# Synchrowave Monitoring

## Instruction Manual

20250221

SEL SCHWEITZER ENGINEERING LABORATORIES

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SECTION 1

# Introduction

Synchrowave® Monitoring provides visualization, analysis, and archiving of power system data. Synchrowave Monitoring is comprised of a suite of applications running on the Synchrowave Platform.

## Feature Highlights

**Disturbance Monitoring.** Analyze archived synchrophasor data and relay event reports together in one a common dashboard for a completed disturbance monitoring solution. Easily find system disturbances, and export data to CSV and COMTRADE data formats for NERC PRC-002-2 compliance.

**Renewable Energy Monitoring.** Understand how the increasing amount of renewable energy being added to your grid impacts system stability. System dynamics from these generation sources change quickly—too fast to see at traditional SCADA rates. Use high-resolution displays in Synchrowave Monitoring for detection and tracking of the impact of renewables on your system.

**Dashboard Visualization.** 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.

## Functional Overview

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

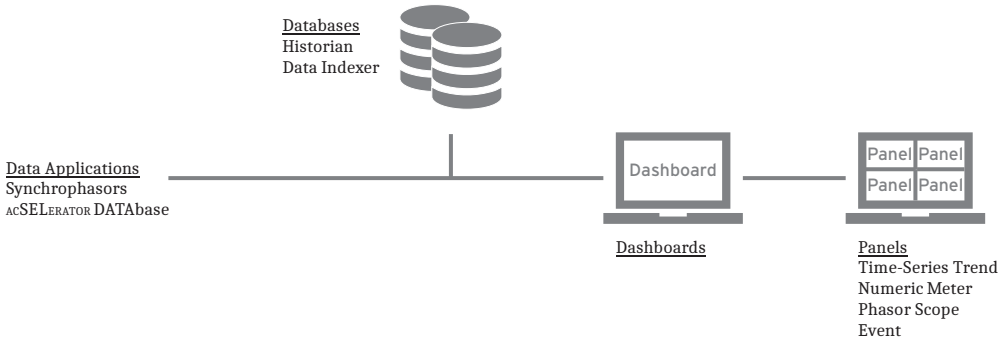


**Figure 1.1 Synchrowave Monitoring and Platform Functional Diagram**

# Applications

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

*Table 1.1* through *Table 1.4* 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 1.4* are part of the software infrastructure, they are all visible and listed.

**Table 1.1 Synchrowave Monitoring 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. |

**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 Panel Application Highlights**

| Applications | Key Features |
|---|---|
| Numeric Panel | Provides a display of numeric values in dashboards. |
| Time-Series Trend Panel | Provides a display of time-series data 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. |

**Table 1.4 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. |
| IEEE C37.118 Reader | Reads from IEEE C37.118 synchrophasor streams and publishes signals to the platform for visualization and archiving. |
| 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. |
| Data Export | Downloads selected data directly from web-client display in CSV and COMTRADE format. |
| Power Calculation | Calculates real, reactive, and apparent power. |

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.
- Modern HTML5 based server/web-client architecture.
- Power system insight through real-time analytics of high-resolution time-series sensor data.

## Platform Technology Overview

### 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.

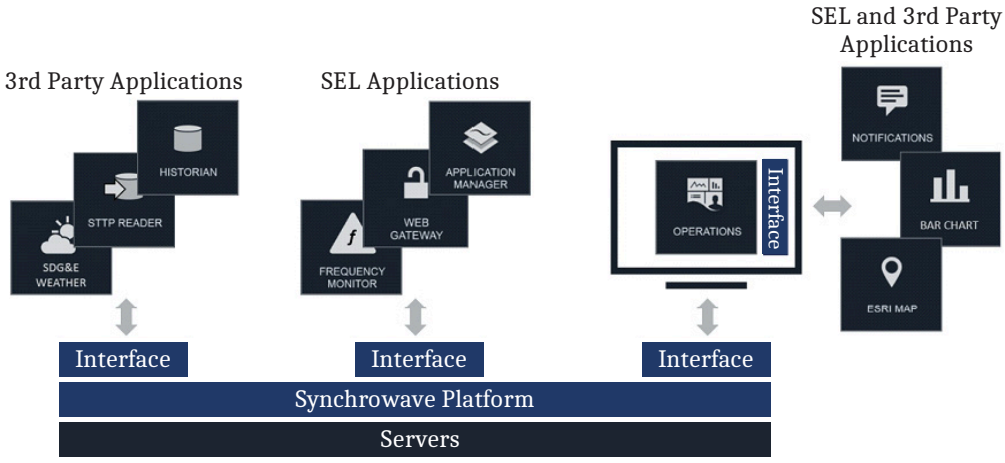


**Figure 2.1 Synchrowave Platform Diagram**

### 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 2.2 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 2.3* shows a growing oscillation captured from a PMU at a wind farm, which went undetected by traditional SCADA measurements.

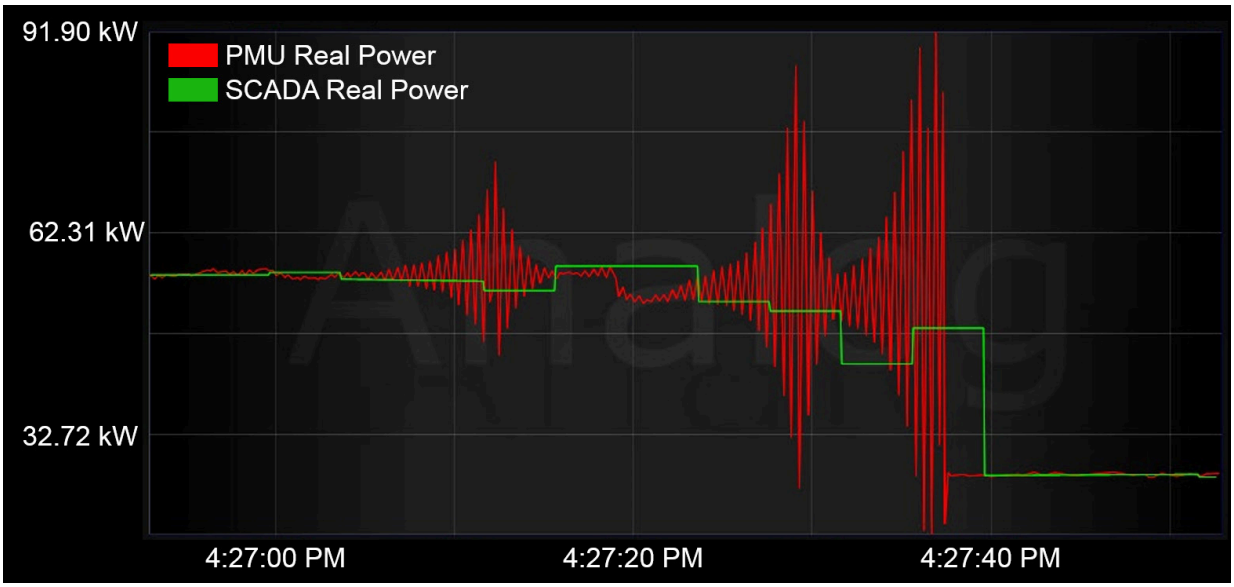


**Figure 2.3 PMU Measurements Compared to SCADA**

# 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.

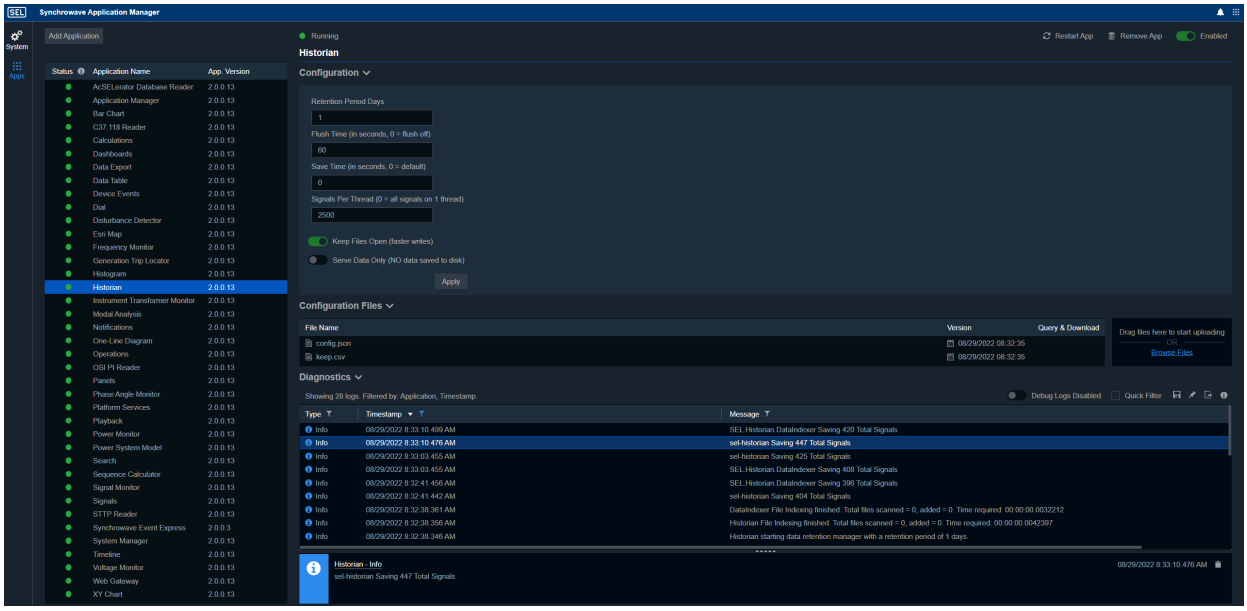


**Figure 2.4 Application Manager**

The Application Manager is accessed through the platform navigation menu.

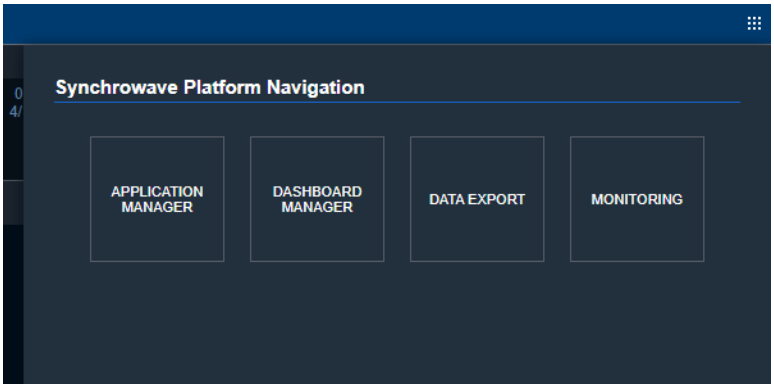


**Figure 2.5 Application Manager in Platform Navigation Menu**

# 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.

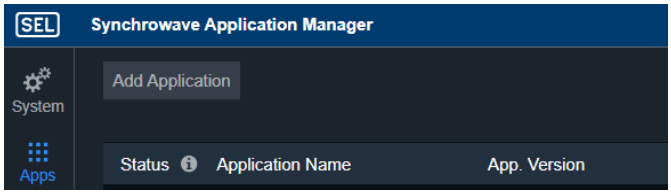


**Figure 2.6 Add Application**

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 2.7 Application Menu**

Access the status definitions shown in *Figure 2.8* by hovering over the Status Information Icon. Additional information regarding the reason for the status may be found in the Application Diagnostic logs.

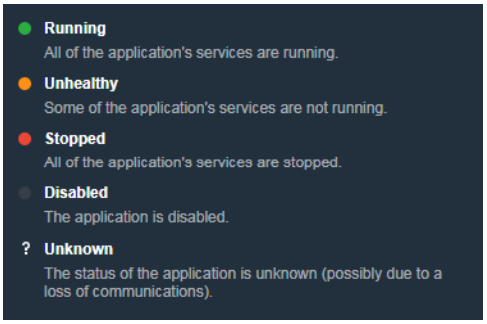


**Figure 2.8 Application Status**

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

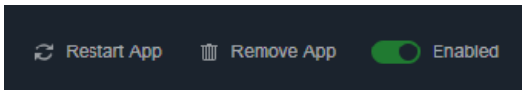


**Figure 2.9 Application Management**

# 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.

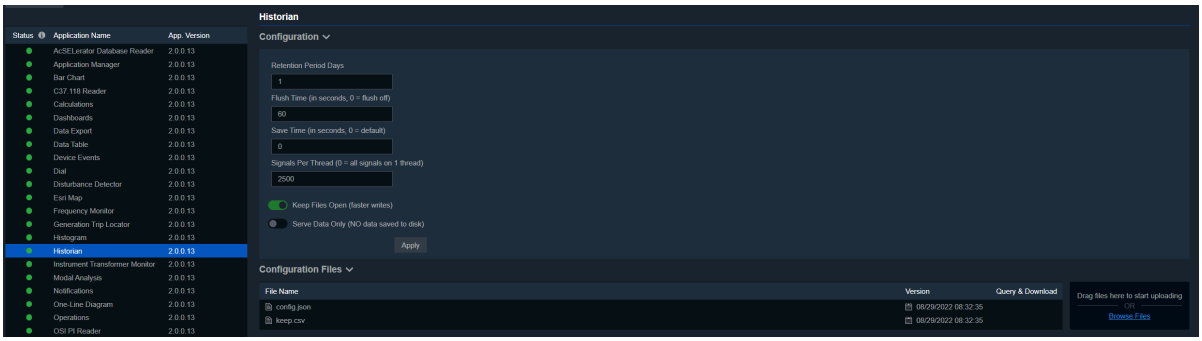


**Figure 2.10 Application Configuration**

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).

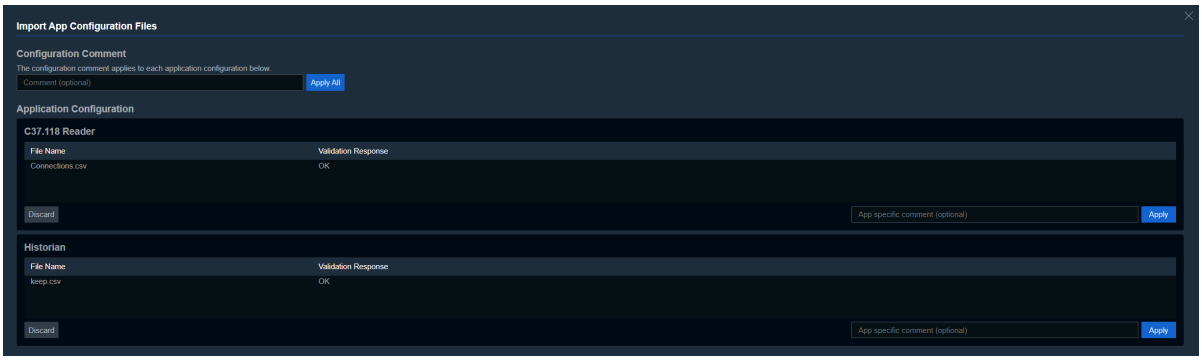


**Figure 2.11 Application Configuration Import Dialog Box**

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.

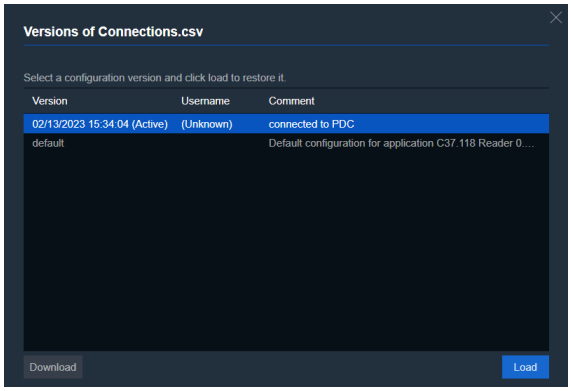


**Figure 2.12 Application Configuration History**

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 2.13*.

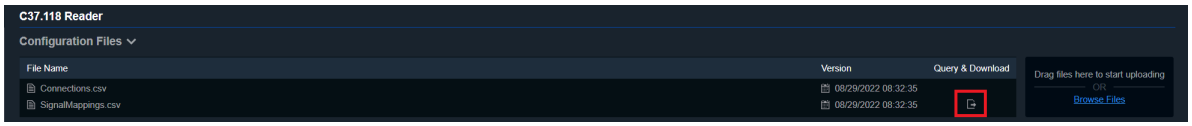


**Figure 2.13 Configuration Query and Download**

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.

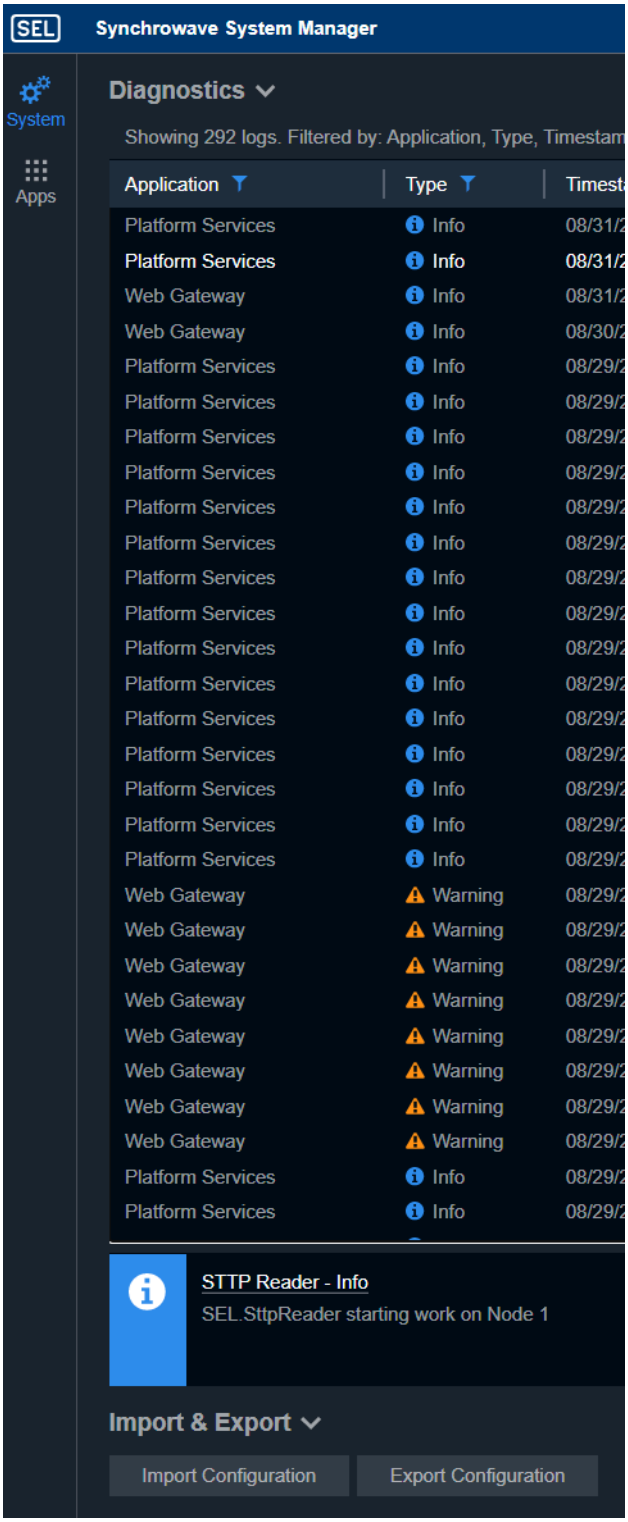


**Figure 2.14 Alternate Configuration Import and Export**

# 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.

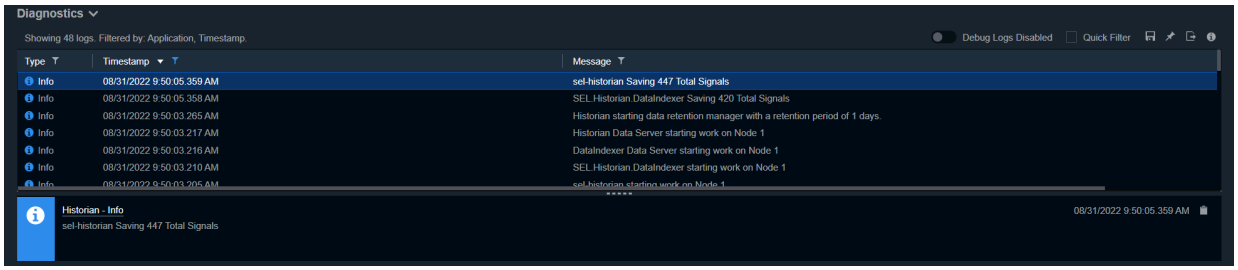


**Figure 2.15 Diagnostic Logs**

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.

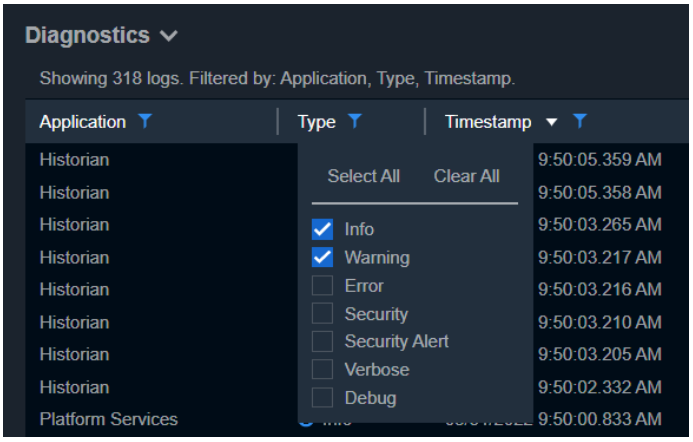


**Figure 2.16 Filtering Diagnostic Log Columns**

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.

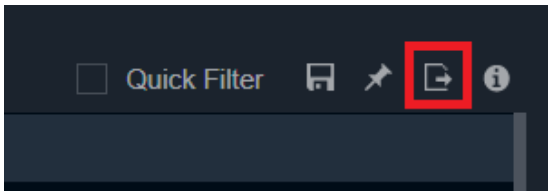


**Figure 2.17 Export Diagnostic Logs to CSV File**

# 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, external file system, and licensing.

The Platform Services configuration allows configuration of the Application Data Directory, Licensing (see *Appendix C: Synchrowave Monitoring Licensing*), and a custom Banner. The Banner appears at the top center of any Synchrowave Monitoring page. Once the desired banner is entered, select the **Apply** button. Optionally, include a comment describing the configuration change. Once **Apply** has been pressed, the comment will be stored in the configuration history of the config.json file.

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

The Application Data Directory is set to the local drive by default. It can also be set to a different folder (on a different drive, for example) or to an external network file system. When using an external network file system, the credentials for file system access are set in the Network Drive Access section.

