firewall access, and DNS resolution issues from each Synchrowave Platform node to the LDAP/Active Directory server. |
| Unable to connect to Web Gateway.<br>Browser times out. | Load balancer is down or misconfigured. | Using the browser, connect directly to one of the Synchrowave platform nodes IP addresses. If a connection is possible, verify load balancer is running and configured correctly. |
| | Network is down between client machine and Synchrowave platform nodes. | Using a secure shell (SSH) terminal, connect to one of the Synchrowave nodes. If unsuccessful, resolve network issues. |
| | Web Gateway application is disabled or not functioning. | If you can access a node via SSH but the Web Gateway is not responding, restart the Web Gateway by using *B. Restarting Web Gateway From Command Line on page 231*. |
| Bad Gateway NGINX Error is displayed when connecting to Web Gateway. | System is starting up. | Wait a couple of minutes for system to complete startup routine. |
| | Web Gateway application is not functioning. | Restart the Web Gateway using *B. Restarting Web Gateway From Command Line on page 231*. |

| Symptom | Possible Causes | Remedy |
|---|---|---|
| Page Not Found is displayed when navigating to the platform URL. | The application serving the Web Gateway default page is not running. | Verify all applications are running following *C. Examining and Restarting Applications From the Application Manager on page 232*. |
| | The Web Gateway default page is set incorrectly. | Follow *D. Reset Web Gateway Default Page on page 232*. |
| Part or all of the Operations page is not displayed correctly or is displayed very slowly. | One or more Operations applications are not functioning. | Verify all applications are running following *C. Examining and Restarting Applications From the Application Manager on page 232*. |
| | The CPU is overloaded on one or more nodes. | Follow *H. Diagnose and Correct CPU Overload on page 234*. |
| One application is not functioning. The Application Manager shows an application is Unhealthy (indicated with an orange status icon). | The application is incorrectly configured. | View the application Diagnostics logs in Application Manager. Correct the issue and, if needed, restart the application by selecting **Restart App**. |
| | The application services are malfunctioning or crashed. | In the Application Manager, restart the application by selecting the application and selecting **Restart App**. |
| The Application Manager shows many applications are Unhealthy (indicated with an orange status icon). | One of the Synchrowave platform nodes is down. | Follow *E. Identify and Restart Failing Synchrowave Platform Node on page 232*. |
| | See *Synchrowave node not functioning* for more causes. | |
| Synchrowave node not functioning. | Out of local disk space on node. | Follow *F. Diagnose and Correct Out of Disk Space on page 233*. |
| | Shared file system is not mounted or mounted incorrectly on the node. | Follow *G. Verifying Shared File System Mount on page 233*. |
| Dashboards or notification are flashing on the Operations client. | Shared file system is not mounted or mounted incorrectly on one or more nodes. | Follow *G. Verifying Shared File System Mount on page 233*. |
| In the Operations client, time jumps backward and forward frequently. | Server system clock times are not synchronized across all Synchrowave platform nodes. | Using an SSH terminal, connect to each node and compare times reported from *date*. |
| | | Ensure time synchronization (ex. Network Time Protocol) is running on all nodes. |
| Real-time data stops displaying for some or all signals. | The connection to the data source (C37.118, STTP, etc.) was lost. | View the data source application Diagnostics logs in Application Manager. Correct the connection issue and restart the application by selecting **Restart App**. |
| | The connection to one or more upstream devices has failed. | The station availability signals may help diagnose the problem. See the instruction manual section for the affected data source application. |
| Historic data are not displayed. | The shared network file system is down or out of disk space. | Follow *F. Diagnose and Correct Out of Disk Space on page 233* and *G. Verifying Shared File System Mount on page 233*. |

| Symptom | Possible Causes | Remedy |
|---|---|---|
| New notifications are not being generated. | The shared network file system is down or out of disk space. | Follow *F. Diagnose and Correct Out of Disk Space on page 233* and *G. Verifying Shared File System Mount on page 233*. |
| Contour layers appear white or empty when configured with measurement points containing non-ASCII characters (e.g., the accented letters é, à, ö, ñ). | Characters are incorrectly encoded in the configuration file. | In the text editor or Microsoft Excel, save the .csv configuration files after selecting the CSV UTF-8 option. |

# Solutions

## A. Restoring Access to Synchrowave When Locked Out

Step 1. Using an SSH terminal, connect to one of the Synchrowave Platform nodes.

Step 2. Set the web gateway back to its factory-default configuration, disabling authentication:

**synchrowave config load sel-webgateway_default_config.json**

Step 3. From the web browser, connect to Synchrowave Application Manager.

Step 4. Navigate to the Web Gateway application.

a. Enable authentication and enter the LDAP server connection parameters and credentials.

b. Select **Test LDAP Connection**.

c. Once successful, select **Apply**.

Step 5. If the problem was caused by a password change only, the previous Web Gateway configuration can now be restored. This is because the password is not stored with the configuration.

a. Select the Config. History tab.

b. Select the version that was active before the lockout occurred. This is likely the second version in the list (because selecting **Apply** in *Step 4* created a new version).

c. Select **Load**.

Step 6. If your system is not restored, you will need to reconfigure all Web-Gateway configuration settings. When completed, select **Apply**.

## B. Restarting Web Gateway From Command Line

Step 1. Using an SSH terminal, connect to one of the Synchrowave Platform nodes.

Step 2. Restart the web gateway:

**synchrowave app restart sel-webgateway**

Step 3. Verify access to web gateway from the web browser is restored.

# C. Examining and Restarting Applications From the Application Manager

Step 1. In a web browser, navigate directly to the application manager by using the URL **https://[domain]/sel.applicationmanager**, where [domain] is replaced with the domain name or IP address of the Synchrowave platform.

Step 2. Examine the status icon of each application.

Step 3. If an application is not green, examine its logs by selecting the application and selecting the Diagnostics tab.

Step 4. Resolve the problem and restart the application by selecting **Restart App**.

# D. Reset Web Gateway Default Page

Step 1. In a web browser, navigate directly to the application manager by using the URL **https://[domain]/sel.applicationmanager**, where [domain] is replaced with the domain name or IP address of the Synchrowave platform.

Step 2. Select Web Gateway.

Step 3. Select the Configuration tab.

Step 4. Type **sel.applicationmanager** into the Default Page field. This restores the Application Manager as the default page.

Note that you can use another page for the default page. For example, entering **sel.operations** sets the Operations application (if it is installed) as the default page.

Step 5. Select **Apply**.

# E. Identify and Restart Failing Synchrowave Platform Node

Step 1. Using an SSH terminal, connect to one of the Synchrowave Platform nodes.

Step 2. Examine the status of Synchrowave nodes:

**synchrowave system nodes**

Step 3. Examine the output to determine which node(s) are listed as **Down** under the STATUS column. The hostname of the node is listed under the HOSTNAME column.

Step 4. Connect to the failing node with SSH.

Step 5. Soft restart the node:

**k3s-killall.sh**

**sudo systemctl start k3s**

Step 6. If this does not resolve the issue, see *Synchrowave node not functioning* in *Table B.1*.

# F. Diagnose and Correct Out of Disk Space

Step 1. Using an SSH terminal, connect to the Synchrowave Platform node that is not functioning.

Step 2. Examine disk free space:

**df**

Step 3. If the **Use%** column indicates any file system near 100%, follow one of these steps to resolve the problem:

a. Remove some files on the file system to make additional space.

b. Increase the size of the mounted file system.

c. Create a new file system and copy all files.

Step 4. Once space has been freed up, restart Synchrowave. If the shared network file system is the file system that was full, run this command on all nodes:

**k3s-killall.sh**

**sudo systemctl start k3s**

# G. Verifying Shared File System Mount

Step 1. Using an SSH terminal, connect to one of the Synchrowave platform nodes. If one node is suspected to be malfunctioning, connect to a different node first.

Step 2. Navigate to the shared file system location (as configured in Application Manager under Platform Services, or with synchrowave mount).