**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.

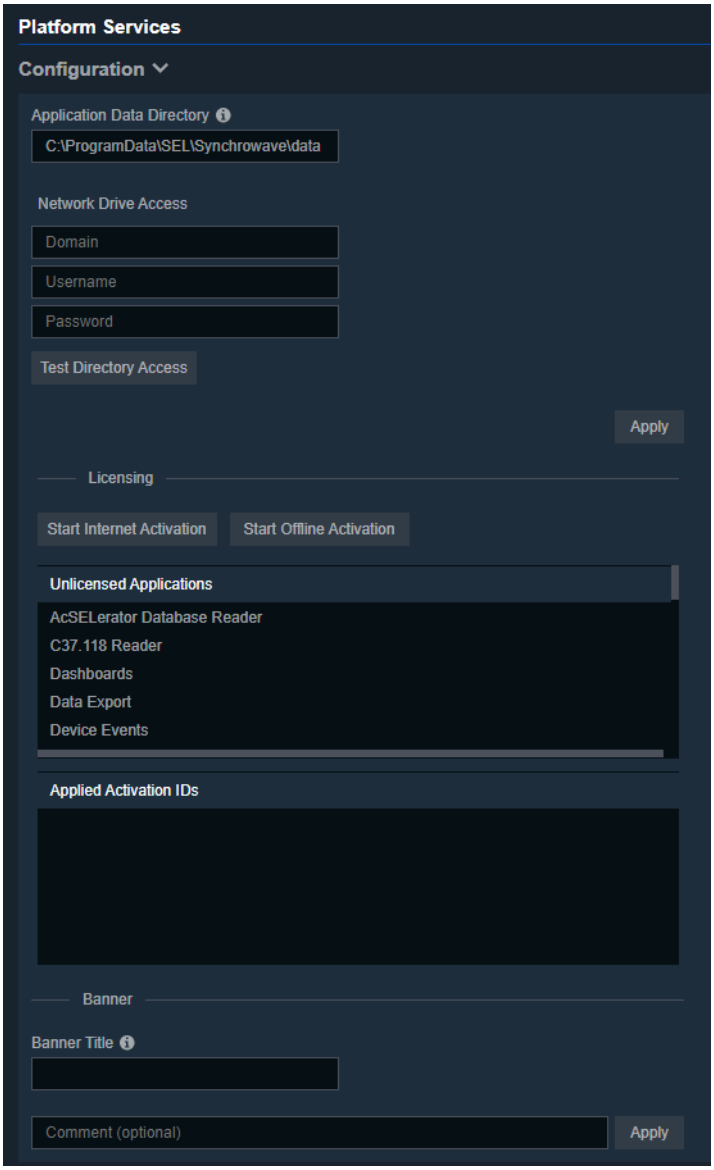


**Figure 2.18 Platform Services Configuration**

# 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.

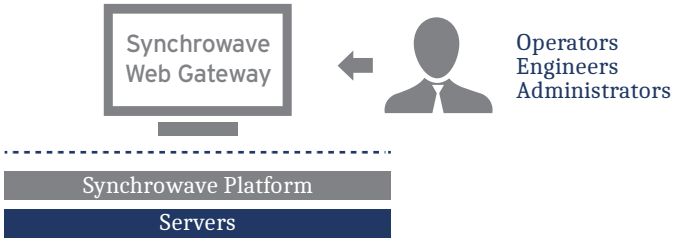


**Figure 2.19 Web Gateway Overview**

# 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.

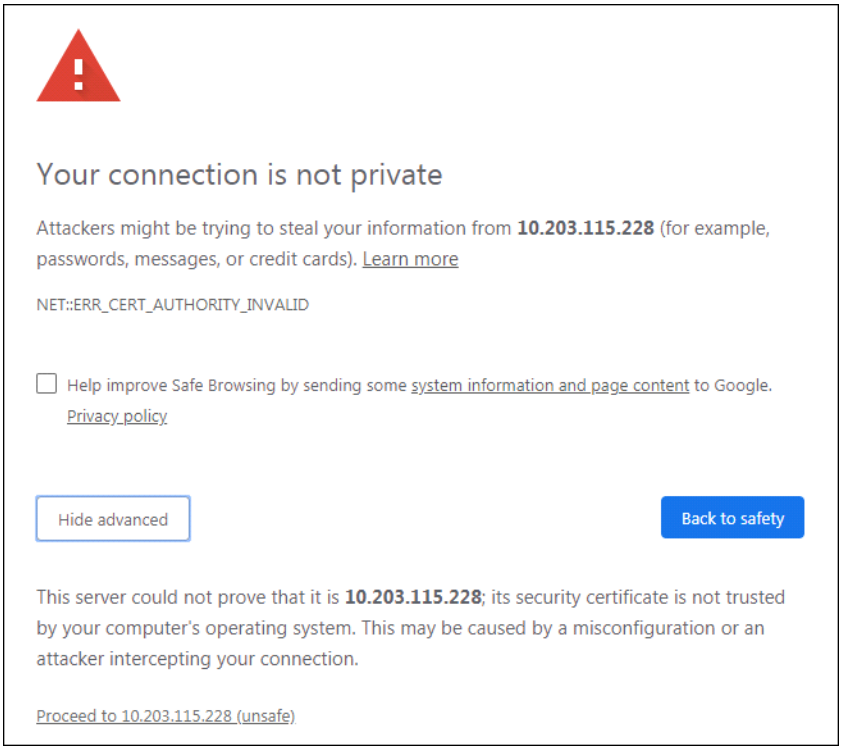


**Figure 2.20 Web Browser Not Secure Warning**

The configuration for the Web Gateway application provides two methods for uploading a signed HTTPS certificate, as shown in *Figure 2.21*. 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.

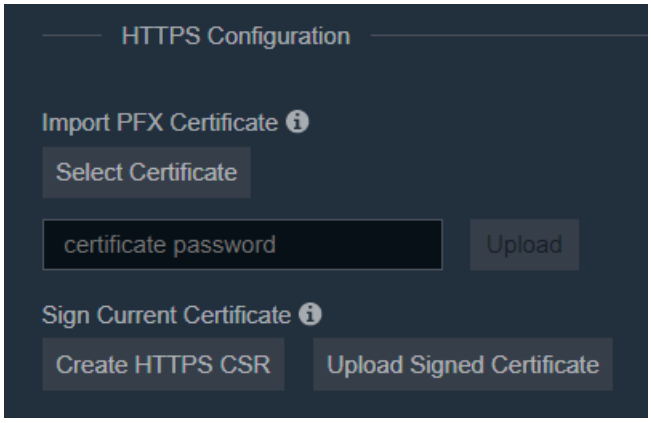


**Figure 2.21 HTTPS Configuration**

Alternatively, the **Create HTTPS CSR** button opens a dialog (as shown in *Figure 2.22*) 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.

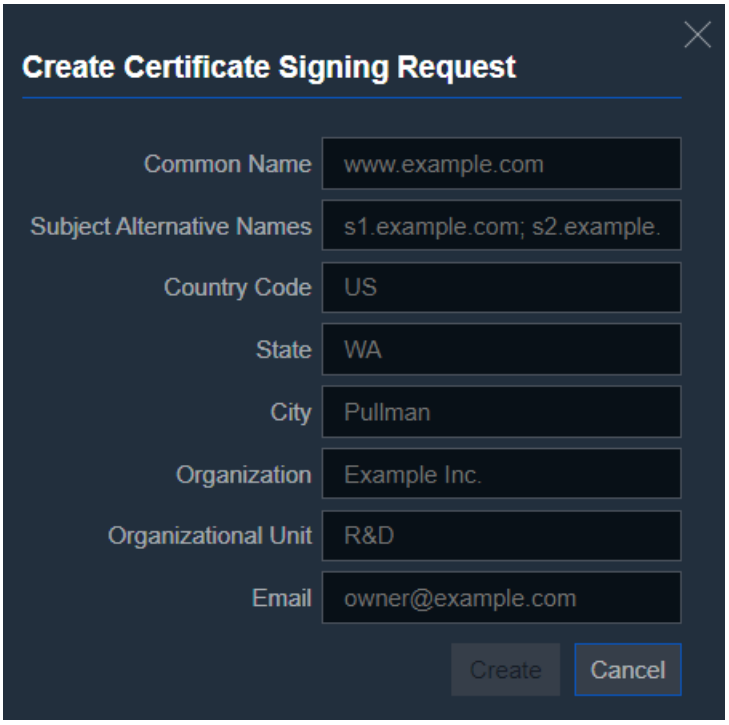


**Figure 2.22 CSR Dialog**

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

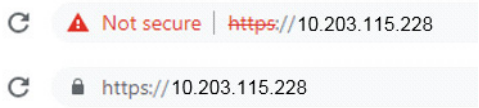


**Figure 2.23 Web-Client HTTPS Status Indication**

# 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.

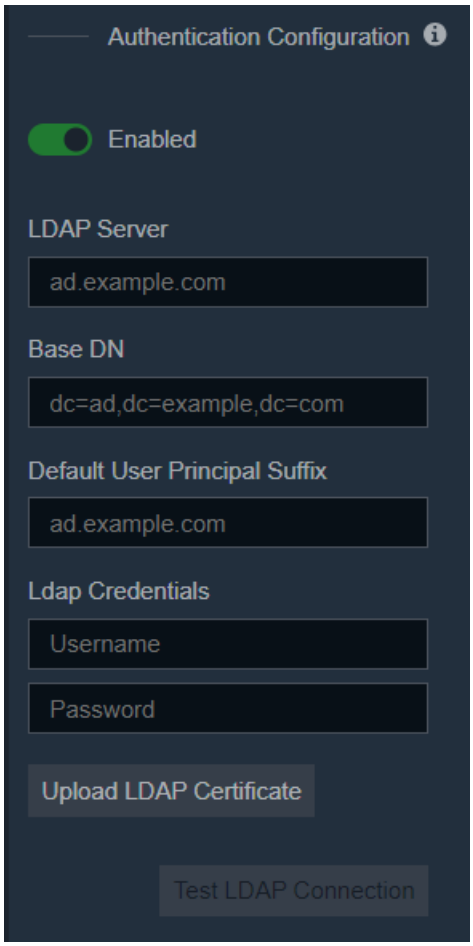


**Figure 2.24 LDAP Server Connection Setup**

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.

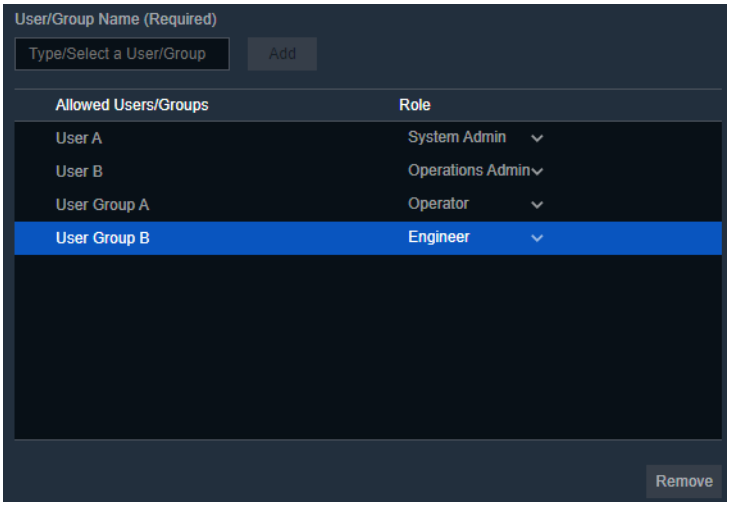


**Figure 2.25 Adding/Removing Users and User Groups**

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.

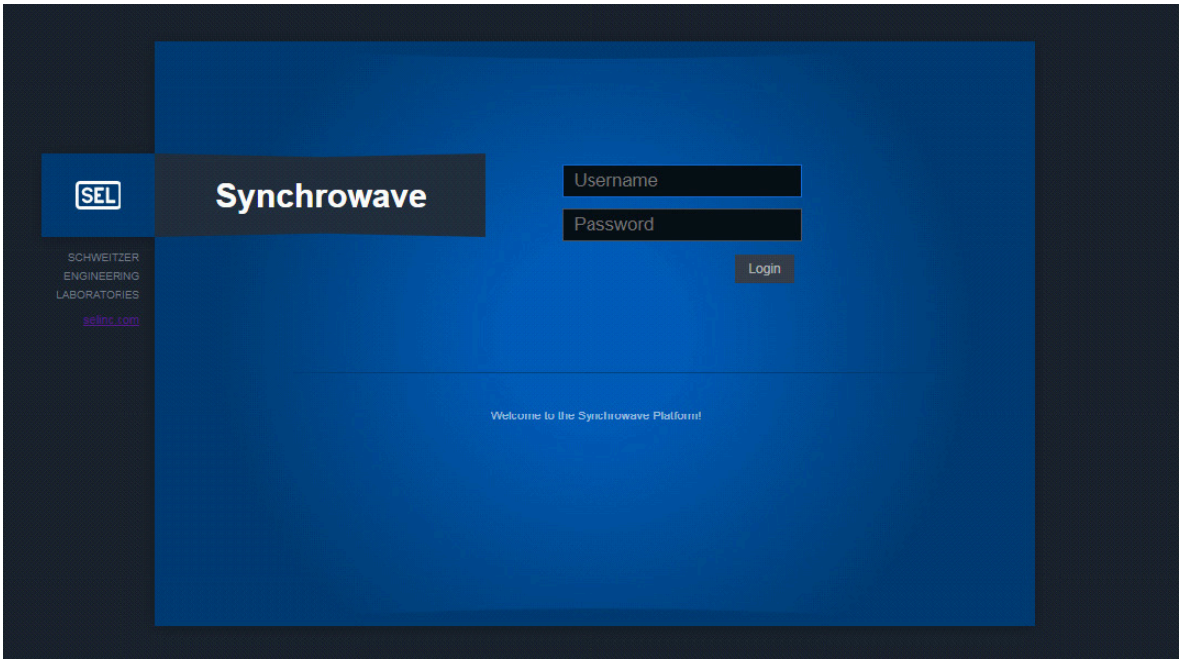


**Figure 2.26 Synchrowave Platform Login Page**

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.

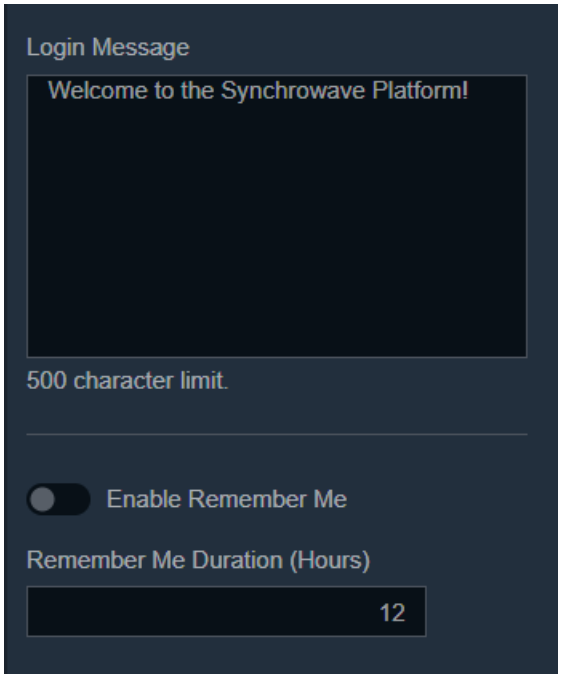


**Figure 2.27 Login Message and Enable Remember Me**

## 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.

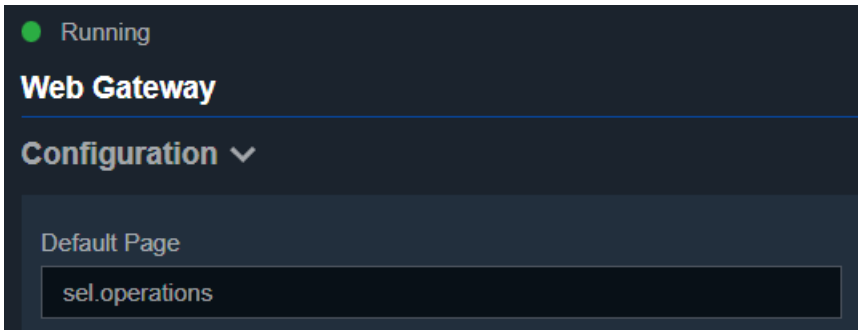


**Figure 2.28 Configuration of Default Application Page**

# 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.

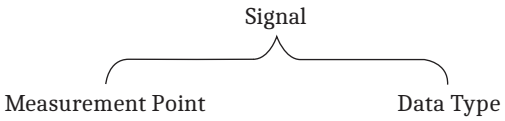


**Figure 2.29 Signal Definition**

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.

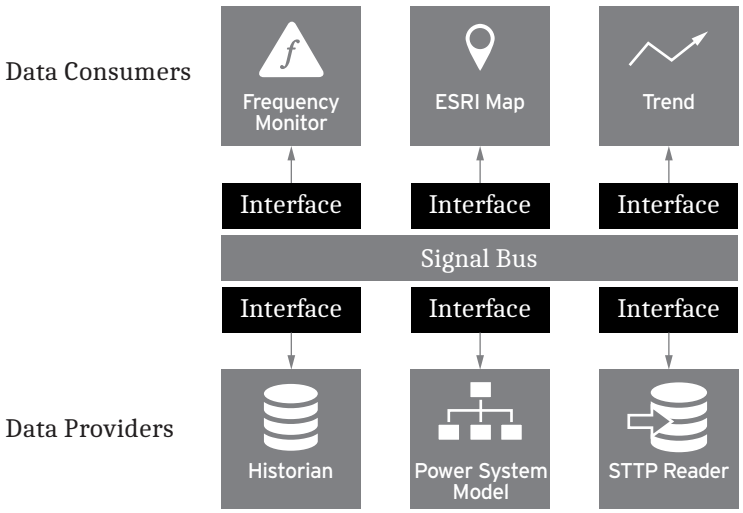


**Figure 2.30 Signal Bus Overview**

## 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.

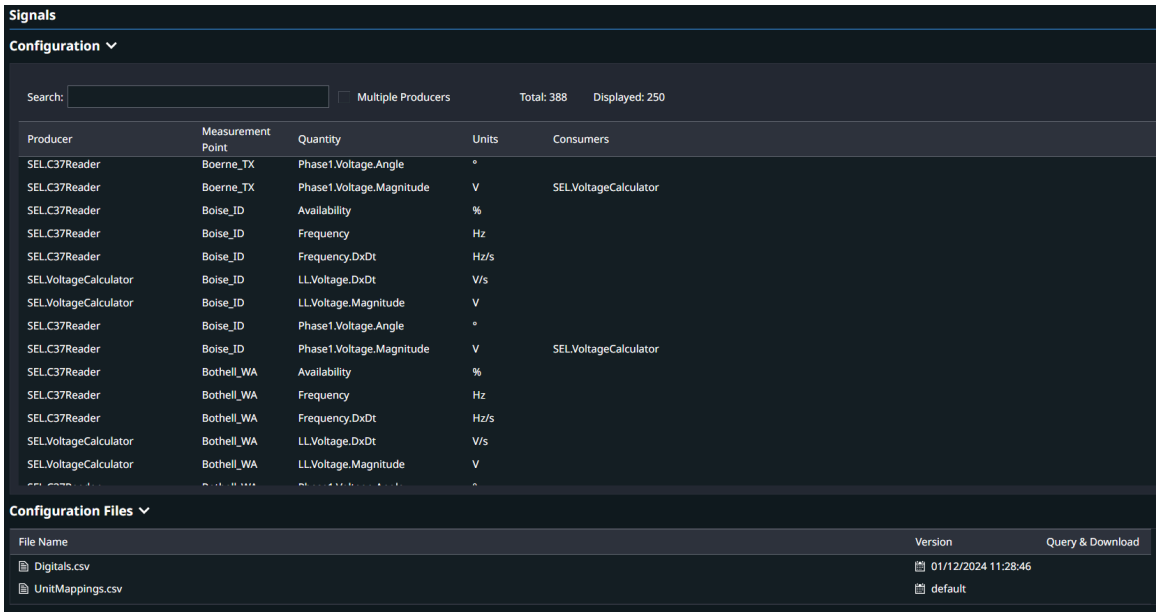


**Figure 2.31 Signals Application**

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 2.32*.

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

**Figure 2.32 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 2.33 Digital Signals Configuration File**

SECTION 3

# Synchrowave Monitoring

## Introduction

Synchrowave Monitoring provides visualization, analysis, and archiving of power system data. The applications listed in this section provide the base functionality for Synchrowave Monitoring.

## Software User Interface 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 3.1 Software User Interface—Timeline Application**

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

## Dashboard Application Overview

Dashboards provide the primary visualization of power system data and information in Synchrowave Monitoring. 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.

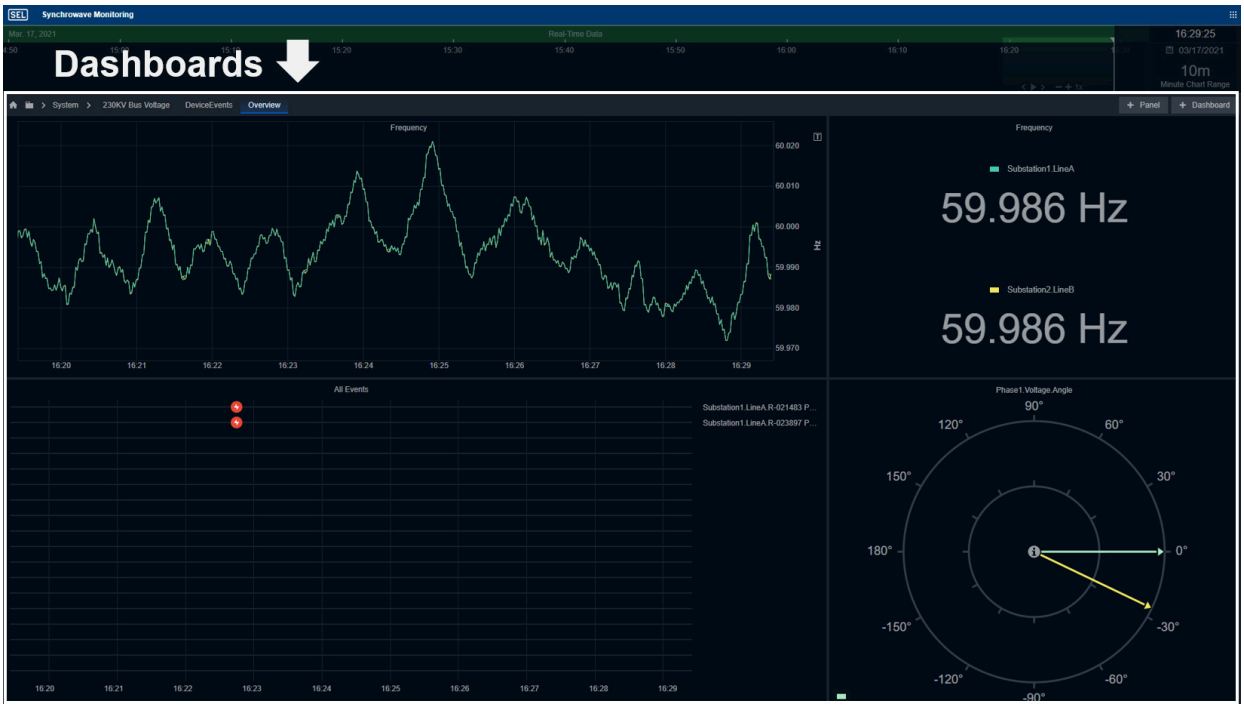


**Figure 3.2 Software User Interface—Dashboards and Dashboard Navigation**

# 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.

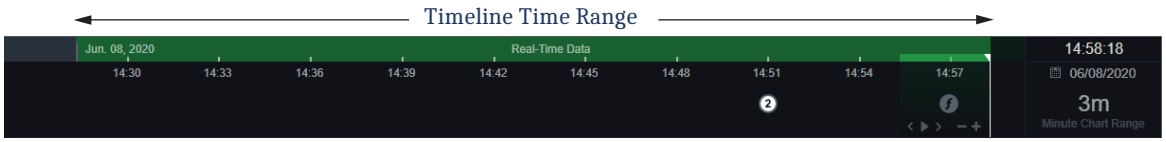


**Figure 3.3 Timeline Time Range**

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.

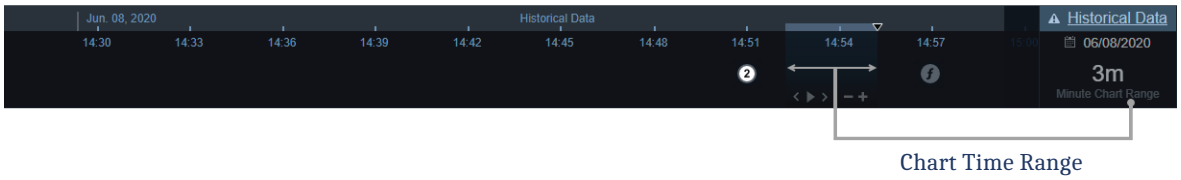


**Figure 3.4 Timeline Chart Time Range**

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.

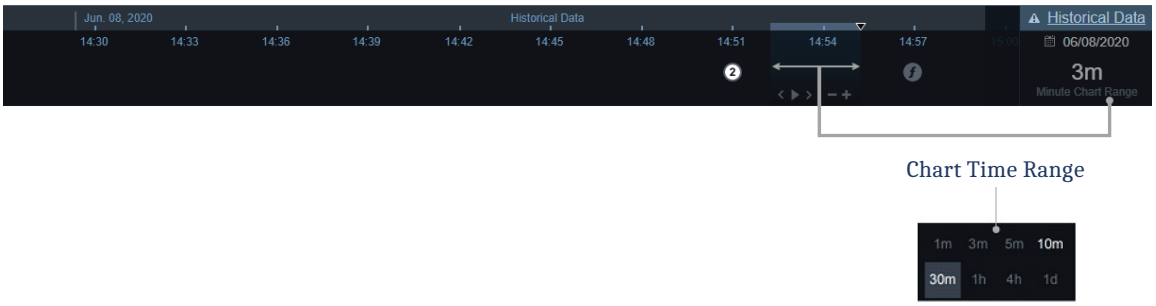


**Figure 3.5 Timeline Chart Time Range Default Values**

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 3.6*, the cursor is at the right edge of the chart time range and indicates the most recent data within that range.

**Figure 3.6 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."

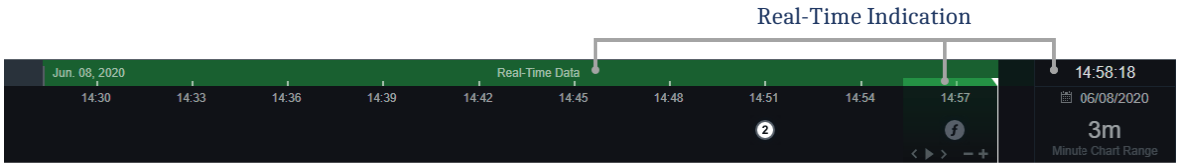


**Figure 3.7 Timeline Real-Time Mode Indication**

**Figure 3.8 Timeline Historic Mode Indication**

The calendar icon (see *Figure 3.9*) in the time control provides the ability to navigate the software to any date in history for analysis of historic conditions.