Step 3. Create a file at that location:

**sudo touch test_file.txt**

Step 4. Connect to each of the other nodes in the platform. If one node is suspected to be malfunctioning, prioritize that node in the connection order.

Step 5. Navigate to the shared file system location and verify the file exists:

**ls**

Step 6. If the file does not exist on one or more of the nodes, the file system mounts on one or more of the nodes are not configured correctly.

Step 7. Note that in Linux, if a mount is not setup and the system attempts to write files to the mount location, the files will be written to the local file system instead of the network fileshare. This causes both the user and the Synchrowave platform to be confused. Synchrowave will write files to the local file system instead of the network fileshare. If this occurs, these files should be (carefully) deleted before remounting the network file system.

Step 8. To help diagnose the problem, examine the file system mounts on the node:

**sudo mount**

Step 9. Ensure the mount for the Synchrowave shared file system (as configured in Application Manager under Platform Services, or with synchrowave mount) is listed. If not, correct the problem (usually via **/etc/fstab**).

Step 10. Once the file system mount problem has been resolved, restart Synchrowave on all affected nodes:

**k3s-killall.sh**

**sudo systemctl start k3s**

# H. Diagnose and Correct CPU Overload

Step 1. Using an SSH terminal, connect to each of the Synchrowave platform nodes.

Step 2. Examine CPU usage:

**sudo top -c**

Step 3. Examine the **%Cpu(s):** row at the top of the display. The total of **us**, **sy**, and **ni** values should be less than 50 percent. The **wa** value should be less than 10 percent.

Step 4. If the CPU usage is high, examine the processes listed at the top of the list. The process name after **dotnet** begins with the application name. For example, **SEL.Notifications.MainService.dll** belongs to the Notifications application.

Step 5. In Application Manager, examine the Diagnostics log for the application that is using high CPU. This may provide clues as to the problem.

Step 6. Restarting the application may resolve the problem:

**synchrowave app restart [app-id]**

To find the [app-id] of the application, run:

**synchrowave app ls**

Step 7. If this does not resolve the high CPU, restarting the platform on the affected node may resolve the problem:

**k3s-killall.sh**

**sudo systemctl start k3s**

APPENDIX C

# Creating SVG Diagrams

## Introduction

The One-Line Diagram Panel provides visualization of scalable vector graphics (SVG) drawings. SVG objects and data values can update based on real-time or historical data. This appendix describes the process of creating an SVG diagram and mapping SVG object states to measurement points.

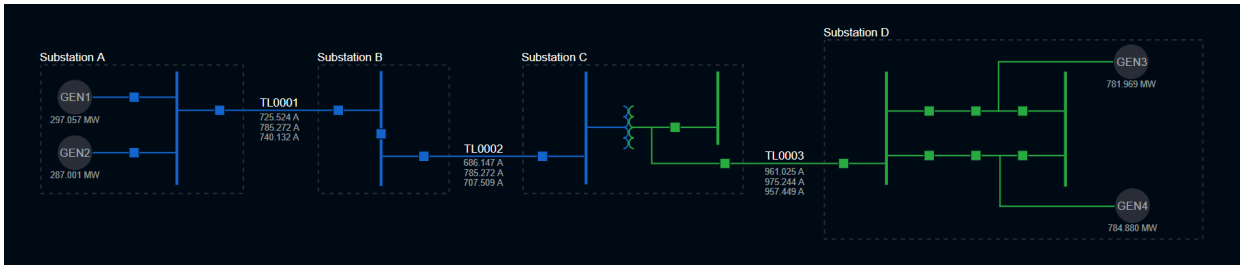



**Figure C.1 One-Line Diagram Panel Overview**

## Creating SVG Diagrams

### Install SVG Drawing Tool

The One-Line Diagram application in Synchrowave Operations uses SVG drawings. There are many good SVG drawing tools publicly available. Inkscape is a free open-source SVG editor and is used throughout this appendix to draw SVG diagrams for Synchrowave Operations. Inkscape provides many software tutorials.