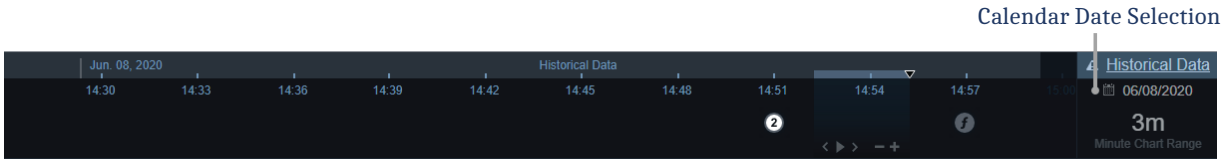


**Figure 3.9 Timeline Calendar Date Selection**

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.

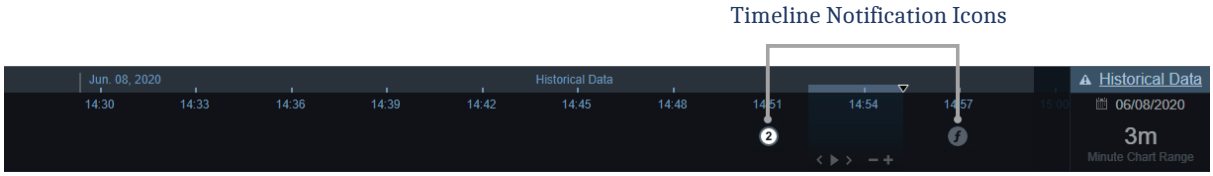


**Figure 3.10 Timeline Notification Icons**

# 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.

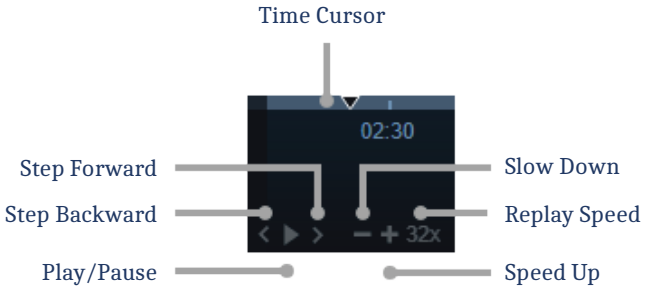


**Figure 3.11 Timeline Replay Controller**

# 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 users need to efficiently analyze the power system is always available.

## System Monitoring

Dashboards provide operators visibility across the entire power system for operators use cases such as system frequency, phase angle stress, and voltage monitoring.

**Figure 3.12 System Monitoring 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 3.13 Dashboard Navigation Toolbar**

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

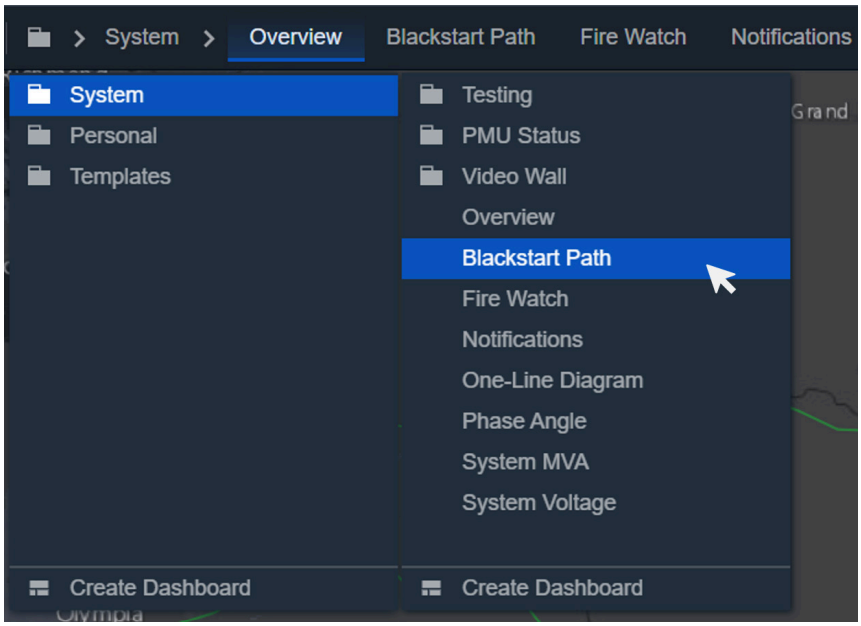


**Figure 3.14 Dashboard Navigation Menu**

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.

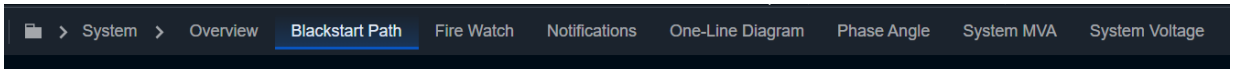


**Figure 3.15 Dashboard Navigation Path**

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.

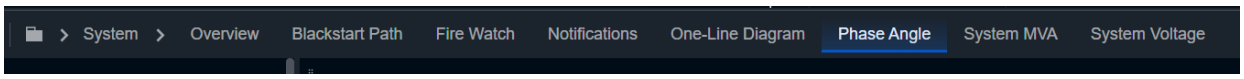


**Figure 3.16 Navigating to Dashboards in the Same Folder**

## 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 3.17 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.

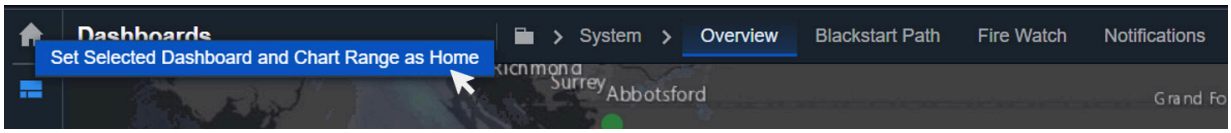


**Figure 3.18 Setting the Home Dashboard**

## 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.

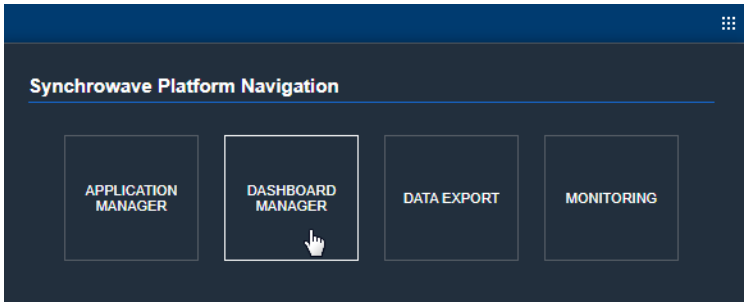


**Figure 3.19 Dashboard Manager in Platform Navigation Menu**

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

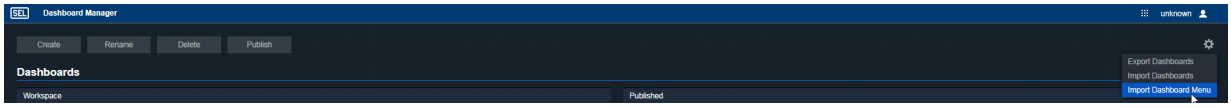


**Figure 3.20 Importing Dashboard Folder Path**

The dashboard folder path can be created or modified using a text editor. The folder structure is built by using forward slashes. Upon importing the Dashboard menu text file, users create dashboards for each folder through the Synchrowave Monitoring user interface.

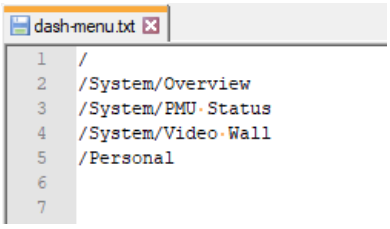


**Figure 3.21 Example Dashboard Folder Path File**

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 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.

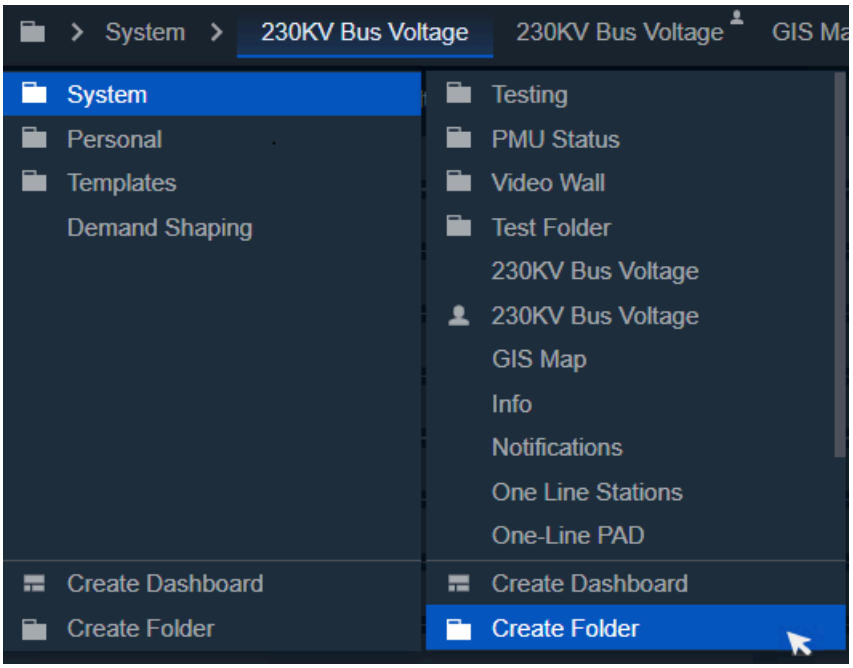


**Figure 3.22 Creating a Dashboard Navigation Folder**

# 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.

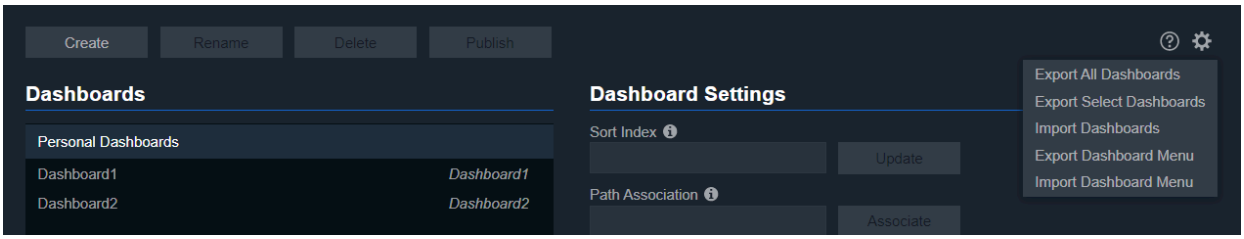


**Figure 3.23 Importing and Exporting Dashboards**

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.

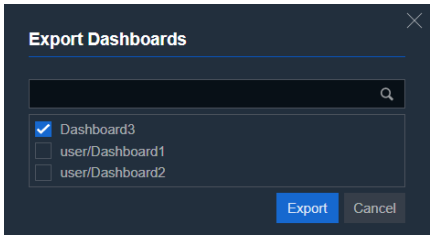


**Figure 3.24 Export Select Dashboards**

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.

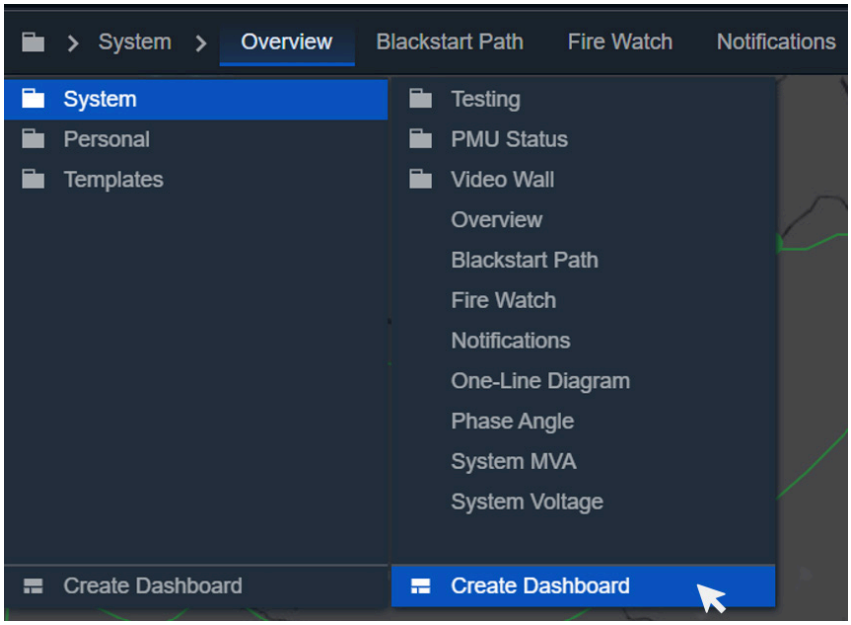


**Figure 3.25 Creating a Dashboard**

Enter a display name for the Dashboard.

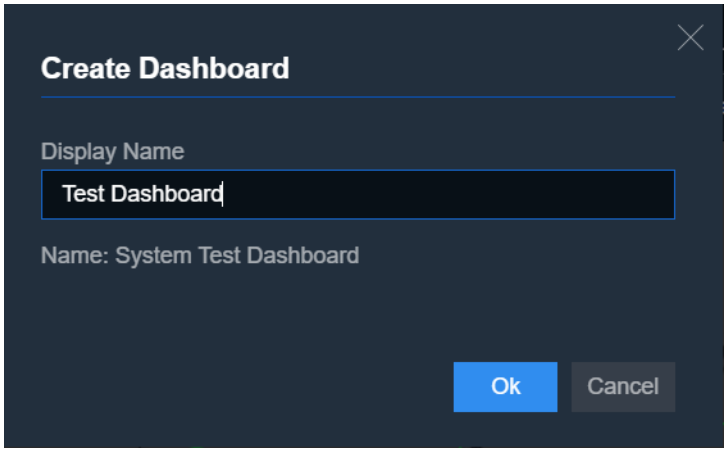


**Figure 3.26 Naming a Dashboard**

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 34* 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.

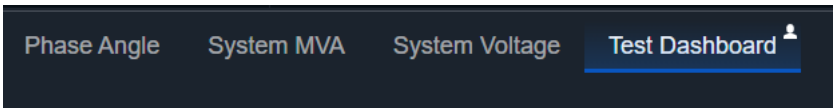


**Figure 3.27 Private User Dashboard Indication**

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 34*.
- **Rename** dashboard. (Private user dashboard only. Published dashboards can only be renamed from Dashboard Manager.) See *Publishing Dashboards on page 34*.
- 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 34*.

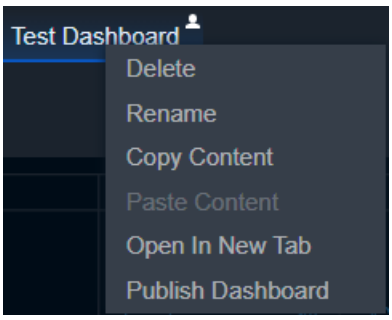


**Figure 3.28 Dashboard Options Menu**

# 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.

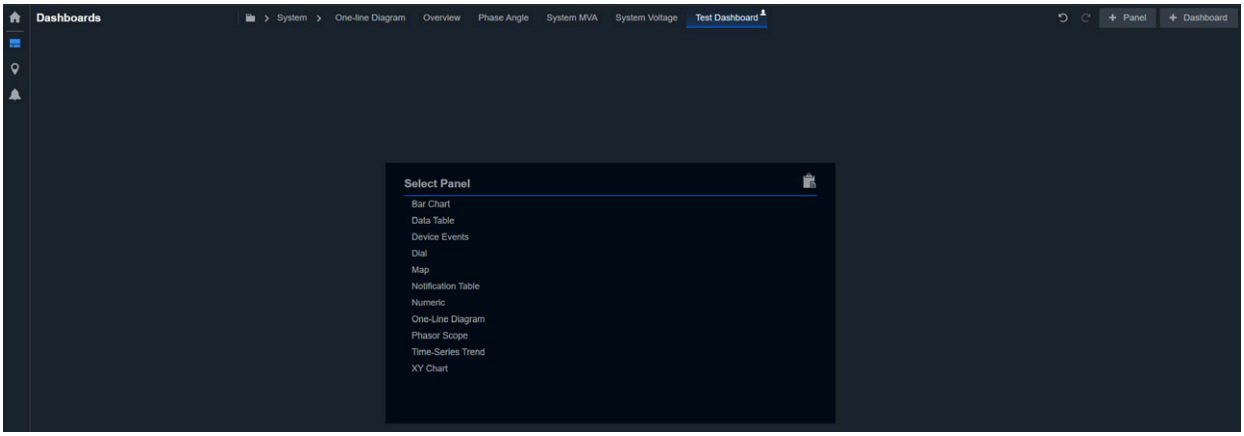


**Figure 3.29 Adding Dashboard Panel**

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.

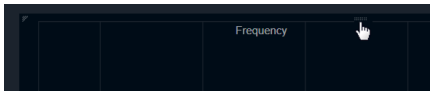


**Figure 3.30 Rearranging Dashboard Panels**

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 3.31 Resizing Dashboard Panels**

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

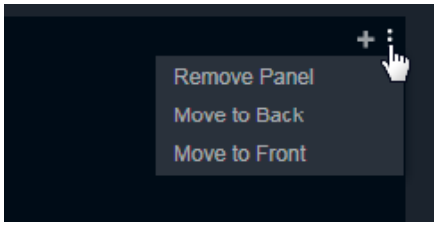


**Figure 3.32 Dashboard Panel Options**

Configure panels by selecting **Edit Panel** in the top right corner of each panel. See *Dashboards Application on page 27* for details regarding configuration for each panel type.

**Figure 3.33 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).

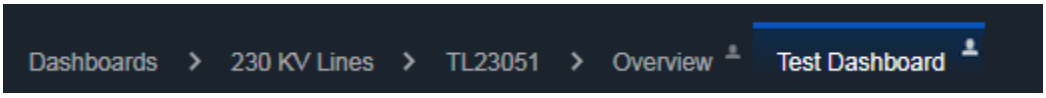


**Figure 3.34 User Dashboard Indication**

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).

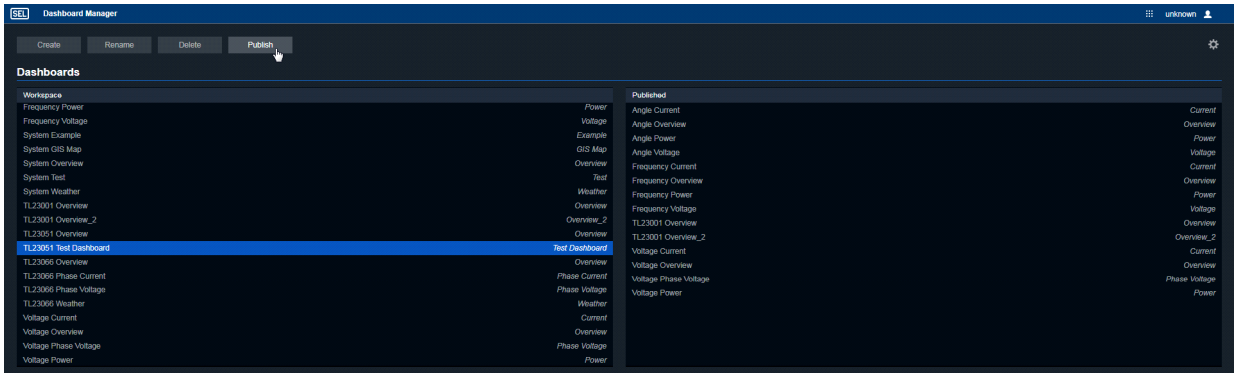


**Figure 3.35 Publishing Dashboards**

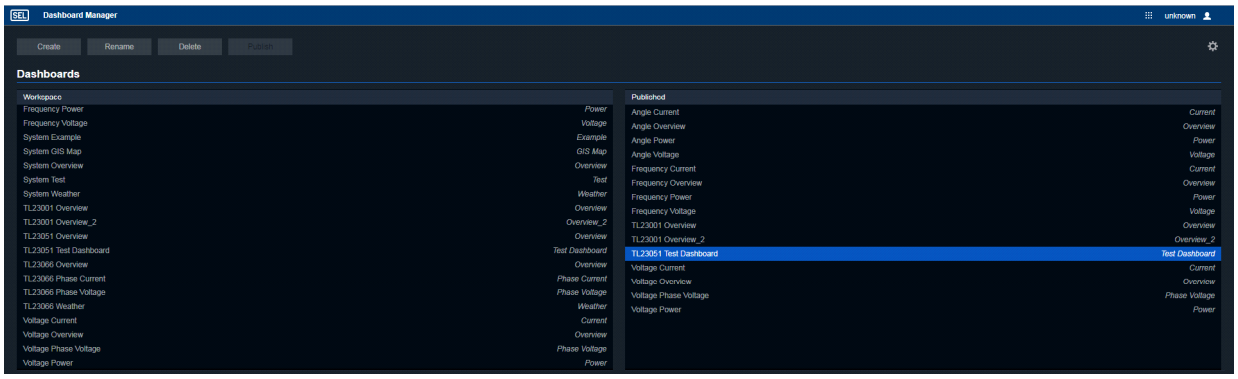


**Figure 3.36 Navigating Published Dashboards**

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.

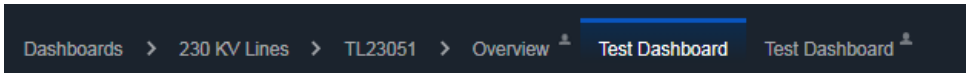


**Figure 3.37 Published Dashboard Indication**

*Figure 3.38* shows the published dashboards visible to other users for the TL23051 Asset in the Dashboard Navigation toolbar.

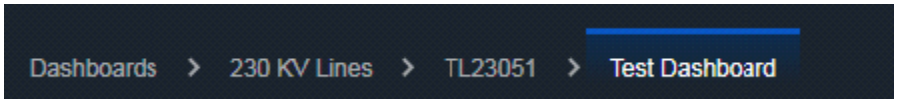


**Figure 3.38 Dashboard Navigation Toolbar for Other Users**

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.

# 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.

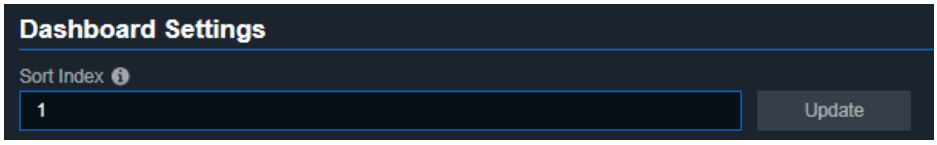


**Figure 3.39 Changing the Dashboard Display Order**

# Changing Dashboard Theme

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

**Figure 3.40 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.

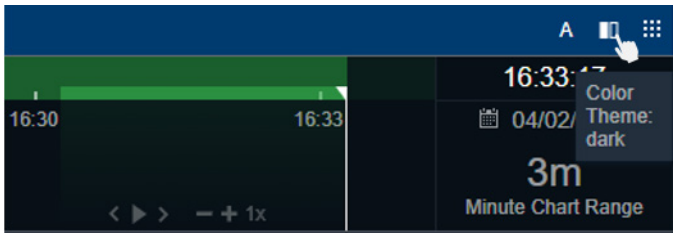


**Figure 3.41 Theme Toggle Button**

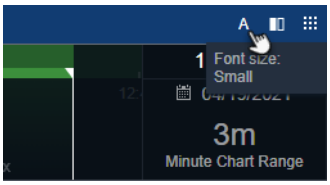


**Figure 3.42 Theme Font Size**

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SECTION 4

# Applications

## 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 24* 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.

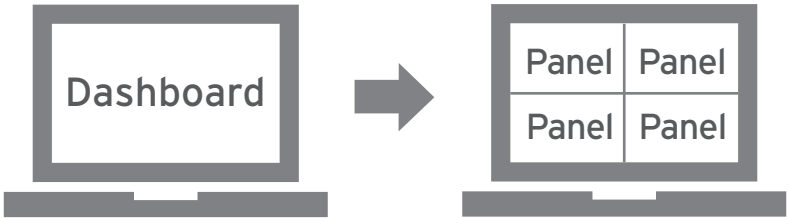


**Figure 4.1 Dashboard Panel Overview**

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

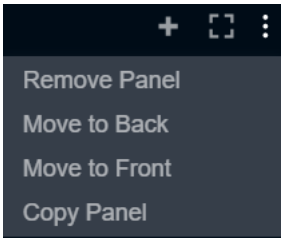


**Figure 4.2 Selecting Copy Panel**

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

**Figure 4.3 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.

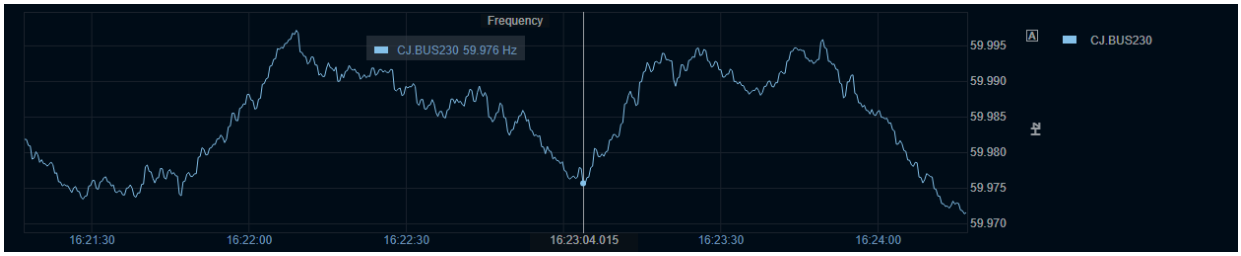


**Figure 4.4 Time-Series Trend Panel Overview**

## 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 56* 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 91* 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 4.5 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).

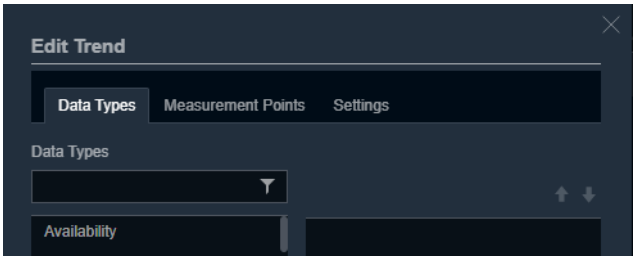


**Figure 4.6 Edit Data Type**

## 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.

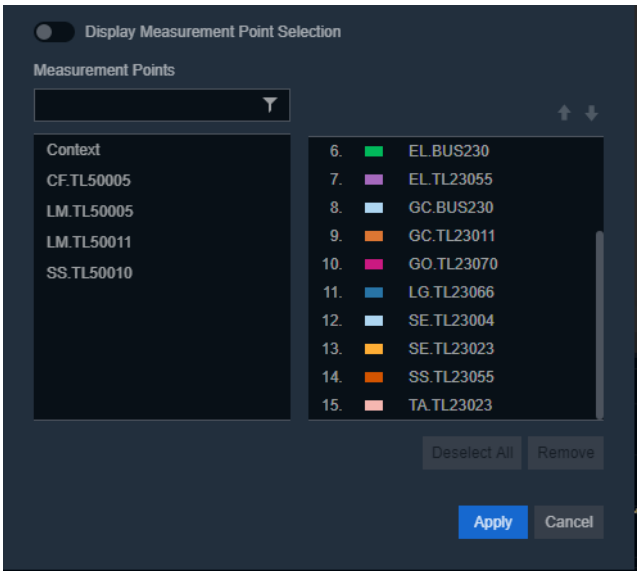


**Figure 4.7 Add/Remove Measurement Points From Time-Series Trend**

## 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.

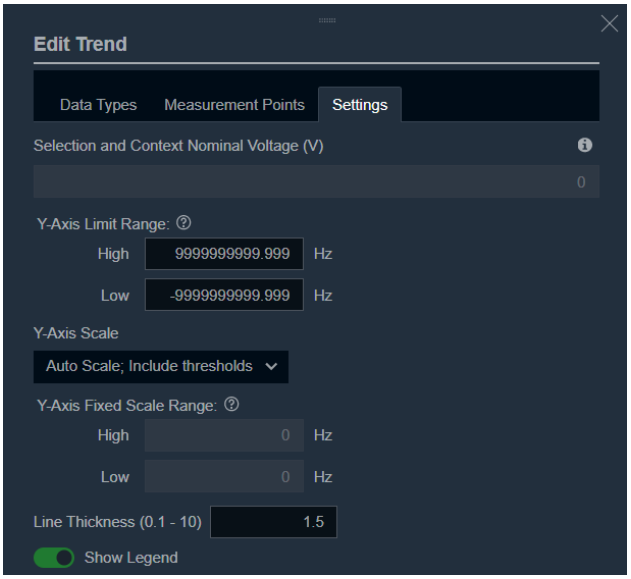


**Figure 4.8 Setting Up Default Time-Series Trend**

# Phasor Scope Panel Application

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

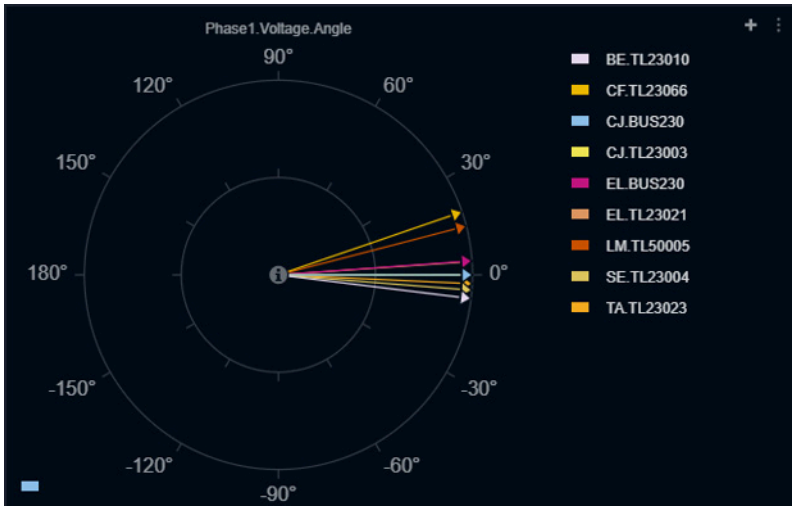


**Figure 4.9 Phasor Scope Panel Overview**

# 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 4.10 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.

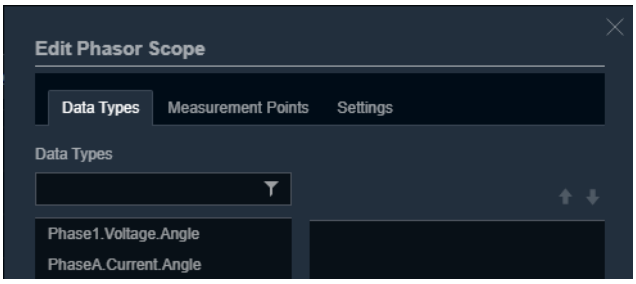


**Figure 4.11 Edit Phasor Scope Panel Data Type**

## 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.

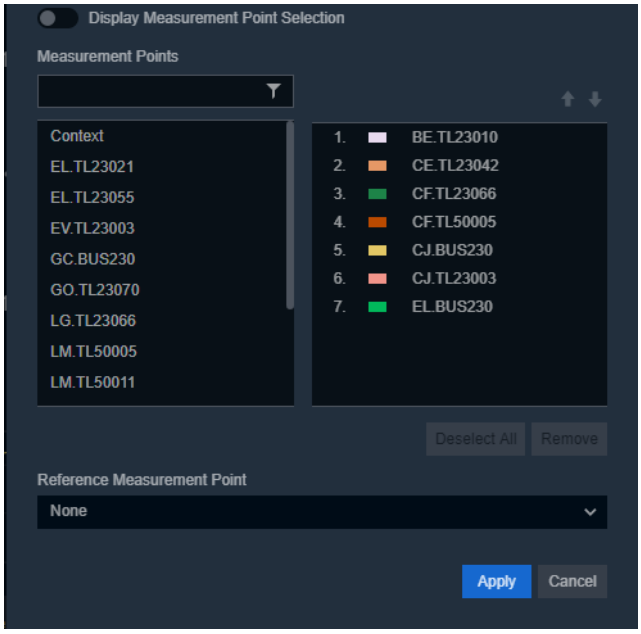


**Figure 4.12 Add/Remove Measurement Points From Phasor Scope Panel**

## 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 4.13 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.

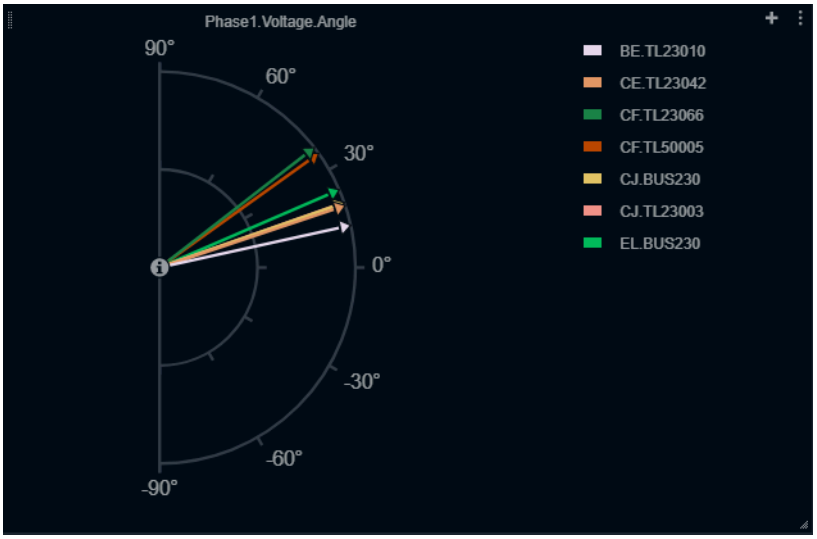


**Figure 4.14 Phasor Scope With Custom Angle Range**

## Setting Zero Position

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

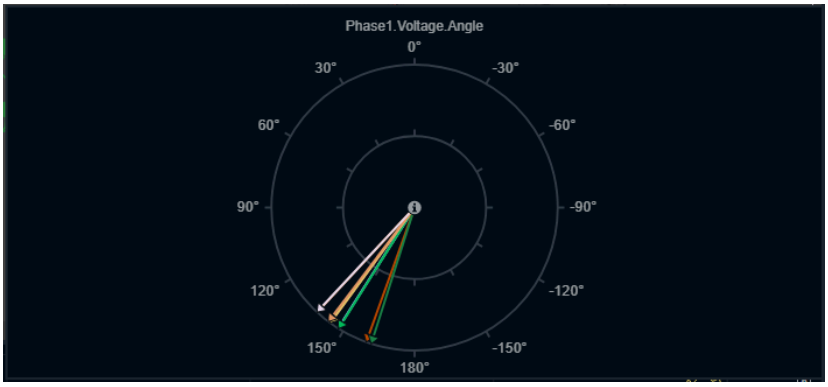


**Figure 4.15 Phasor Scope With Zero Position at Top**

## 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 4.16 Phasor Scope Show Magnitudes Configuration**

# 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.

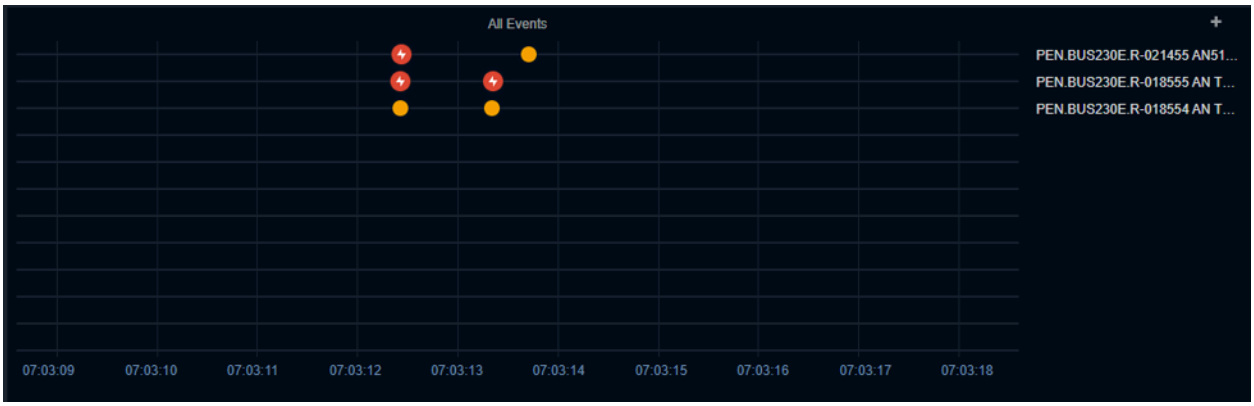


**Figure 4.17 Device Events Panel Overview**

## 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.

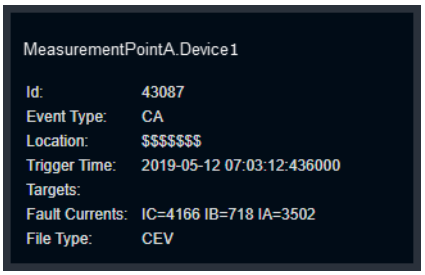


**Figure 4.18 MeasurementPointA.Device1 Summary Example**

## 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 4.19 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.

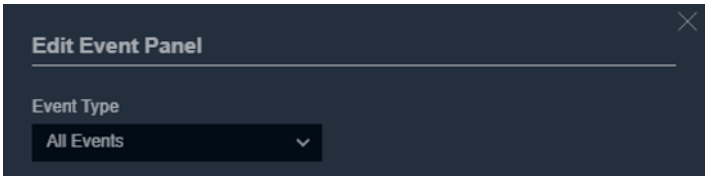


**Figure 4.20 Edit Event Type**

## 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**.

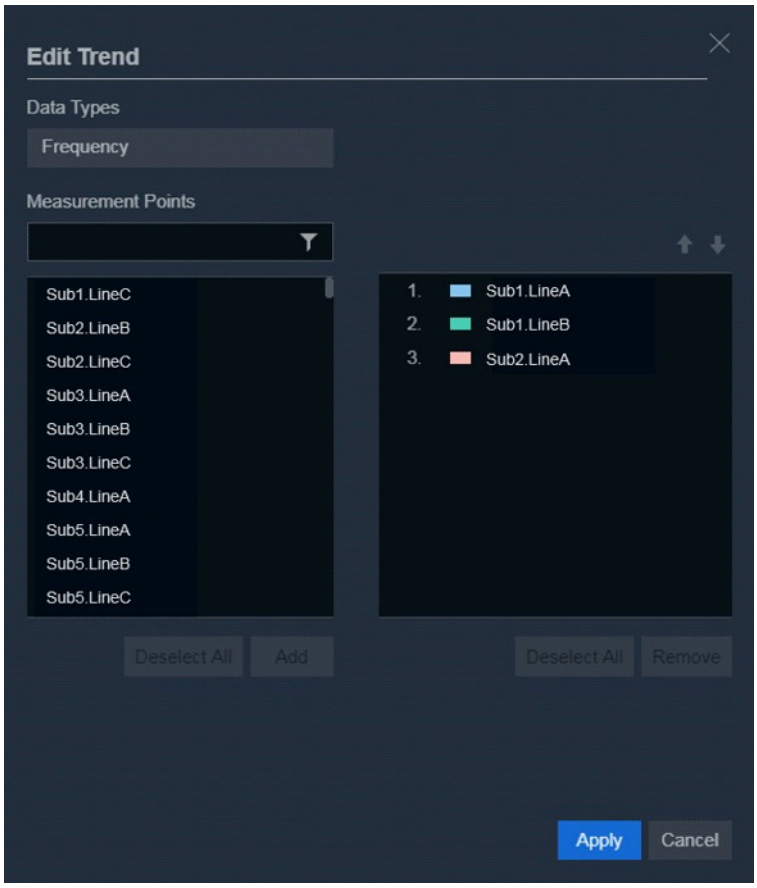


**Figure 4.21 Add/Remove Measurement Point Devices From Device Events Panel**

# Numeric Panel Application

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

**Figure 4.22 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 4.23 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.

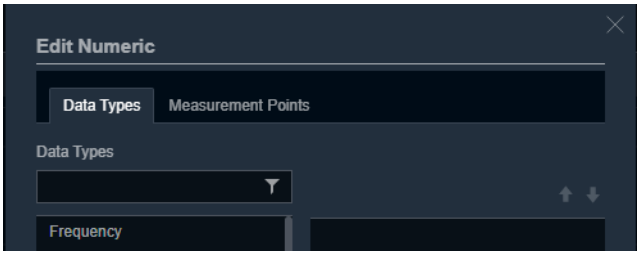


**Figure 4.24 Edit Numeric Panel Data Type**

## 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.

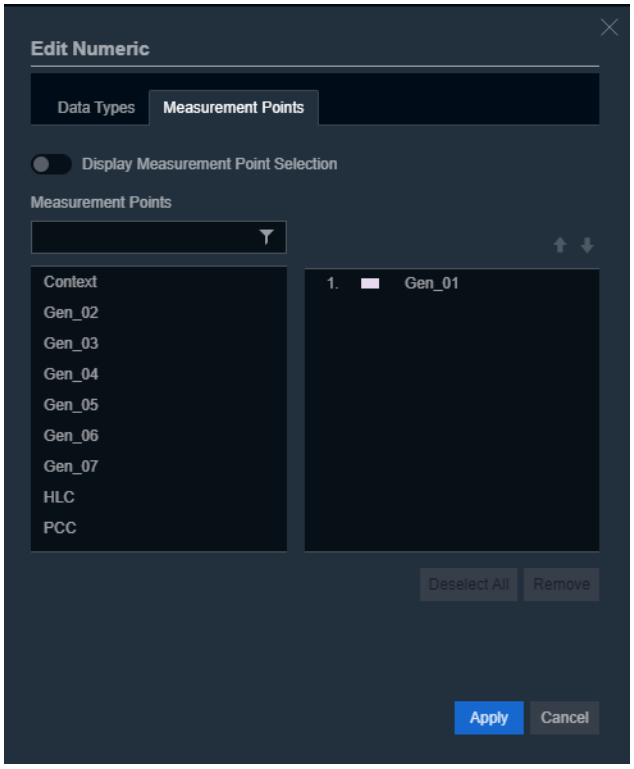


**Figure 4.25 Add/Remove Measurement Points From Numeric Panel**

# Digital Chart Application

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

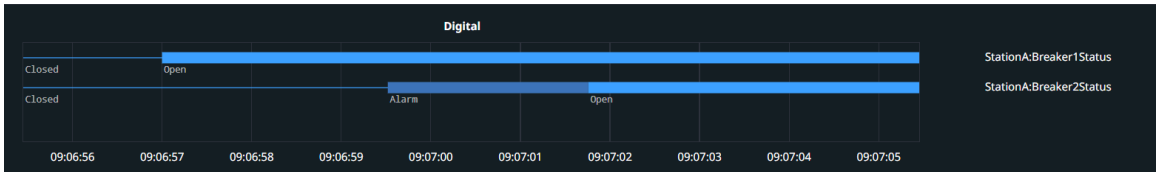


**Figure 4.26 Digital Chart**

# 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.

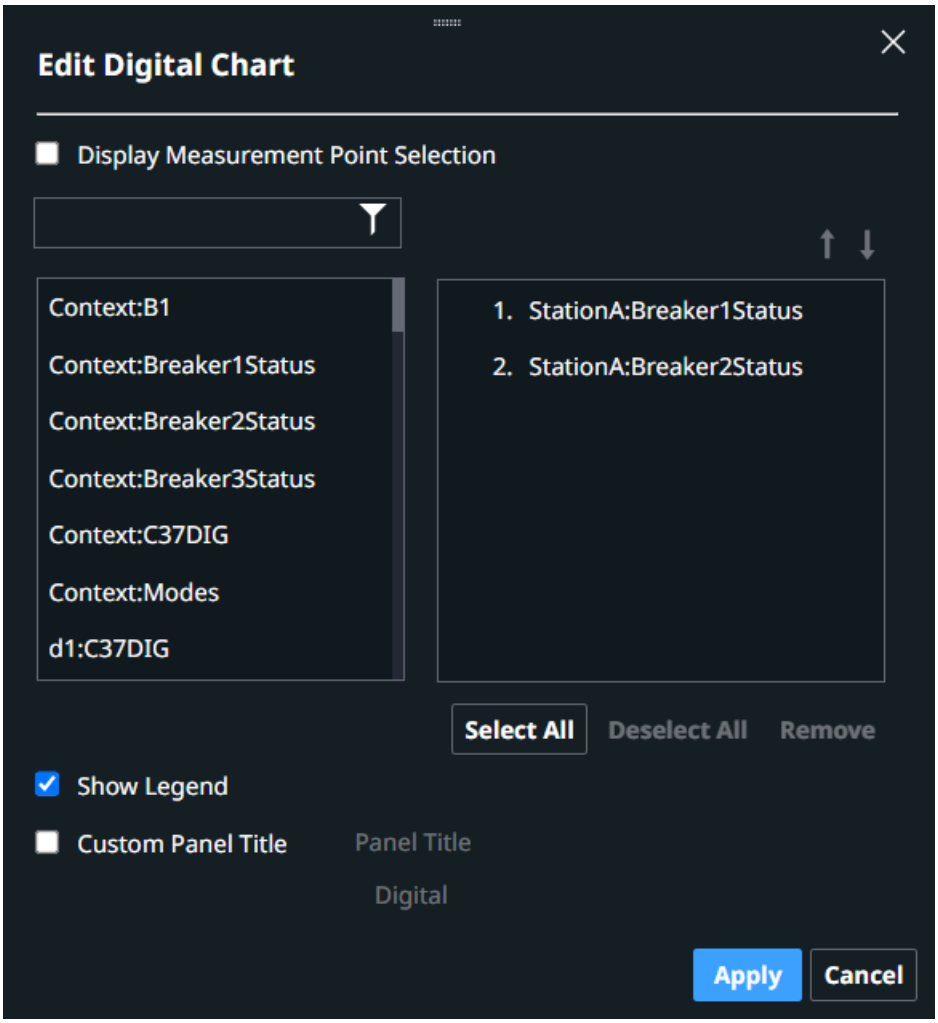


**Figure 4.27 Digital Chart Configuration Dialog**

## 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 21* 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 4.28*. Zooming in at the transition point will increase resolution and the band will disappear when full resolution is available.

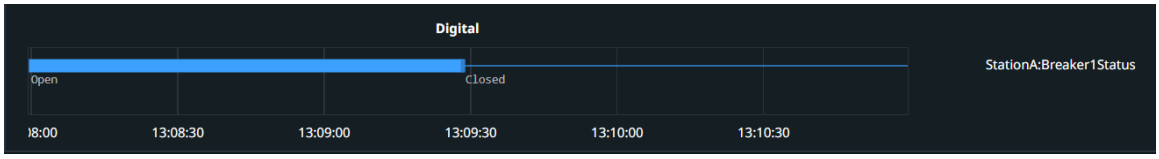


**Figure 4.28 Digital Chart Insufficient Resolution**

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

# 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.

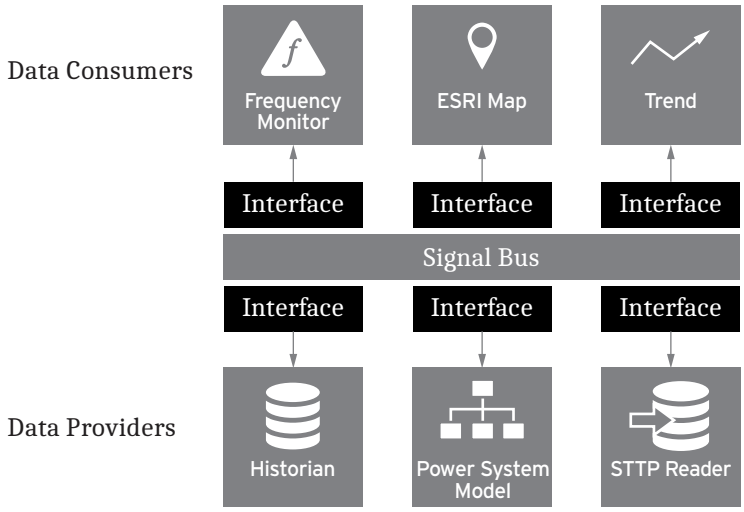


**Figure 4.29 Data and Storage Architecture**

**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.

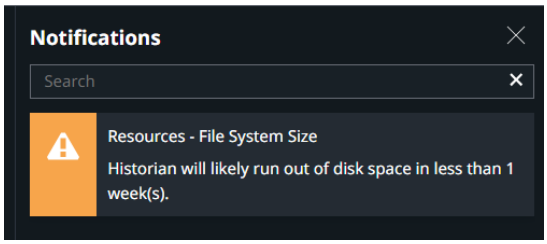


**Figure 4.30 Synchrowave Historian System Notification**

# 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 Application Data Directory location. See *Platform Services Application on page 11* for details on setting the Application Data Directory.