### SVG Templates and Components

SEL has created a template SVG file that includes example bus, line, generator, and transformer SVG objects. This file is included in the default config.zip file for the One-Line Diagram Application. You can create new SVG diagrams more efficiently by copying these components. You can also create new SVG components to meet new use cases.

To create SVG diagrams using Inkscape that are consistent with the Synchrowave Operations style, copy the template and palette files (available upon request—contact SEL to have them sent to you) into the directories specified by Inkscape. To determine the correct directories, open Inkscape and go to Edit > Preferences > System. Look for the User templates and User palettes paths and create the directories if they do not already exist.

# Adding Attributes to SVG Objects

## Overview

To drive a state change (or other change) of an SVG object, you must add an attribute to the object that describes the conditions for the desired change. Use the XML editor in the SVG drawing tool to edit the XML text and apply the attribute to the SVG object. To add the attribute, select the object in the SVG editor and open the XML editor.

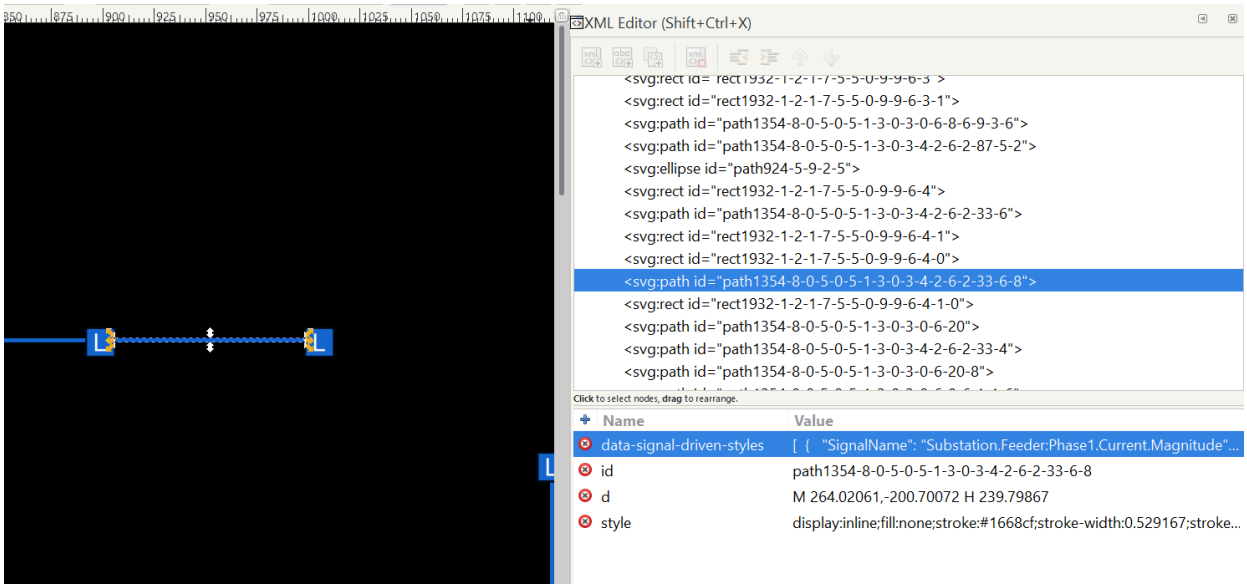



**Figure C.2 Adding an Attribute to an SVG Object**

## Changing the Color of an Object Based a Signals Value (Line, Bus, Transformer, etc.)

To change the color of an SVG object based on a signals value, add **data-signal-driven-styles** to the attribute in the Name field. Enter the text in *Figure C.3* into the Value field to have the object turn from white to blue when the current magnitude is greater than 30 A.

```
[
    {
       "SignalName":"Substation.Feeder:Phase1.Current.Magnitude",
       "ItemName":"stroke",
       "NoData":"var(--foreground-color-disabled)",
       "Setpoints":[
          {
             "Operation":"LT",
             "SignalValue":30,
             "ItemValue":"#ffffff"
          },
          {
             "Operation":"GTEQ",
             "SignalValue":30,
             "ItemValue":"#1668cf"
          }
       ]
    }
 ]
```