## 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.

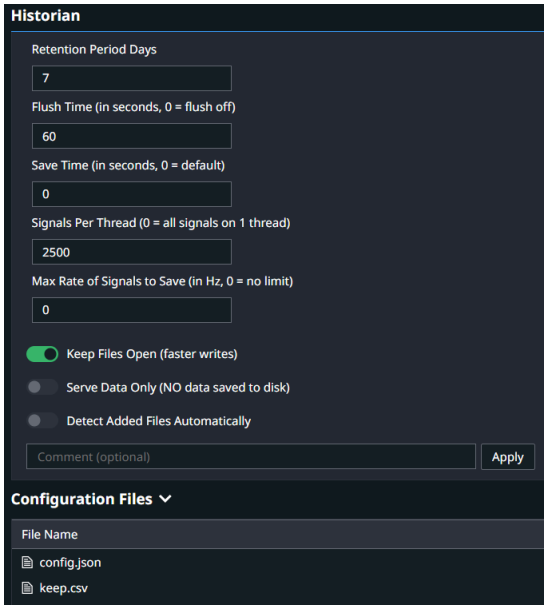


**Figure 4.31 Synchrowave Historian Data Retention Configuration**

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 4.32 Synchrowave Historian Deletion Exemption Configuration**

# SWave Server

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 Monitoring.

**NOTE**
The SWave Server is available to any past SYNCHROWAVE Central customer. Contact Synchrowave@selinc.com to receive the SWave Server application.

## Loading SWave Data

**NOTE**
The use of forward slashes, /, in directory paths is preferred over backslashes to maintain compatibility with Unix systems.

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:

- Copy the **Historian/** and **Index/** folders from a SYNCHROWAVE Central SWave Database manually to the **[***Application Data Directory***]sel-swaveserver/** folder.
- Set an alternate folder location in the **C:/ProgramData/SEL/Synchrowave/platform.settings** file. Open the file in a text editor and scroll down to find the `sel-swaveserver` section as shown in *Figure 4.33*(a). You may enter the path to the SWave folder using one of three methods:

  **NOTE**
  The default value for the [Application Data Directory] path is C:/ProgramData/SEL/Synchrowave/data/apps. An alternate location can be specified in the Platform Services Configuration tab.

1. Local relative path: This is the path relative to the **[Application Data Directory]sel-swaveserver** folder. For example, to specify the folder location **C:/ProgramData/SEL/Synchrowave/data/Swave** folder, specify the relative path as **../../SWave**.
2. Local absolute path: This is the path on your local machine. For example, if SynchroWAVe Central was previously installed on this machine, the default path would be **C:/SynchroWAVe Database** (see *Figure 4.33*(b)).
3. Network path: Specify the computer, mount, and path using UNC notation as follows, //**[computer]/[mount]/folder**. Note that mapping a network file server to a drive letter and using method 2 is not supported.

```
(a)
 "sel-swaveserver": {
   "DataDirectory": "",
   "ServicesAdresses": {}
 },
```

```
(b)
 "sel-swaveserver": {
   "DataDirectory": "C:SynchroWAVe DataBase",
   "ServicesAdresses": {}
 },
```

**Figure 4.33 SWave Server Connection Mapping**

**NOTE**
Synchrowave Monitoring runs under an unprivileged user by default. To be able to access networked file locations, Synchrowave Monitoring must be run by a user who has privileges to access that networked file location.

# 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 4.34* 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 4.34 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.

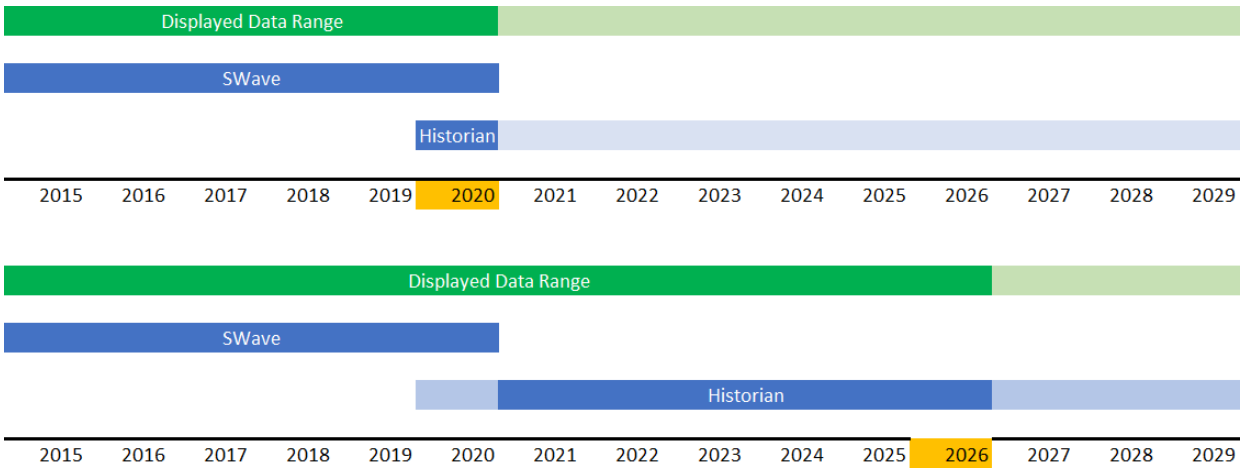


**Figure 4.35 SWave Server Initially Functioning Correctly**

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.

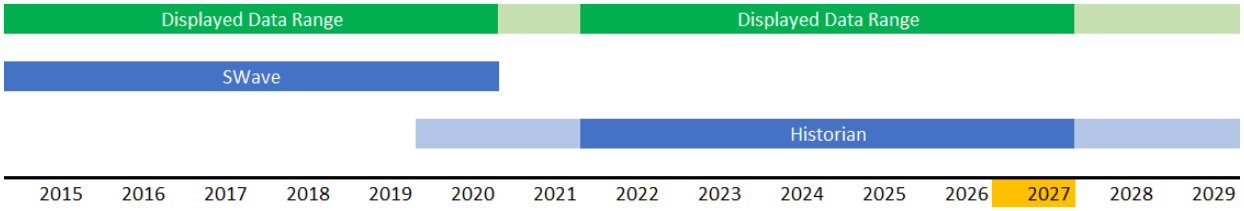


**Figure 4.36 Incorrectly Configured SWave Server**

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

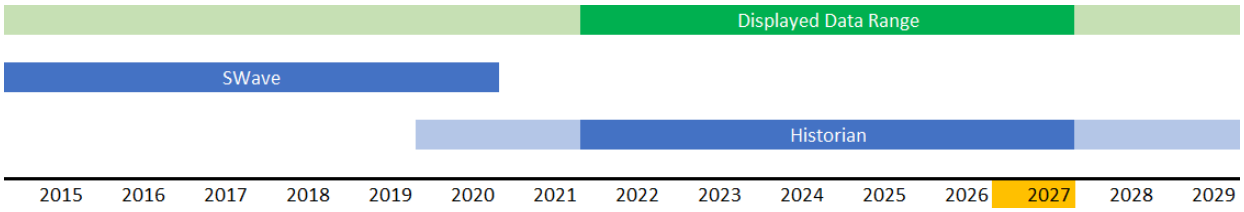


**Figure 4.37 Correctly Configured SWave Server**

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.

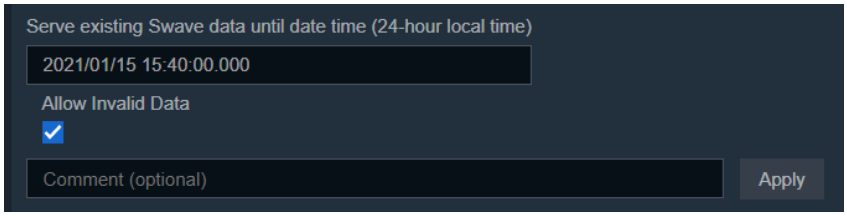


**Figure 4.38 Disable SWave Server After Set Time**

# 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 4.39 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 4.40 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 4.41 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 4.42*).

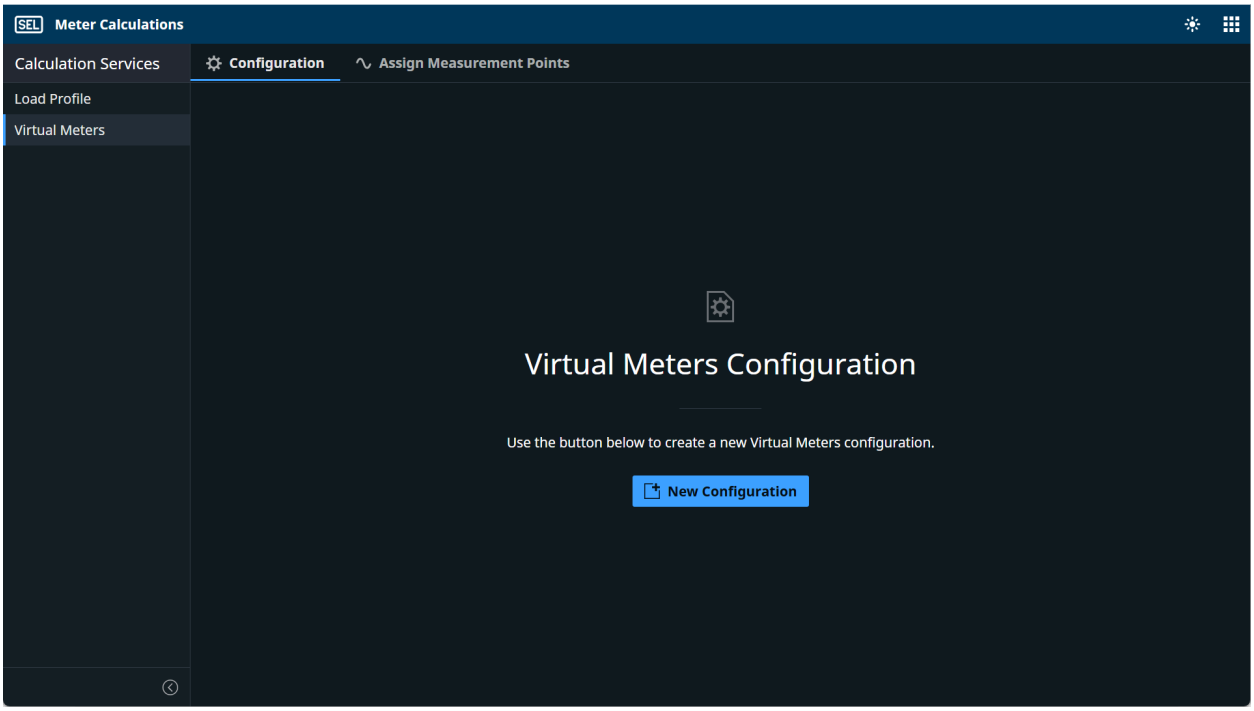


**Figure 4.42 Meter Calculations With No Configurations**

Fill in the settings on the Configuration tab, as shown in *Figure 4.43*. The settings available depend on the calculation service.

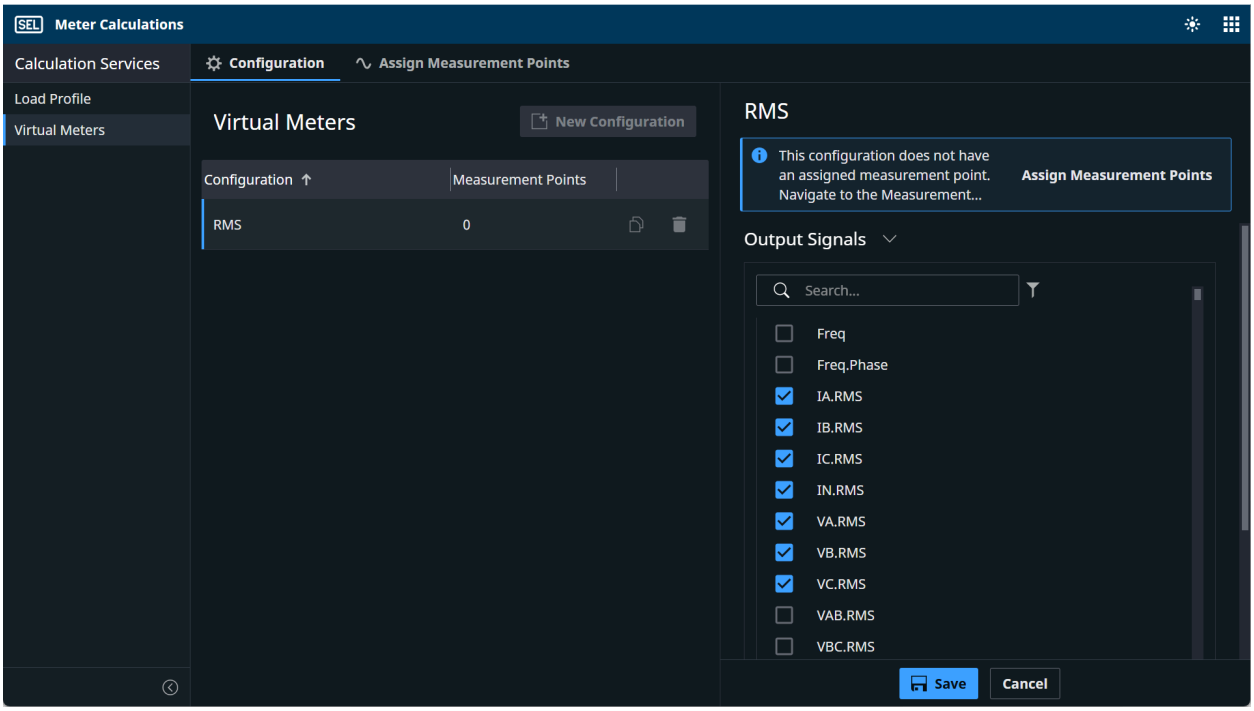


**Figure 4.43 Meter Calculations Configuration**

Assign measurement points to the configuration, as shown in *Figure 4.44*. 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.

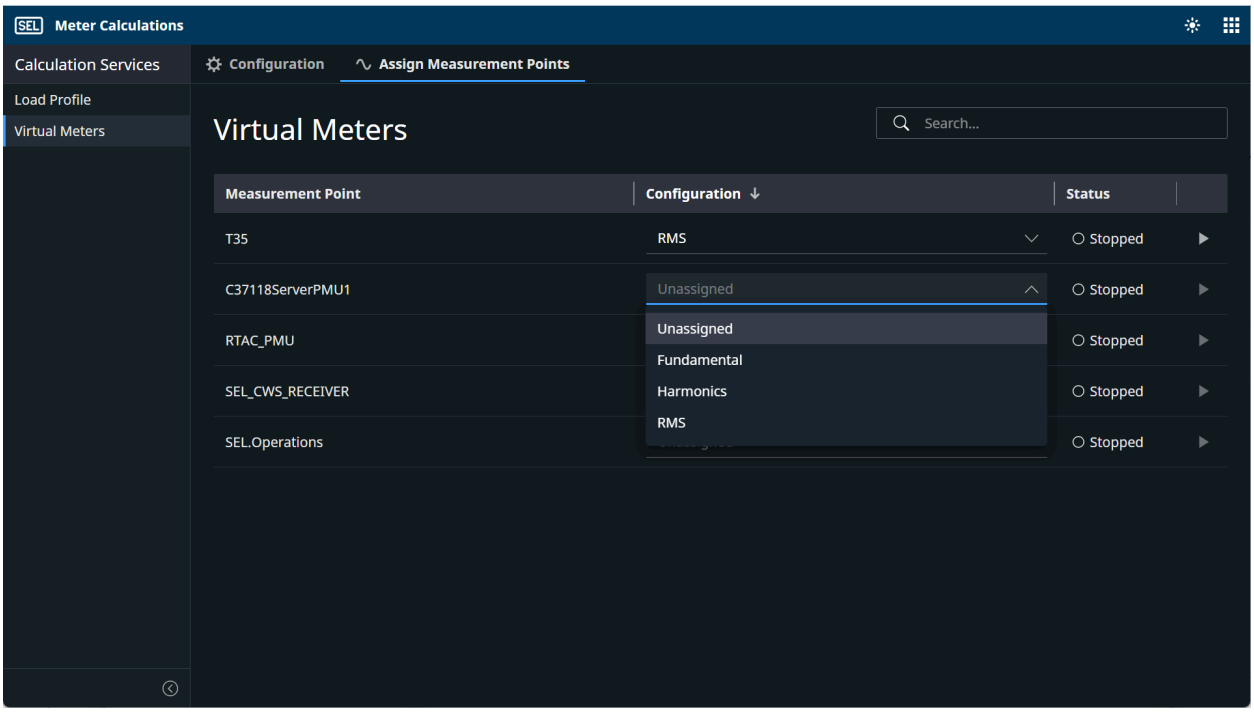


**Figure 4.44 Meter Calculations Assign Measurement Points**

# 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 67* 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 71* 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 4.45* 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 4.45 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 4.46* 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 4.46 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 67* 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 71*. 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 4.45* 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 4.47 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 4.47* 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 4.48 Configured Mappings File**

# 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.

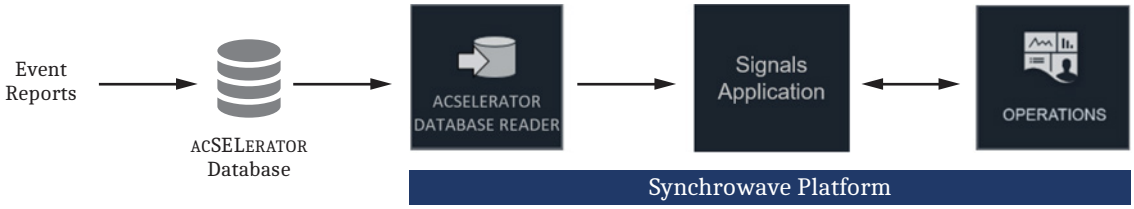


**Figure 4.49 ACSELERATOR Database Reader Overview**

# 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**.

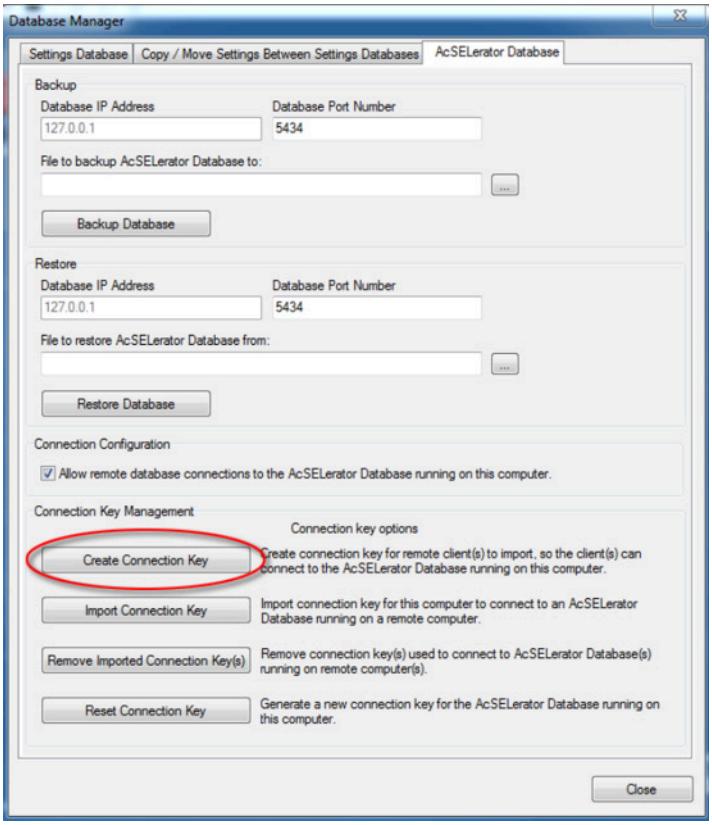


**Figure 4.50 ACSELERATOR Database Manager**

Step 6. When prompted, enter your desired password and select **Submit**. Make note of the password.

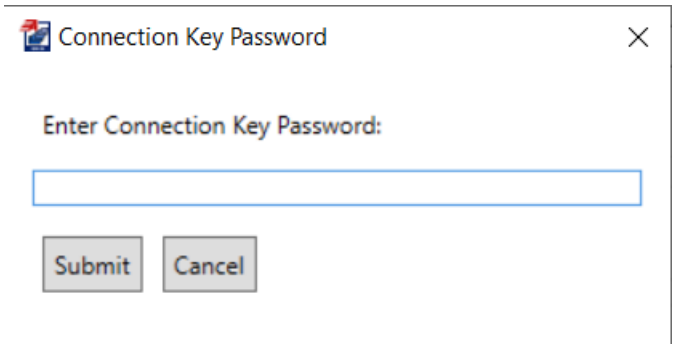


**Figure 4.51 ACSELERATOR Database Connection Key Password Prompt**

## 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**.

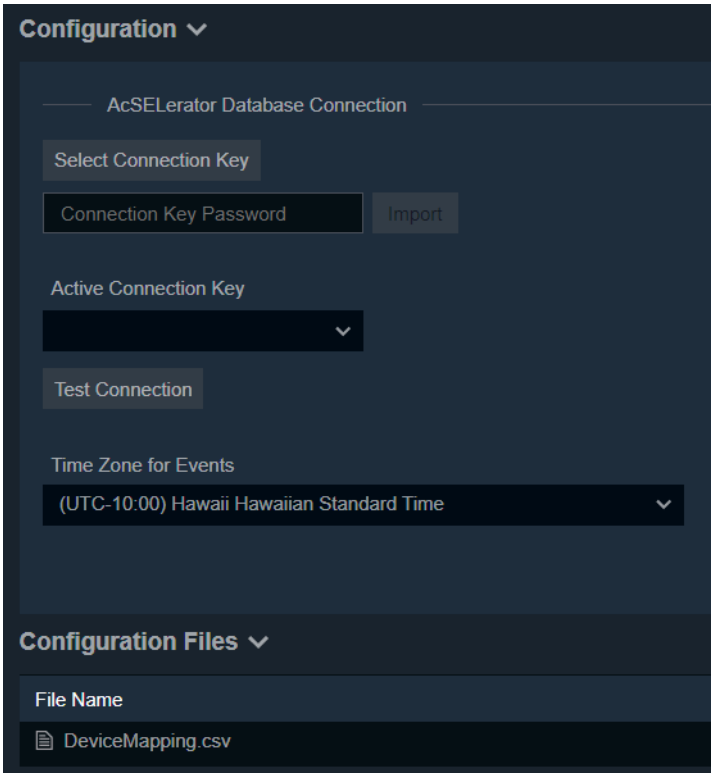


**Figure 4.52 ACSELERATOR Database Reader Configuration**

## 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 4.53 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).

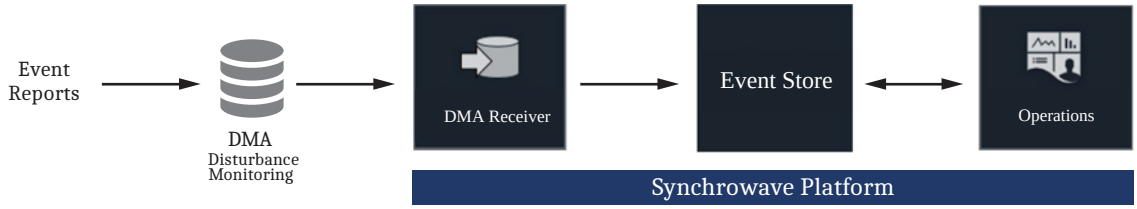


**Figure 4.54 DMA Receiver Overview**

## 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 4.55*).

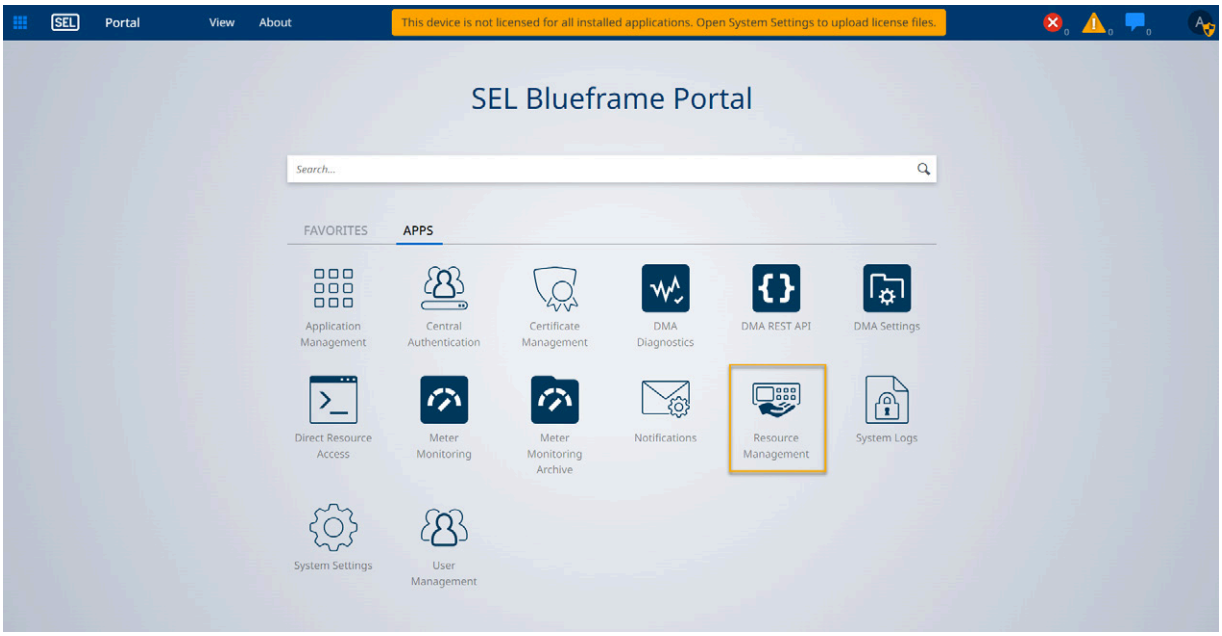


**Figure 4.55 Resource Management**

Step 1. Create a folder for Synchrowave connections.