**Figure C.3 JSON for Changing Color of Feeder Object**

## Changing the Color of an Object Based a Signals State (Circuit Breaker, Recloser, etc.)

To change the color of an SVG object based on a signals state, add the **data-signal-driven-styles** to the attribute in the Name field. Enter the text in *Figure C.4* into the Value field to have the object turn from white to blue when the circuit breaker status is 1 (closed).

```
[
      {
         "SignalName":"Substation.Feeder:BreakerStatus",
         "ItemName":"fill",
         "NoData":"var(--foreground-color-disabled)",
         "Setpoints":[
            {
               "Operation":"LT",
               "SignalValue":0.5,
               "ItemValue":"#ffffff"
            },
            {
               "Operation":"GTEQ",
               "SignalValue":0.5,
               "ItemValue":"#1668cf"
            }
         ]
      }
   ]
```

**Figure C.4 JSON for Changing Color of Breaker Object**

## Changing Visibility of an Object Based a Signals State (Power Flow Arrow Direction, etc.)

To change the visibility of an SVG object based on a signals value, add **data-signal-driven-attribute** to the attribute in the Name field. Enter the text in *Figure C.5* or *Figure C.6* into the Value field to have the object turn from invisible to visible when the power across the line is in the positive direction.

```
[
      {
         "SignalName":"Substation.Line:ThreePhase.Power.Real",
         "ItemName":"display",
         "NoData":"block",
         "Setpoints":[
            {
               "Operation":"LT",
               "SignalValue":0,
               "ItemValue":"none"
            },
            {
               "Operation":"GTEQ",
               "SignalValue":0,
               "ItemValue":"block"
            }
         ]
      }
   ]
```

**Figure C.5 JSON for Right Power Flow Arrow**

```
[
       {
          "SignalName":"Test:ThreePhase.Power.Real",
          "ItemName":"display",
          "NoData":"none",
          "Setpoints":[
             {
                "Operation":"LT",
                "SignalValue":0,
                "ItemValue":"block"
             },
             {
                "Operation":"GTEQ",
                "SignalValue":0,
                "ItemValue":"none"
             }
          ]
       }
    ]
```

**Figure C.6 JSON for Left Power Flow Arrow**

# Update Text Value Based on Real-Time, Historic, Threshold, and/or Selection State

To display the textual value of a signal and include real-time, historic, threshold and selection state indications, add the attributes in *Figure C.7* through *Figure C.9* to the SVG text object.

```
data-measurement-point-name="Test">
   <tspan
      x="26.082621"
      y="45.531357"
      data-signal-data-and-units="Test:ThreePhase.Power.Real"
      data-alarm-selection-realtime-driven-style="
      [
          {
              "SignalName":"Test:ThreePhase.Power.Real",
              "ItemName":"fill",
              "Important":"true",
              "AlertValue":"var(--foreground-color-hover)",
              "WarningValue":"var(--foreground-color-hover)",
              "SelectionValue":"var(--foreground-color-hover)",
              "RealTimeValue":"var(--foreground-color)",
              "HistoricValue":"var(--foreground-color-historic)"
          }
      ]"
   >000.000 MW</tspan>
```

**Figure C.7 JSON for Signal Values and Threshold State (Alarm State)**

```
data-selection-driven-styles="
 [
    {
       "MeasurementPointName":"Test",
       "ItemName":"display",
       "TrueValue":"block",
       "FalseValue":"none"
    }
 ]"
```

**Figure C.8 JSON for Selection State—Top and Bottom Bar**

```
data-measurement-point-name="Test"
 data-alarm-selection-realtime-driven-styles="
 [
    {
       "SignalName":"Test:ThreePhase.Power.Real",
       "ItemName":"fill",
       "AlertValue":"var(--alert)",
       "WarningValue":"var(--warning)",
       "SelectionValue":"var(--background-color-focus-transparent)",
       "RealTimeValue":"transparent",
       "HistoricValue":"transparent"
    }
 ]"
```