Step 2. Open the folder and create a new **Resource** (*Figure 4.56*).

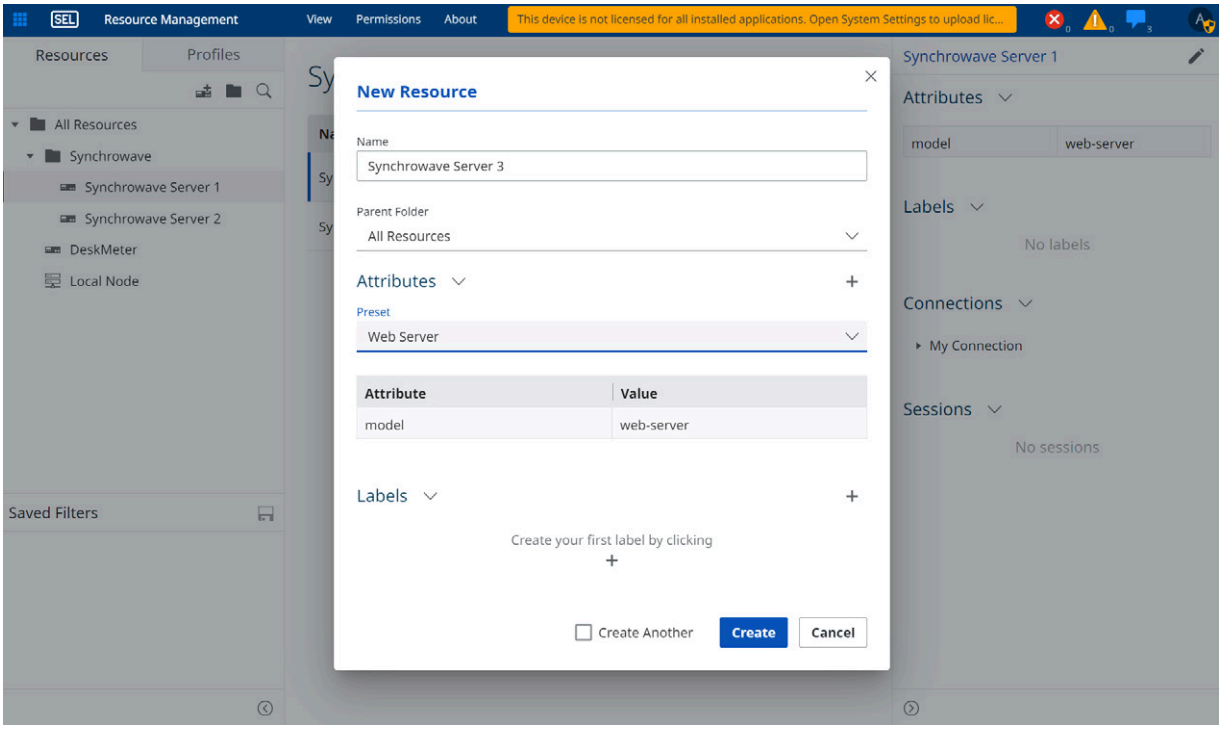


**Figure 4.56 Create a New Web Server Resource**

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 4.57*).

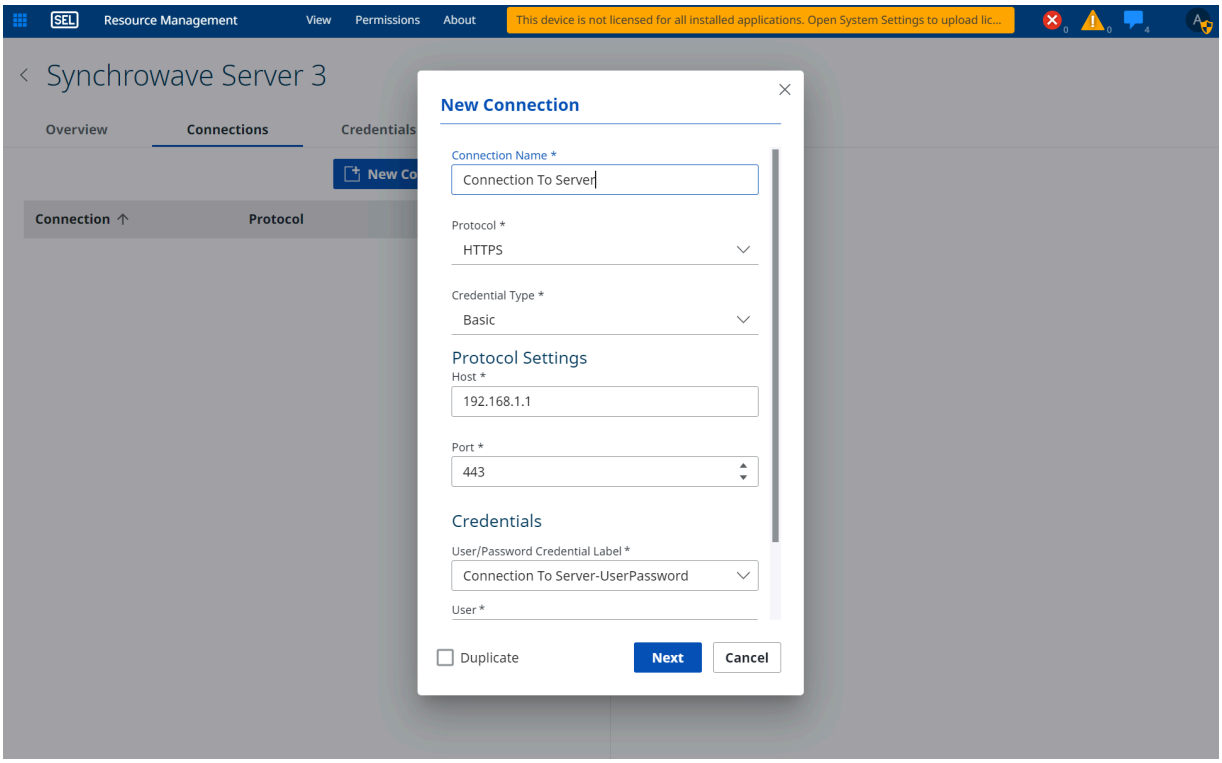


**Figure 4.57 Add a Connection to the Web Server**

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 15* 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 4.58*).

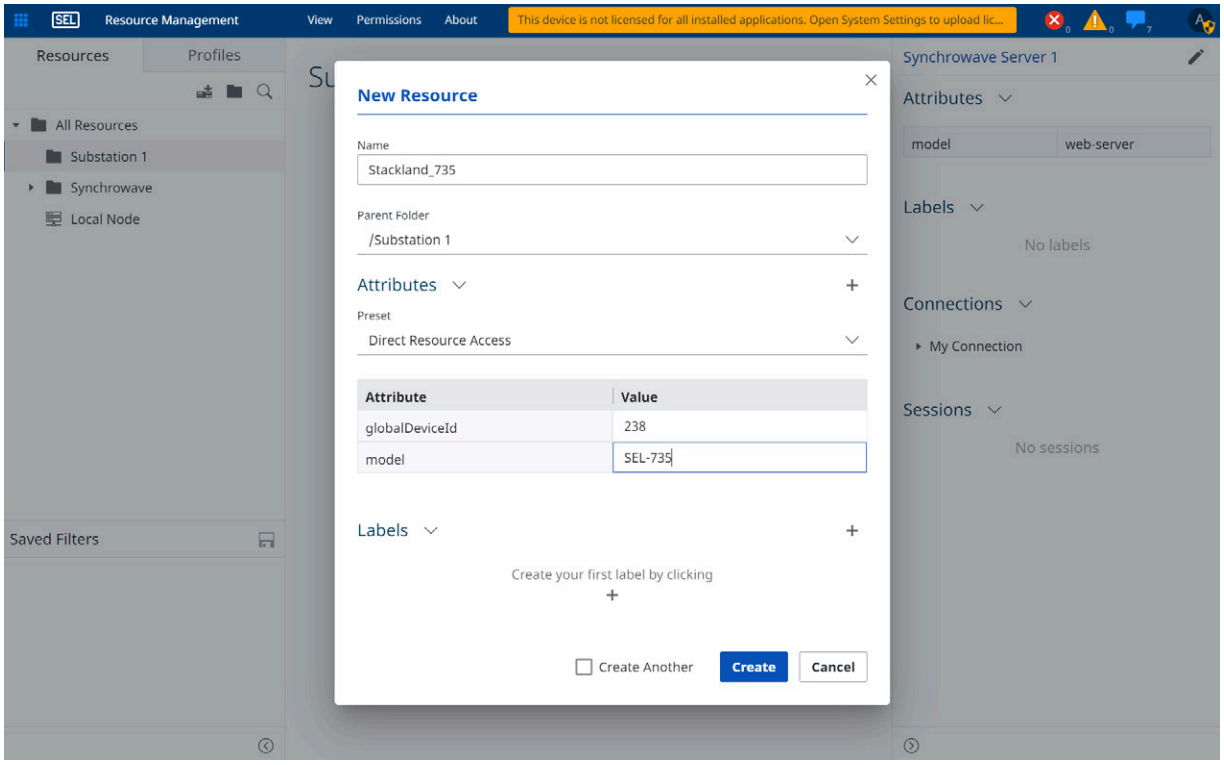


**Figure 4.58 Create a New Direct Resource Access**

Step 18. Double-click on the new resource.

Step 19. Select the **Connections** tab.

Step 20. Create a **New Connection** (*Figure 4.59*).

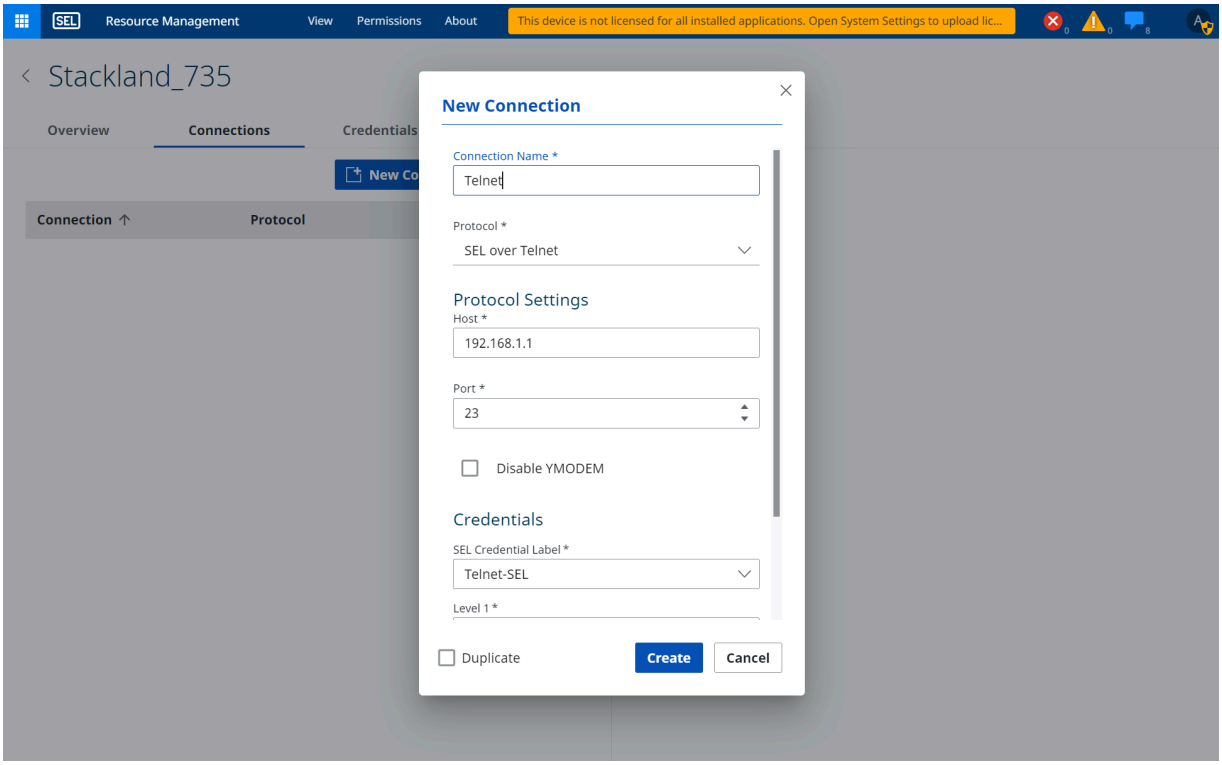


**Figure 4.59 Add a Connection to the Direct Resource Access**

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 4.60*).

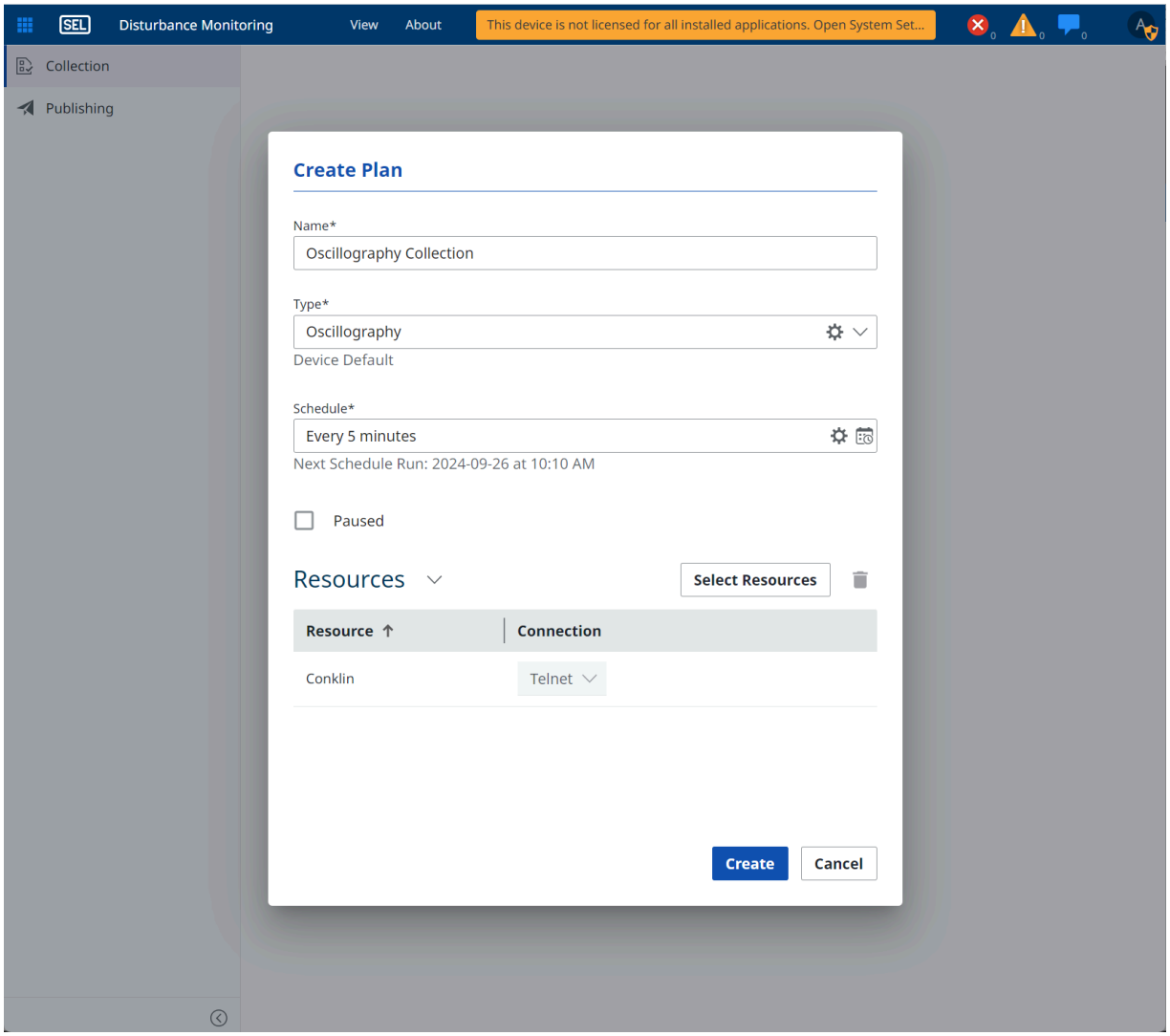


**Figure 4.60 Create a Collection Plan**

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 4.61*).

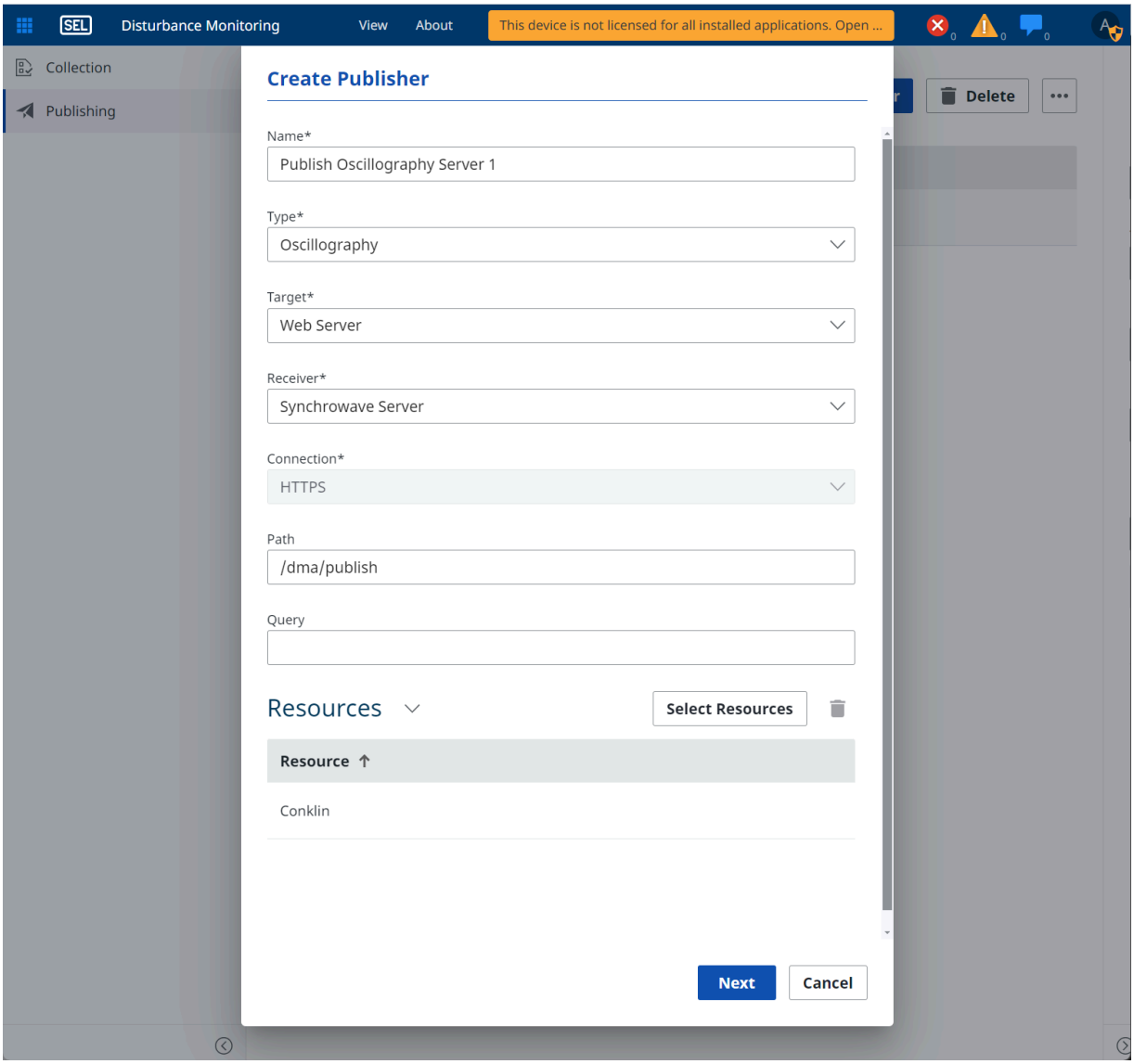


**Figure 4.61 Create a New Publishing Plan**

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.

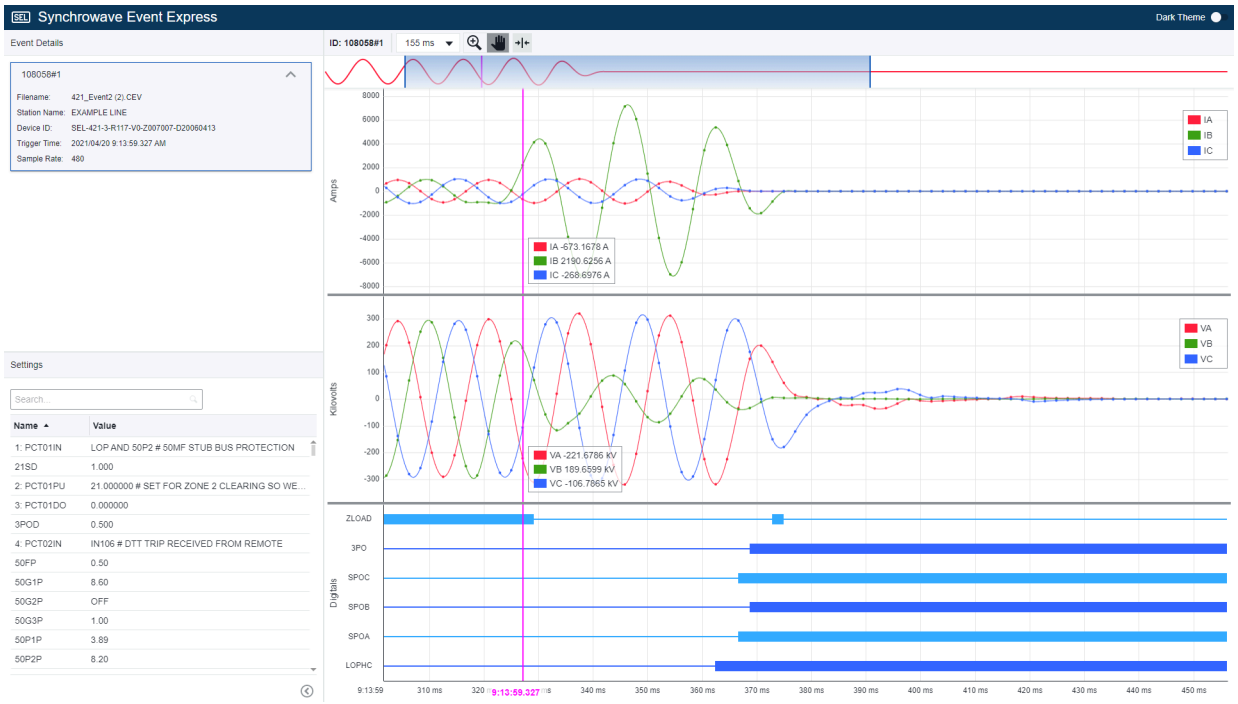


**Figure 4.62 Synchrowave Event Express Overview**

# 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 4.63 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 4.64 Event Details Information**

# Relay Settings

Search through relay settings as set in the device at the time of the event.