**Figure C.9 JSON for Selection State—Threshold Region for Selection State**

This page intentionally left blank

APPENDIX D

# Installation Checklist

The following criteria should be met before installing Synchrowave Platform:

- SELinux
  - If your organization does not require SELinux, disable it by setting **SELINUX=disabled** in **/etc/selinux/config** and rebooting.
  - If your organization requires SELinux, the following setup is required:
    - Install the k3s-selinux policy on each node before installing k3s.
      - Download the latest stable policy for the appropriate OS version: https://github.com/k3s-io/k3s-selinux/releases
      - Install by running **rpm -i**
    - Install the Synchrowave SELinux policy on each node before installing Synchrowave.
      - The policy is distributed by SEL.
      - Install by running **rpm -i**
    - If using a file share (NFS or CIFS) for the data directory (multinode setup), add the following client mount option in **/etc/fstab** on each node: **context="system_u:object_r:container_file_t:s0"**
    - If using a local path for the data directory other than the default, add the **container_file_t** type to the data directory. For example, for a directory path **/data** this would be done as follows:
      - Update policy: **semanage fcontext -a -t container_file_t "/data(/.*)?"**
      - Restore tags from updated policy: **restorecon -R /data**
- Ensure /dev/log, the standard Unix socket for communicating with syslog, exists. It must be present on every standard out-of-the-box installation.
- Use only one single external-facing Ethernet interface on the server. If multiple exist, K3s does not know which to use. A simple work around is to disable the additional interfaces, install, and then re-enable the interfaces.
- Use static IPs for the primary interface in a multinode system.
- Ensure firewalld is configured on multinode setups. Any firewalls in use must allow the correct ports. See *Network Requirements on page 203* for the ports list.
- Regardless of hard drives partitions, dedicate at least 50 GB for /var/lib/rancher/k3s and 50 GB for /usr/local/synchrowave. If application data is left in the default location, the amount of space required for /usr/local/synchrowave is determined by how much data storage is desired.
- Permanently mount the NFS file system (/etc/fstab) before a multinode install.

- Mount the NFS file system with lookupcache=none.
- Ensure the subnet 10.43.* is not used by any server or client computers on the network. If needed, configure K3s to use a different subnet.

APPENDIX E

# Cybersecurity Features

## Introduction and Security Environment

### Product Function

Synchrowave Monitoring and Operations (hereafter, Synchrowave) software hosts web applications that store and visualize power system data. Other applications analyze the data and notify users of events.

### Security Requirements

Synchrowave is expected to be installed on secured servers with access restricted to administrators. The network storage (required for multi-node installations) is also expected to be secured with access restricted to administrators. Both the server and network storage should be isolated from the Internet.

## Version Information

### Obtaining Version Information

The Application Manager application in Synchrowave provides options for managing installed applications. The Application Manager displays installed applications' versions. The version of the platform can be found as the version of the Platform Services application.

## Commissioning and Decommissioning

### Commissioning

#### Synchrowave Windows Platform

A Windows service is created upon installation for orchestrating all the Synchrowave applications. The Windows service uses a virtual service account with the name "NT SERVICE\SEL Synchrowave" and has no credentials.

#### Synchrowave Linux Platform (Synchrowave Operations Only)

Installation requires root. See the Linux Software Installation section for details.

#### Data Storage

##### Sensitive Data Storage

Synchrowave encrypts all sensitive data (such as credentials and keys) at rest.

### General Data Storage

Synchrowave stores other non-sensitive data on a shared network file system for multi-node clusters or optionally on a node's local file system for a single node installation. The network file system should be placed in the same trust zone (within the same security perimeter) as the Synchrowave server nodes.

This data store includes:

- Application configuration data such as user preferences, dashboards, and notification data.
- Application binaries (executables and DLLs).
- Power system data such as voltage signals and derived signals.
- System logs.

Encryption at rest, if required, is configured at the file system level.

**SECURITY NOTE**
Permission to the shared network file system should be restricted to system administrators only. Administrators may enable encryption at the file system level for this network share.

## Secure Operation Recommendations

SEL recommends that administrators ensure the following:

- Servers used for hosting are dedicated solely to this purpose.
- Administrators are the only user with access to the Synchrowave servers.
- Authentication is enabled (see *Configuration of Authentication on page 19*).
- Authorization roles are configured.
- A trusted HTTPS certificate is configured (see *Configuration of HTTPS on page 17*).
- Only system administrators have access to the network shared file system.
- Servers are not connected to the internet.
- Synchrowave server(s) and file system are placed behind a firewall that only allows the minimum set of required ports.

## Decommissioning

A Synchrowave Linux installation can be decommissioned through the Synchrowave CLI command "system uninstall". This command preserves the k3s cluster and data stored on the network storage device.

A Synchrowave Windows installation can be decommissioned using Windows' Add/Remove program tool. This preserves stored data.

# External Interfaces

## Ports and Services

### Logical Ports

Synchrowave accepts connection over HTTPS (443) and HTTP (80 redirected to HTTPS). For a complete list of ports that may be opened depending on installed applications, see *Network Requirements on page 203*.

### Application Interfaces

Please contact SEL support for details on accessing application interfaces.

## File System Interfaces

Synchrowave creates an application directory with sub-directories for data, configuration, logs, and application images. Default locations are /usr/local/synchrowave/app for Linux and C:\ProgramData\SEL\Synchrowave for Windows (both locations are user-configurable).

# Access Controls

## Privilege Levels

Role-based access control (RBAC) is used to manage access to Synchrowave with predefined roles and capabilities. See *Adding/Removing Users on page 20* for details on user roles.

## Centrally Managed Accounts

Synchrowave authenticates all incoming web traffic via connection to an Active Directory server (LDAP over TLS). Synchrowave uses JSON Web Tokens (JWTs) for web application session management.

**SECURITY NOTE**
The connection to LDAP and list of authorized users and roles must be configured after Synchrowave installation.

## Local Accounts

Synchrowave does not support local accounts.

## X.509 Certificates

Synchrowave uses X.509 certificates for establishing trust for HTTPS and LDAP protocols. The certificates generated by default use the following certificate parameters:

- 4096-bit RSA
- SHA256 Hash Algorithm
- Pkcs1 Padding

**SECURITY NOTE**
A default HTTPS certificate is generated upon initial startup of the system. This certificate must be explicitly trusted by clients, or the certificate must be replaced by one issued by a trusted certificate authority.

# Logging

## Security Events

Synchrowave has two types of security events that can appear in the logs:

- Security Alert—Information alerting of potential security concerns.
  - Examples: login failure, unauthorized access attempts, invalid session token detection.
- Security—Information relating to security.
  - Examples: user logging in, user logging out.

The logs can be viewed from the System Manager page.

## Internal Log Storage

Synchrowave stores logs for 90 days. Logs older than 90 days are deleted.

## Syslog

Synchrowave provides the option in the Platform Services application to direct all logs generated by Synchrowave to syslog.

# Backup and Restore

See *Synchrowave Platform Backup Procedure on page 213*.

# Malware Protection Features

Synchrowave installers are digitally signed by SEL. Linux installers can be verified as authentic using SHA-256 hash values available from SEL. Installers should be verified as authentic. All Synchrowave applications are signed by SEL and Synchrowave verifies their signatures when they are installed.

# Product Updates

Release notes for Synchrowave can be found in *Appendix A: Software and Manual Versions*. Information about the SEL process for disclosing security vulnerabilities can be found at https://selinc.com/security_vulnerabilities/.

## Obtaining Updates

The latest software version can be found at https://selinc.com/products/software/latest-software-versions/. To obtain the latest software, contact SEL.

## Update Verification

Synchrowave installers are digitally signed by SEL. Linux installers can be verified as authentic using SHA-256 hash values available from SEL. Installers should be verified as authentic. All Synchrowave applications are signed by SEL and Synchrowave verifies their signatures when they are installed.

# Contact SEL

For further questions or concerns about product security, contact SEL at security@selinc.com or +1.509.332.1890.

This page intentionally left blank