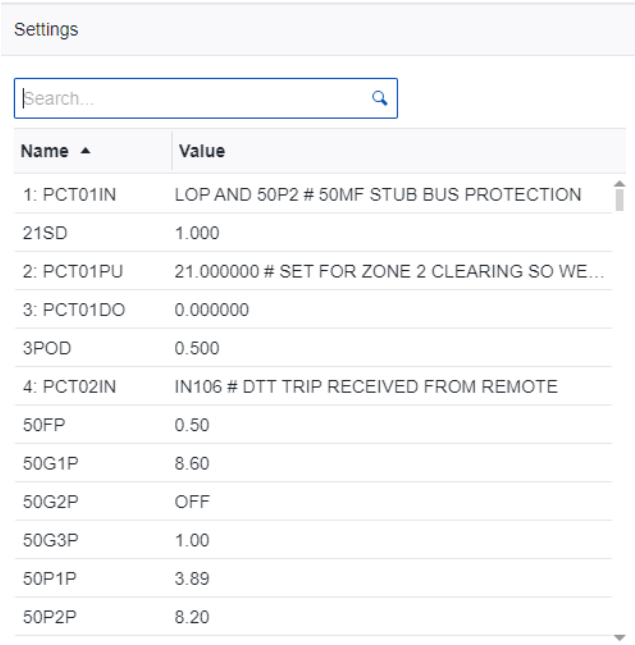


**Figure 4.65 Relay Settings From Event Report**

# 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.

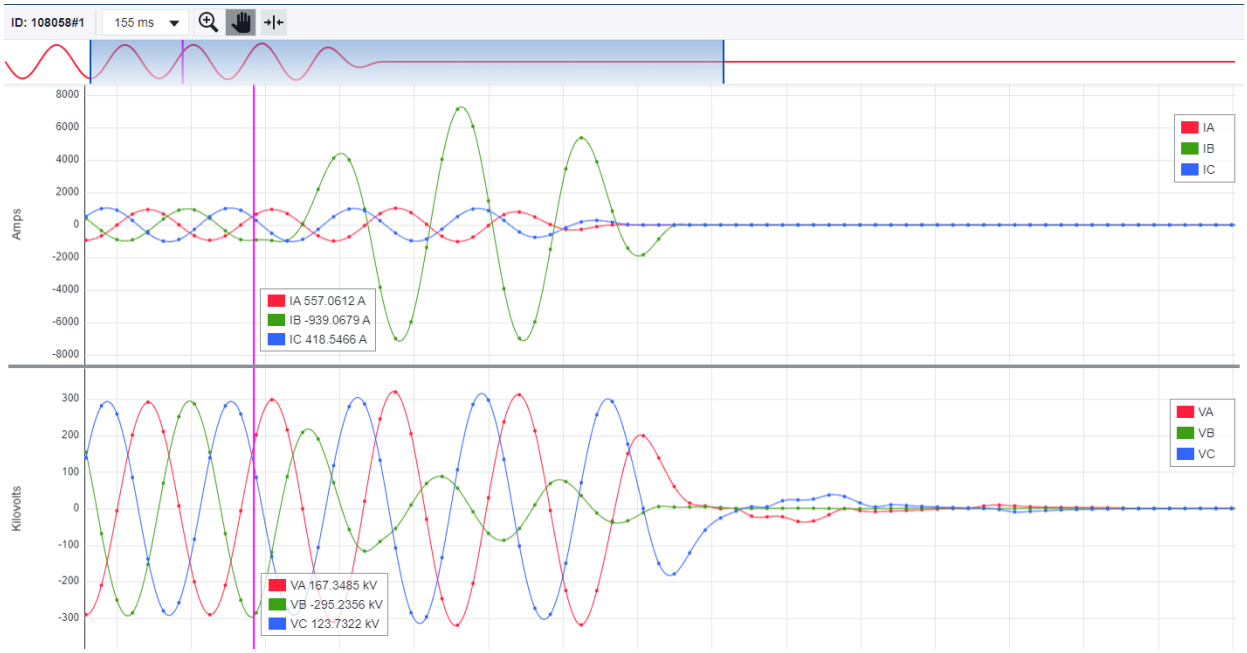


**Figure 4.66 Default Analog Charts Displaying Current and Voltage Oscillography**

## Digital Chart

The Digital chart displays Relay Word bits from the event report to help engineers understand root cause of an event.

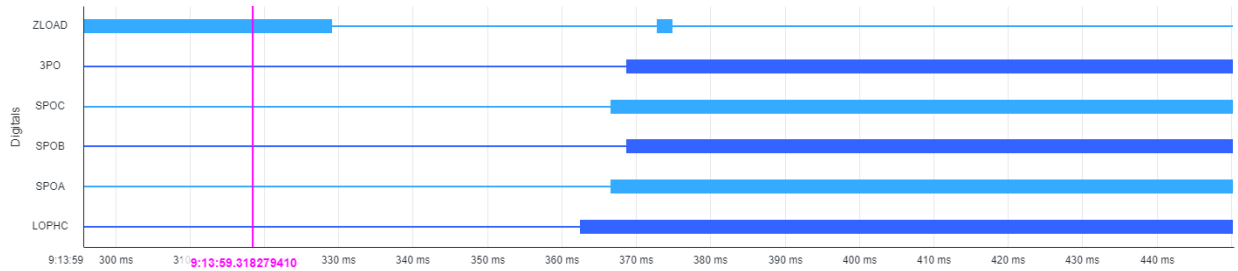


**Figure 4.67 Default Digital Chart Displaying Relay Word Bits**

## 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 4.68 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.

# 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.

# Power Calculator Application

The Power Calculator computes real, reactive, and apparent powers, and power factors. For measurement points with both voltage and current phasors available, powers and power factors are calculated automatically. Optionally, other combinations of voltage and current measurement points can be configured for power and power factor calculations.

## Power Calculation

Single- and three-phase powers and power factors are calculated from current and voltage phasor measurements at user-defined measurement points.

**NOTE**
The Power Calculator only works on voltage and current signals that use standard quantity names (see Standard Quantities on page 20).

Given the voltage and current phasor measurements 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 Calculator

If powers and power factors are desired for measurement point combinations beyond those that are automatically calculated, configure the Power Calculator using the config.csv file. It is a blank file with three columns: VoltageMP, CurrentMP, and PowerMP. VoltageMP and CurrentMP are the measurement points from which the Power Calculator will take the voltage and current phasors, respectively. PowerMP is the measurement point to which the calculations will be published. Enter your desired measurement points into the file and then import it back into Synchrowave.

| | A | B | C |
|---|---|---|---|
| 1 | VoltageMP | CurrentMP | PowerMP |
| 2 | Station1.Line1 | Station1.Line1 | Station1.Line1 |
| 3 | Station1.Bus1 | Station1.Line2 | Station1.Line2 |

**Figure 4.69 Power Calculator CSV Setting File Format**

# 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 4.70* 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 4.70 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.

# Calculations Application

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

**Figure 4.71 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 4.72*.

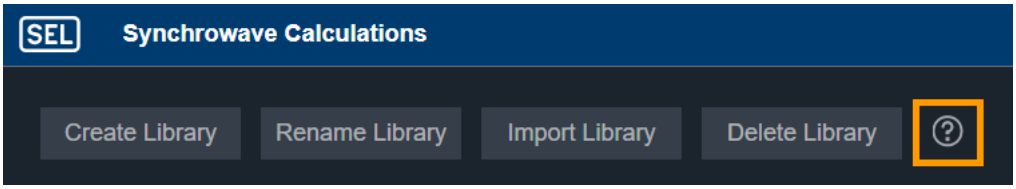


**Figure 4.72 Accessing Calculations Help Menu**

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

**Figure 4.73 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.

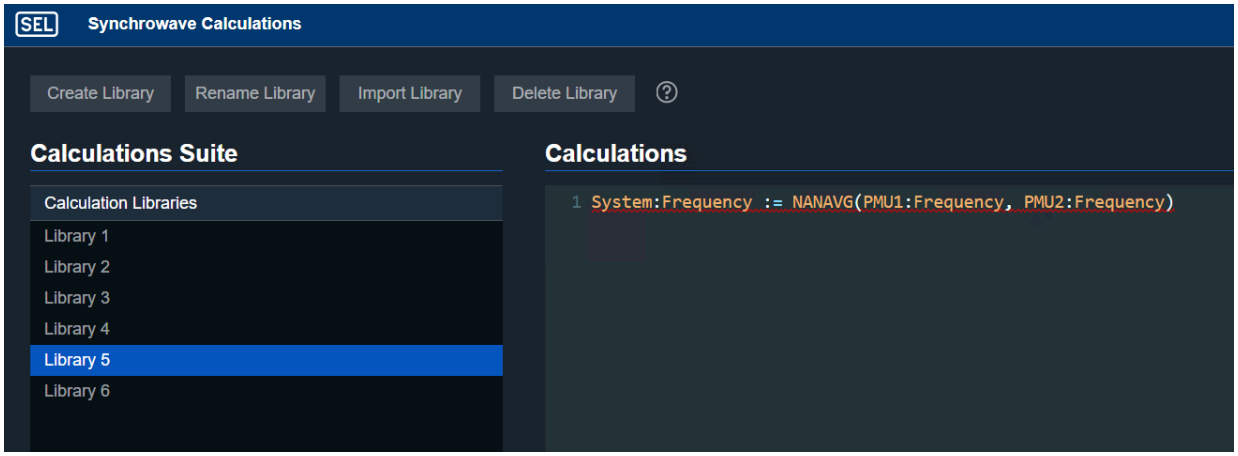


**Figure 4.74 Calculations Libraries**

# 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).

SECTION 5

# Installation and Hardware Requirements

## Introduction

This section describes installation features and installation requirements for the Synchrowave Platform and Synchrowave Monitoring.

Consider the following when installing the Synchrowave Platform and Synchrowave Monitoring:


- *Deployment Network Architecture on page 99*
- *Server and Client Requirements and Specifications on page 101*
- *Data Storage Requirements on page 103*
- *Software Installation on page 104*


## 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.

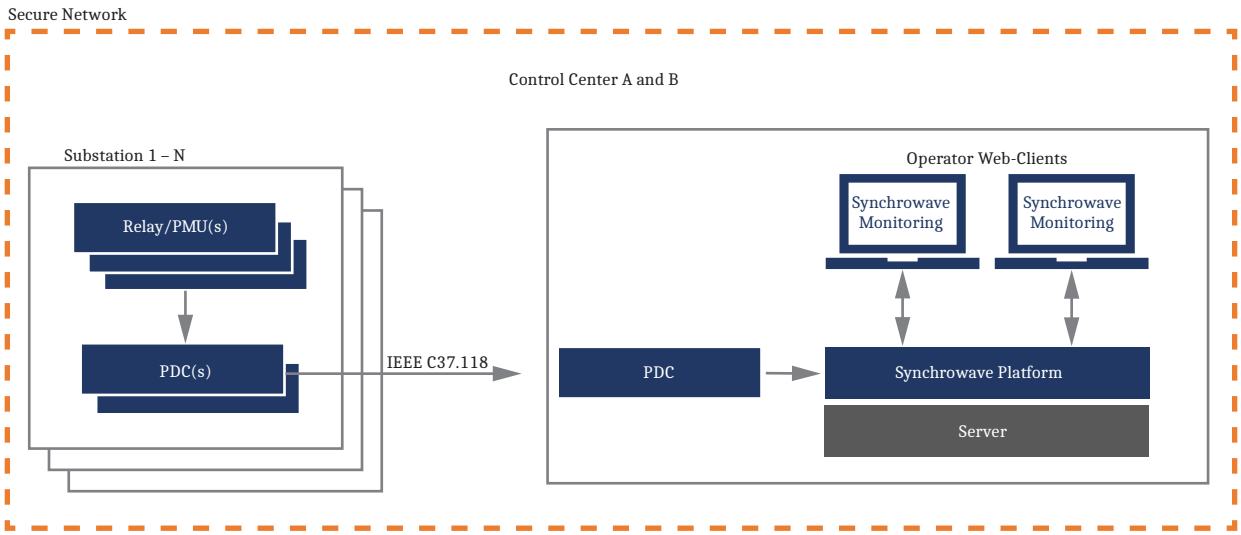


**Figure 5.1 Secure Network Deployment Architecture**

SEL recommends never connecting critical infrastructure to the internet.

Any applications that are integrated with the Synchrowave Platform should 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.

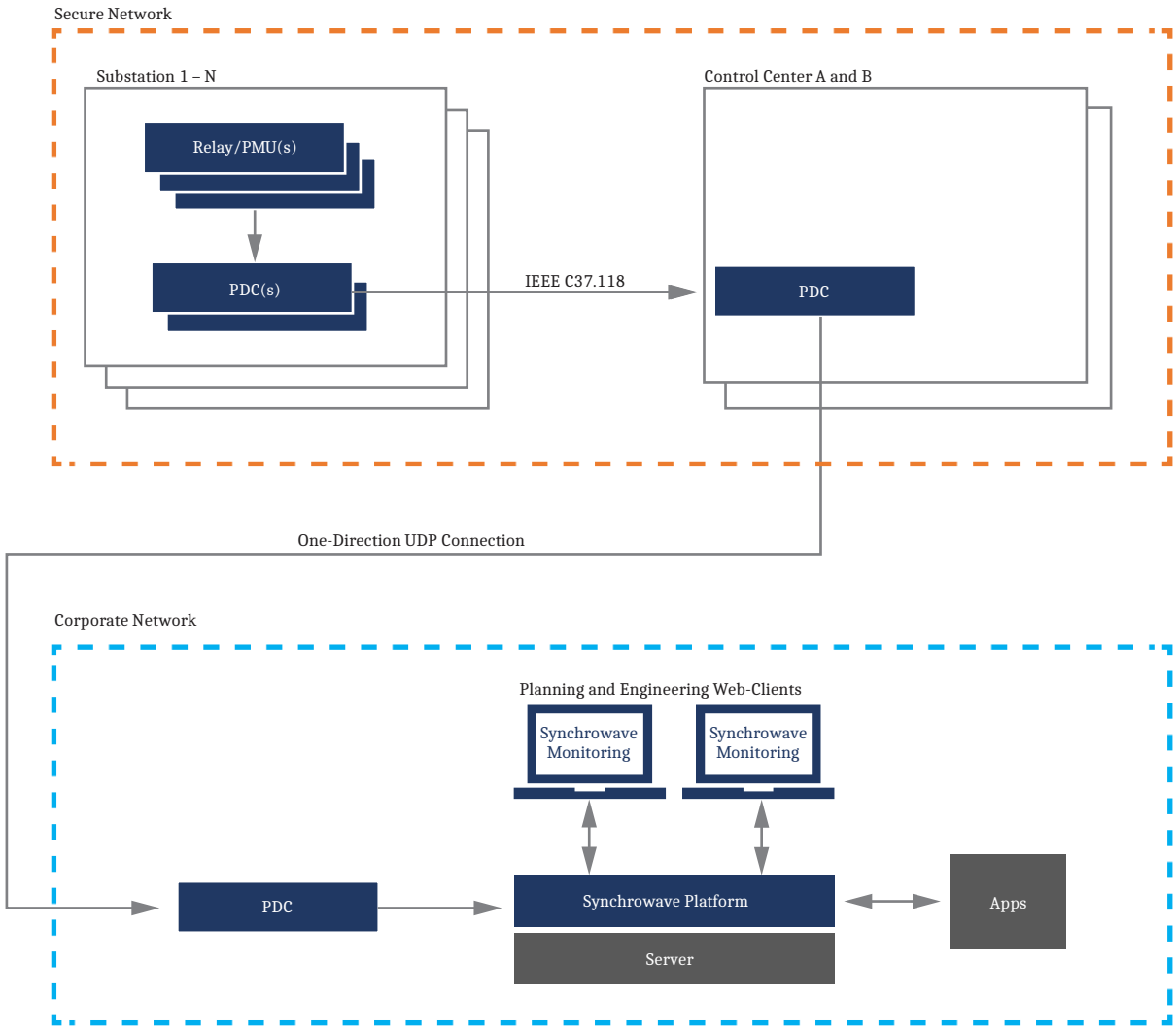


**Figure 5.2 Corporate Network Deployment Architecture**

Any applications that are to be integrated with the Synchrowave Platform should reside within the corporate network.

# Server and Client Requirements and Specifications

## Single Server Configuration

### Single Server

Synchrowave Platform, on which Synchrowave Monitoring runs, supports installation on a single server. 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.

**NOTE**
For high-availability environments, consider deploying the Synchrowave Platform on a Linux server cluster (only available for Synchrowave Operations).

## Hardware Server Requirements

### Minimum Server Requirements

Not all performance timing responses will be met with the minimum system.

- 2.1 GHz Dual Core
- 4 GB RAM
- 100 Mbps Network Card
- 240 GB SSD (see *Data Storage Requirements on page 103* for data archive requirements)

### Recommended Server Requirements

- 2.1 GHz Processor With 16+ Cores
- 8 GB RAM
- 1 Gbps Network Card
- 240 GB SSD (see *Data Storage Requirements on page 103* for data archive requirements)

### Physical Server Versus Virtual Machine

A virtual machine can be used for single server deployments.

## Software Server Requirements

### Supported Operating Systems

The Synchrowave Platform requires one of the following Microsoft Windows operating systems: Windows 10 (version 1909 or later, Enterprise Edition), Windows 11, Windows Server 2016 Standard, Windows Server 2019 Standard, or Windows Server 2022 Standard.

### Server Time Synchronization

To seamlessly display real-time data, the server should be time aligned within 2 seconds of the PMU time source(s).

### Other Applications

Running applications other than Synchrowave Monitoring on the server may degrade the performance and cybersecurity of Synchrowave Monitoring.

## 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 Monitoring 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 **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

These ports must be opened on the server and on the network connecting the server to the clients LDAP server.

**Table 5.1 Single-Node System**

| Direction | Protocol | Port | From | To | Description |
|---|---|---|---|---|---|
| Inbound | TCP/ HTTP | 80 | Clients | Platform | Web-gateway traffic. Port 80 is used only to redirect HTTP requests to HTTPS, Port 443. |
| Inbound | TCP/ HTTPS | 443 | Clients | Platform | Web-gateway traffic. |
| Outbound | TCP/ LDAP | As Configured (Default: 389; use 636 for LDAPS) | Platform | LDAP Server | User authentication with LDAP server. |

**Table 5.2 Cluster**

| Direction | Protocol | Port | From | To | Description |
|---|---|---|---|---|---|
| Inbound | TCP/ HTTP | 80 | Clients | Platform | Web-Gateway traffic. Port 80 is used only to redirect HTTP requests to HTTPS, Port 443. |
| Inbound | TCP/ HTTPS | 443 | Clients | Platform | Web-Gateway traffic. |
| Outbound | TCP/ LDAP | As Configured (Default: 389; use 636 for LDAPS) | Platform | LDAP Server | User authentication with LDAP server. |

## Monitoring Applications

*Table 5.3* lists the required ports for each application that is part of the Synchrowave Monitoring system.

**Table 5.3 Monitoring Applications**

| Application | Direction | Protocol | Port | From | To | Description |
|---|---|---|---|---|---|---|
| ACSELERATOR Database Reader | Outbound | TCP | As Configured (Default: 5434) | Platform | ACSELERATOR Database Server | Connection to database |
| IEEE C37.118 Reader | Outbound | TCP | As Configured (Default: 4712) | Platform | C37.118 Phasor Data Concentrator (s) | Synchrophasor 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, Device Event Panel, Historian, Monitoring, Platform Services, Signals, and Timeline.

# 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.

## Network Storage Requirements

For security reasons, Synchrowave Monitoring is, by default, run as an unprivileged user and therefore restricted from accessing network drives, which require additional permissions. Network drive access can be enabled by entering the required network credentials in the configuration of the Platform Services (see *Platform Services Application on page 11* for details).

**NOTE**
If you need a networked location for the synchrophasor database, use the full network name for the path setting. Using the mapped drive letter alone does not work.

Contact SEL if you need assistance.

# 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.Monitoring.Package-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. See *Platform Services Application on page 11* for details.

# Synchrowave Platform Backup Procedure

A Synchrowave Windows 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 server and, if applicable, the data stored on the network file system.

## Server Local File System Backup

To back up data on the server, perform the following:

Step 1. Stop the platform to avoid changes during the backup. From the Windows Task Manager, select the **Services** tab. Find the SEL Synchrowave service, right-click it, and select **Stop**. Wait until the service PID disappears.

Step 2. Back up the server's local file system.

Step 3. Restart the platform. From the Windows Task Manager, select the **Services** tab. Find the SEL Synchrowave service, right-click it, and select **Start**.

## Server Local File System Restore

To restore a server from a backup, perform the following:

Step 1. Resolve the problem that necessitated the restore.

Step 2. Restore the server's file system from the backup.

Step 3. Start the platform. From the Windows Task Manager, select the **Services** tab. Find the SEL Synchrowave service, right-click it, and select **Start**.

## Network File System Backup

Step 1. Take a snapshot of the Synchrowave NAS file system folder. Using snapshots provides:

- A synchronized view of all system states, avoiding possible issues related to some files being backed up at significantly different times than related files.
- The ability to copy files without interfering with active modifications by the system.

Step 2. Back up the file system snapshot.

Optionally, if the backups will not include historic data, exclude the sel-historian folder from the backup.

# Network File System Restore

To restore a server from a backup, perform the following:

Step 1. Stop the platform to avoid changes during the backup. From the Windows Task Manager, select the **Services** tab. Find the SEL Synchrowave service, right-click it, and select **Stop**. Wait until the service PID disappears.

Step 2. Restore the file system from the backup.

Step 3. Restart the platform. From the Windows Task Manager, select the **Services** tab. Find the SEL Synchrowave service, right-click it, and select **Start**.

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 Monitoring 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 Monitoring Package Revision History**

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 2.9.1 | ➤ Added the Meter Calculations application.<br>➤ Resolved an issue that caused a partial lock-up of the Virtual Meters application.<br>➤ Improved Virtual Meters application memory usage.<br>➤ Added a CRM option to the Load Profile 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 Continuous Waveform Streaming Receiver application.<br>➤ Added the Load Profile application.<br>➤ Added the Virtual Meters application.<br>➤ Added the Calculations 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>➤ Improved the configuration of the C37.118 Reader for UDP_S connections.<br>➤ Added the ability to save the file name in a Data Export template.<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 highlighting in the cursor legend of the Time-Series Trend.<br>➤ Added the Event Store application.<br>➤ Added the DMA Receiver application. | 20241008 |
| 2.7.0 | ➤ Improved support for digital signals and added the Digital Chart application. | 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. | 20231201 |
| 2.5.0 | ➤ Made line thickness configurable on Time-Series Trend.<br>➤ Added Line Frequency setting for COMTRADE data export. | 20230714 |

| Version Number | Summary of Revisions | Manual Date Code |
|---|---|---|
| 2.4.0 | ➤ Added Configuration History details, including support for comments. | 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 | ➤ Improved performance of Device Events panel.<br>➤ Added ability to copy and paste panels in dashboards. | 20220426 |
| 1.4.3 | ➤ Added Power Calculation application.<br>➤ Added Data Export templates.<br>➤ Fixed functionality issues related to foreign language versions of Windows. | 20210812 |
| 1.4.0 | ➤ Initial version. | 20210429 |

*Table A.2* lists the Synchrowave Platform 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.2 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.3* lists the product manual release dates and a description of modifications. The most recent product manual revision is listed at the top.

**Table A.3 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 Monitoring package version 2.9.1. |
| 20250108 | **Section 4**<br>➤ Added *Continuous Waveform Streaming Receiver Application* and *Calculations Application*.<br><br>**Section 5**<br>➤ Added Continuous Waveform Streaming Receiver to *Table 5.3: Monitoring Applications*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Monitoring package version 2.9.0. |
| 20250103 | **Appendix A**<br>➤ Updated for Synchrowave Monitoring package version 2.7.3. |
| 20241008 | **Section 4**<br>➤ Updated *Configuring Data Export* in *Data Export Application*.<br>➤ Added *DMA Receiver Application* and *Event Store Application*.<br><br>**Appendix A**<br>➤ [Cybersecurity Enhancement] Updated for Synchrowave Monitoring package version 2.7.2.<br>➤ Updated for Synchrowave Windows Platform software version 2.7.2. |
| 20240124 | **Section 2**<br>➤ Updated *SEL Signals Diagnostic Menu and Configuration* in *SEL Signals Application*.<br><br>**Section 4**<br>➤ Added *Digital Chart Application*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Monitoring package 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><br>**Appendix A**<br>➤ [Cybersecurity] Updated for Synchrowave Monitoring package version 2.6.1.<br>➤ [Cybersecurity] Updated for Synchrowave Windows Platform software version 2.6.1. |
| 20230811 | **Appendix C**<br>➤ Added *Rehosting an Existing License*. |
| 20230714 | **Section 2**<br>➤ Updated *Figure 2.24: LDAP Server Connection Setup*.<br><br>**Section 3**<br>➤ Added information about deleting dashboards to *Configuring Dashboard Navigation Folders* in *Dashboard Navigation*. |

| Date Code | Summary of Revisions |
|---|---|
| | **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 4.8: Setting Up Default Time-Series Trend*.<br>➤ Added information about previously configured signals no longer present in the data stream to *Example* in *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 the platform to an LDAP server.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Monitoring Package version 2.5.0.<br>➤ Updated for Synchrowave Windows Platform software version 2.5.0.<br><br>**Appendix B**<br>➤ Added *Web Gateway login failed* to *Table B.1: Symptoms*.<br>➤ Added *A. Restoring Access to Synchrowave When Locked Out* to *Solutions*.<br><br>**Appendix C**<br>➤ Updated *Overview*.<br><br>**Appendix E**<br>➤ Updated *General Data Storage* in *Commissioning*. |
| 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 *Importing and Exporting Dashboards* and *Adding Dashboard Panels* in *Dashboards Application*.<br><br>**Section 4**<br>➤ Added *Displaying Magnitude* in *Configuring the Phasor Scope Panel*.<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*.<br><br>**Section 5**<br>➤ Added Windows 11, Windows Server 2019 Standard, and Windows Server 2022 Standard to list of supported operating systems in *Software Server Requirements*.<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 Monitoring package version 2.4.0.<br>➤ Updated for Synchrowave Windows Platform software version 2.4.0.<br>➤ Moved applicable version 2.0.0 revision statements from *Table A.1: Synchrowave Monitoring Package Revision History* to *Table A.2: Synchrowave Windows Platform Software Revision History*. |
| 20220908 | **General**<br>➤ Added *Appendix D: Cybersecurity Features*.<br><br>**Section 2**<br>➤ Updated *Adding/Removing Users* in *Configuration of Authentication* under *Platform Applications > Web Gateway Application*.<br><br>**Section 4**<br>➤ Updated *Configuring the Archive Data Directory* in *Historian Application Configuration* under *Time-Series Historian Application*.<br>➤ Added *Sequence Calculator Application*. |

| Date Code | Summary of Revisions |
|---|---|
| | **Section 5**<br>➤ Added *Synchrowave Platform Backup Procedure*.<br><br>**Appendix A**<br>➤ Updated for Synchrowave Monitoring package version 2.0.0. |
| 20220628 | **Section 4**<br>➤ Updated *ACSELERATOR Database Reader*.<br><br>**Appendix A**<br>➤ Updated Synchrowave Monitoring package version 1.6.1. |
| 20220426 | **Section 2**<br>➤ Added *Platform Services Configuration* to *Platform Applications*.<br><br>**Section 4**<br>➤ Added *Figure 4.2: Selecting Copy Panel* and *Figure 4.3: The Clipboard Icon for Pasting Panel*.<br>➤ Updated *Y-Axis Scaling* under *Navigating the Time-Series Trend* in *Time-Series Trend Panel Application*.<br>➤ Updated *Configuring Data Retention and Performance* under *Historian Application Configuration* in *Time-Series Historian Application*.<br><br>**Appendix A**<br>➤ Updated Synchrowave Monitoring package version 1.6.<br>➤ Updated Synchrowave Platform software version 1.6. |
| 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>➤ Added *Power Calculator Application*.<br><br>**Appendix A**<br>➤ Updated Synchrowave Monitoring package version 1.4.3.<br>➤ Updated Synchrowave Platform software version 1.4.3.<br><br>**Appendix B**<br>➤ Updated *Table B.1: Symptoms*. |
| 20210429 | ➤ Initial version. |

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APPENDIX B

# Troubleshooting SEL Synchrowave Platform and Monitoring

## 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 115*. |
| | 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 Synchrowave at https://localhost.<br><br>**Note:** The latest log file at the following location may provide additional information: %PROGRAMDATA%\SEL\Synchrowave\data\apps\sel-platform\logs. | Port 443 (default for https) or 80 are already in use by another application. | Disable other applications (IIS, for example) that may be serving web traffic on port 443. |
| | | If the system has containerization software (Docker, for example) or virtualization software (Hyper-V or VMWare, for example), they may be using or reserving these ports. Running the following command from an administrator command prompt may resolve the issue temporarily: `net stop winnat`.<br>To resolve the issue, disable or reconfigure the virtualization software. |
| | | Change the port numbers that Synchrowave uses for web access: %PROGRAMDATA%\SEL\Synchrowave\platform.settings. |

| Symptom | Possible Causes | Remedy |
|---|---|---|
| Unable to connect to Synchrowave from another client computer. | Windows firewall is blocking incoming ports. | Allow incoming traffic on ports 80 and 443 to allow external computers to access Synchrowave. |
| | Network is down between client machine and Synchrowave Platform nodes. | Run the ping command on the client computer to determine if it has network access to the computer running Synchrowave. Resolve any networking issues. |
| | Web Gateway application is disabled or not functioning. | Restart the SEL Synchrowave service using the Windows Services application. |
| 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 *A. Examining and Restarting Applications From the Application Manager on page 115*. |
| | The Web Gateway default page is set incorrectly. | Follow *B. Reset Web Gateway Default Page on page 115*. |
| Part or all of the Monitoring page is not displayed correctly or is displayed very slowly. | One or more Monitoring applications are not functioning. | Verify all applications are running following *A. Examining and Restarting Applications From the Application Manager on page 115*. |
| | The CPU is overloaded on server. | Use Windows Task Manager to ensure the computer running the Synchrowave service is not overloaded. |
| One application is not functioning.<br>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**. |
| 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 filesystem is down or out of disk space. | Verify the local disk on the computer running Synchrowave is not out of disk space.<br>Verify the shared filesystem is not out of disk space. |
| | | Verify the computer running the Synchrowave service can access the shared filesystem. |

# Solutions

## A. Restoring Access to Synchrowave When Locked Out

Step 1. Using Windows Explorer, navigate to the following path: %PROGRAMDATA%\SEL\Synchrowave\config\sel-webgateway \active

Step 2. Open the config.json file with Notepad.

Step 3. In the file, find the `"IsAuthenticationEnabled":true` string and change true to false.

Step 4. Restart the SEL Synchrowave service from the Windows Services application (you can access Services by typing "Services" into the Windows search box).

## A. 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**.

## B. 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.monitoring** sets the Monitoring application (if it is installed) as the default page.

Step 5. Select **Apply**.

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APPENDIX C

# Synchrowave Monitoring Licensing

## Overview

Synchrowave software will operate with a warning banner until licensed.

**Figure C.1 Unlicensed Warning Banner**

To purchase a Synchrowave license, visit selinc.com or contact your local SEL sales representative. Once you have purchased a license, perform the following steps as necessary for software licensing:


- *Internet License Activation on page 118*
- *Internet License Deactivation on page 119*
- *Offline License Activation on page 120*
- *Offline License Deactivation on page 122*
- *Rehosting an Existing License on page 125*


The license for Synchrowave does not expire. Once you have licensed Synchrowave, you may use that licensed version in perpetuity. The license is also applicable to upgrades until major feature enhancements are introduced. Contact SEL to determine which software versions are supported by your license.

Procedures for license activation and deactivation are described below. Activation allows for the software to be used with SEL's consent and deactivation allows the license to be transferred to another Synchrowave Platform installation.

The Synchrowave Licensing interface is shown below. All unlicensed applications and applied license activation IDs are listed.

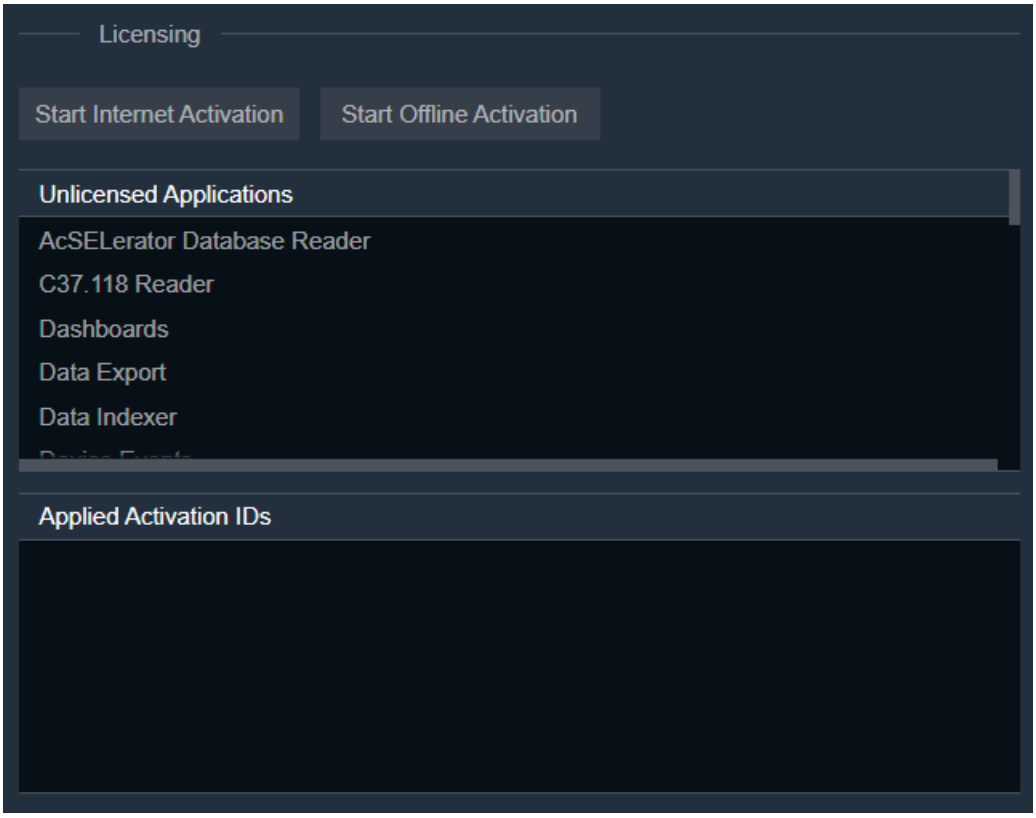


**Figure C.2 Synchrowave Licensing Interface**

# Internet License Activation

Step 1. Install the Synchrowave Platform.

Step 2. Open the **Application Manager** via the Synchrowave web client.

Step 3. Select the **Platform Services** app.

Step 4. Select the **Start Internet Activation** button.

Step 5. Enter your License Activation ID (also called License Authorization Code, LAC) in the dialog box and select **Activate** and then click the **Close** button when it appears.

Step 6. If activation is successful, any applications licensed with the activation ID are removed from the Unlicensed Applications list, the ID appears in the Applied Activation IDs list, and if all applications are licensed, the licensing warning banner should disappear after a few seconds.

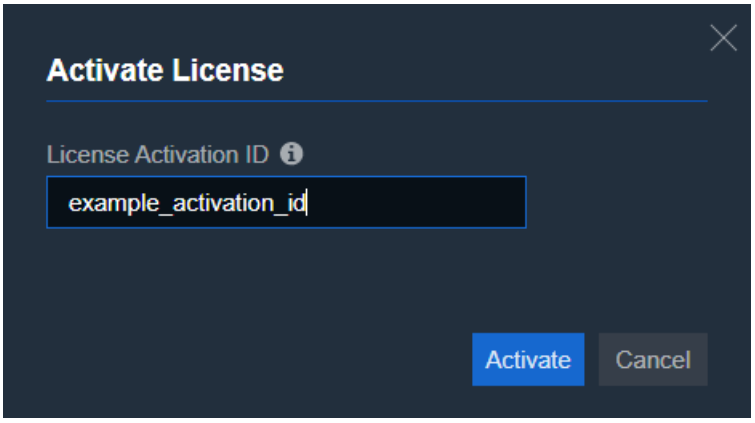


**Figure C.3 Synchrowave Internet License Activation**

# Internet License Deactivation

Step 1. Open the **Application Manager** via the Synchrowave web client.

Step 2. Select the **Platform Services** app.

Step 3. Select the **Internet Deactivate** button associated with the desired license from the Applied Activation IDs list.

Step 4. Click **Deactivate** in the dialog box and then click the **Close** button when it appears.

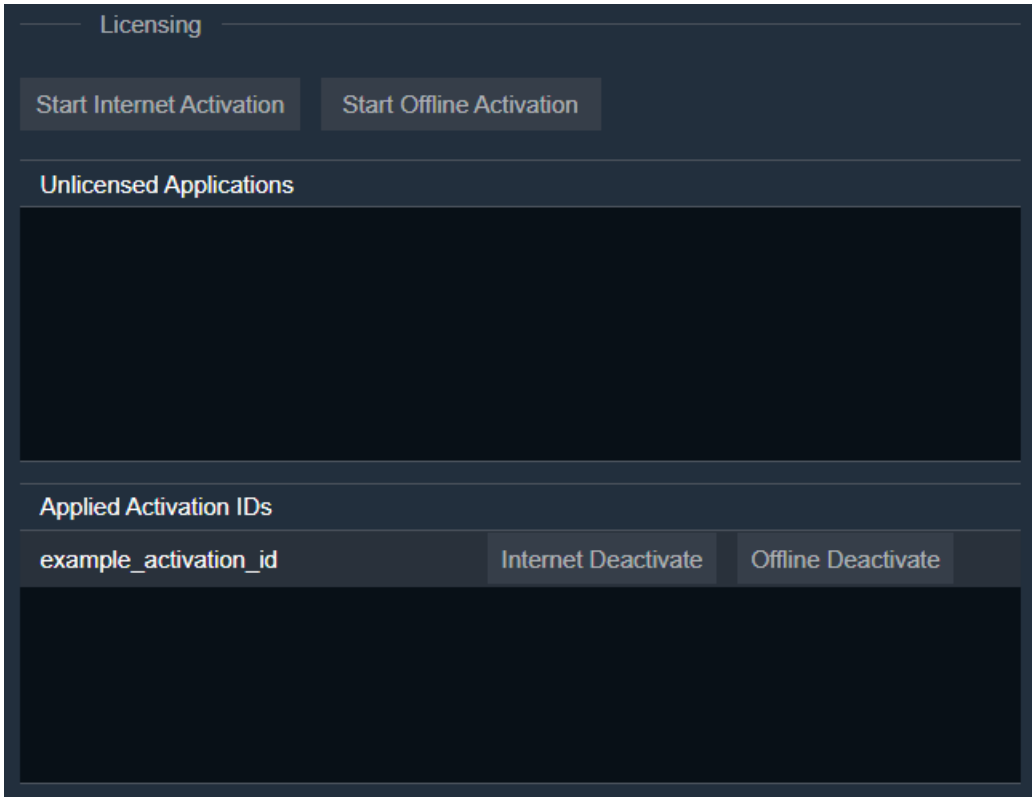


**Figure C.4 Synchrowave Internet License Deactivation**

# Offline License Activation

**NOTE**

Manual license activation and deactivation involve several steps including communication with SEL's licensing server. If either procedure is left unfinished, the license could be left in a state where it is not applied to your software, but it is considered deployed by SEL's licensing system. This situation can only be resolved by contacting SEL. **Please check your License Activation ID carefully before proceeding to the next step.**

Step 1. Install the Synchrowave Platform.

Step 2. Open the **Application Manager** via the Synchrowaveweb client.

Step 3. Select the **Platform Services** app.

Step 4. Select the **Start Offline Activation** button.

Step 5. Enter your License Activation ID (also called License Authorization Code, LAC) in the dialog box.

Step 6. Select the **Download Capability Activation Request** button (the button will be disabled until an Activation ID is entered).

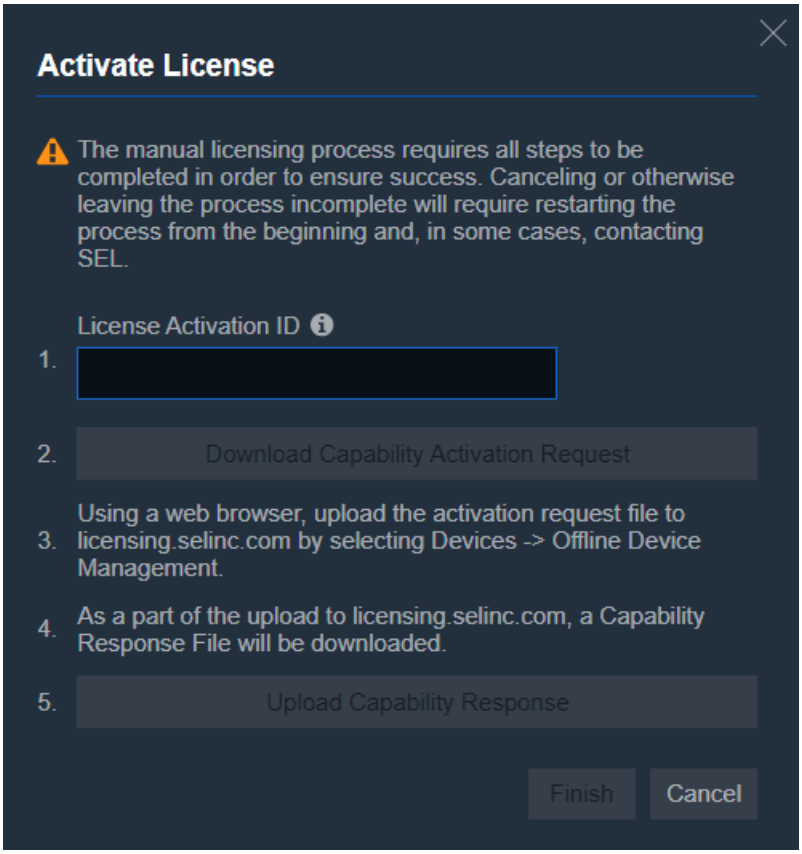


**Figure C.5 Synchrowave Manual License Activation**

Step 7. Save the **Capability Activation Request** file to a thumb drive or a network drive that can be accessed by a computer that has internet access, or email the **Capability Request** file to SEL.

Step 8. From a computer that has internet access, go to **https://licensing.selinc.com** and log in with the activation ID you are activating.

**Figure C.6 SEL Licensing Portal Login Screen**

Step 9. From the **License & Delivery** portal page, click the **Devices** tab and click **Offline Device Management**.

Step 10. From the **Offline Device Management** page, click **Browse** and select the Capability Activation Request File generated in *Step 7*.

Step 11. Click **Upload**.

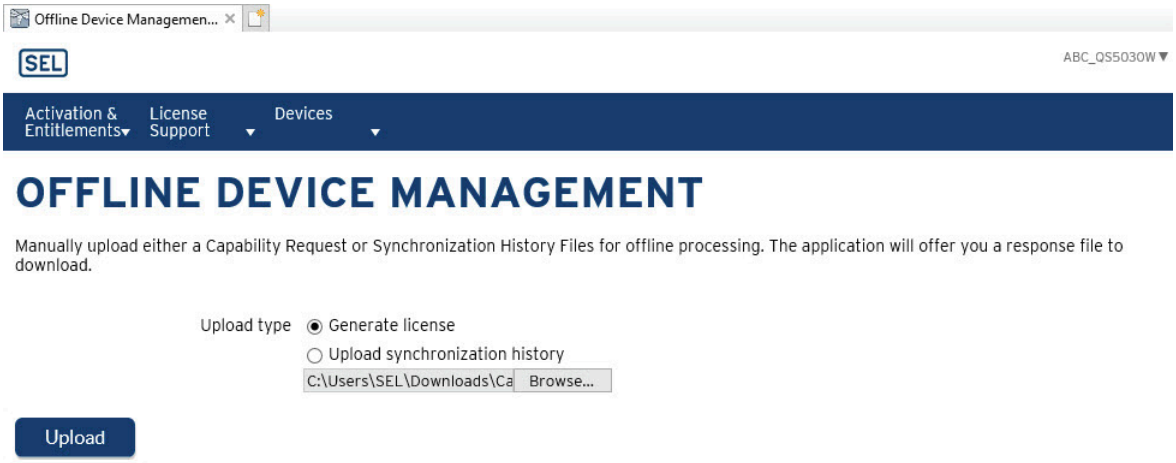


**Figure C.7 Upload Capability Request**

Step 12. Click the link highlighted at the top of *Figure C.8* to download the **Capability Response** file.

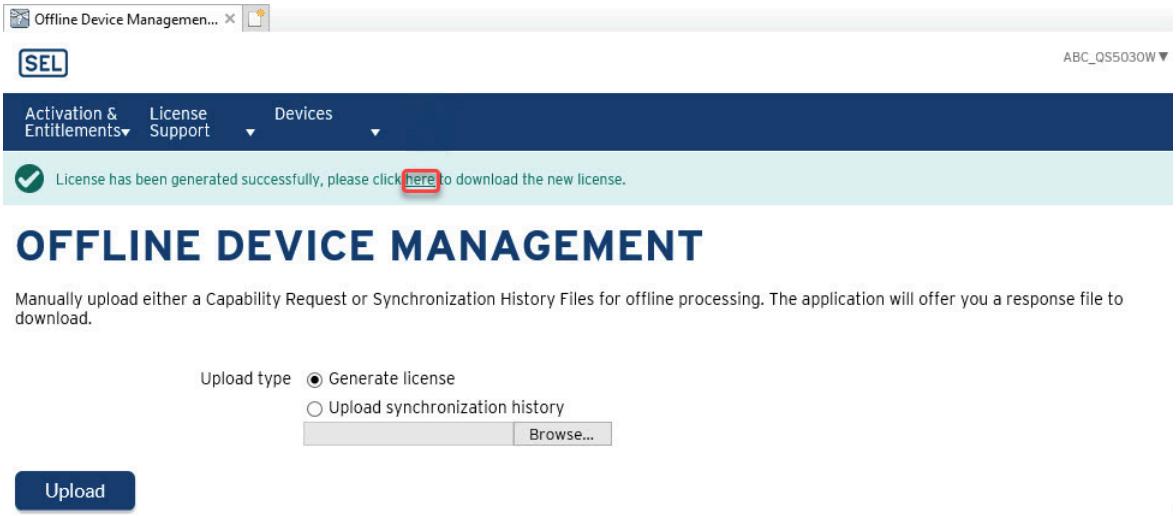


**Figure C.8 Link to Download Capability Response File**

Step 13. Click **Save**.

**Figure C.9 Save the Request File**

Step 14. With the **Capability Response** file saved in *Step 13*, return to the computer where the Synchrowave license is being activated.

Step 15. From the **Activate License** dialog box, click **Upload Capability Response**.

Step 16. Navigate to the location of the **Capability Response** file created in *Step 13* and click **Open**.

Step 17. Click the **Finish** button when it appears.

Step 18. If activation is successful, any applications licensed with the activation ID are removed from the Unlicensed Applications list, the ID appears in the Applied Activation IDs list, and if all applications are licensed, the licensing warning banner should disappear after a few seconds.

# Offline License Deactivation

Step 1. Open the **Application Manager** via the Synchrowave web client.

Step 2. Select the **Platform Services** app.

Step 3. Select the **Offline Deactivate** button associated with the desired license from the Applied Activation IDs list.

Step 4. Select the **Download Capability Deactivation Request** button.

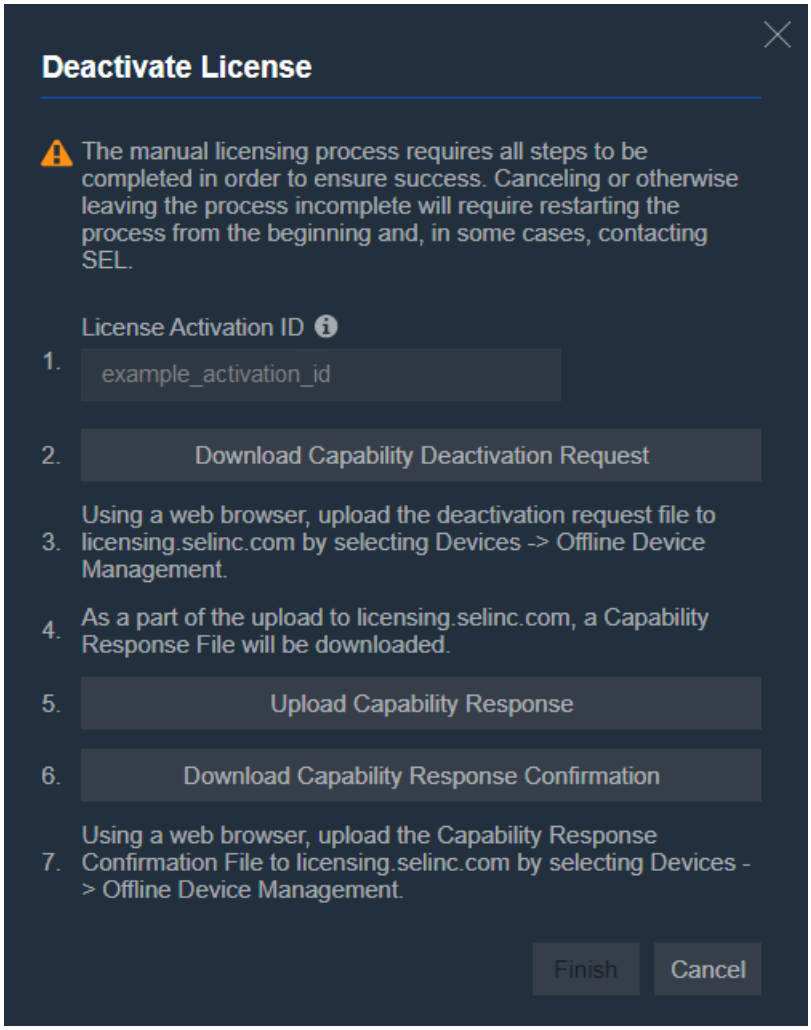


**Figure C.10 Synchrowave Manual License Deactivation**

Step 5. Save the **Capability Request** file to a thumb drive or a network drive that can be accessed by a computer that has internet access, or email the **Capability Request** file to SEL.

Step 6. From a computer that has internet access, go to **https://licensing.selinc.com** and sign in with the activation ID you are deactivating.

Step 7. From the **License & Delivery Portal** page, click the **Devices** tab and click **Offline Device Management**.

Step 8. From the **Upload Capability Request** page, click **Browse** and select the **Capability Request File** generated in *Step 5*. Click **Upload**.

Step 9. Click the highlighted link to at the top of *Figure C.11* to download the **Capability Response** file.

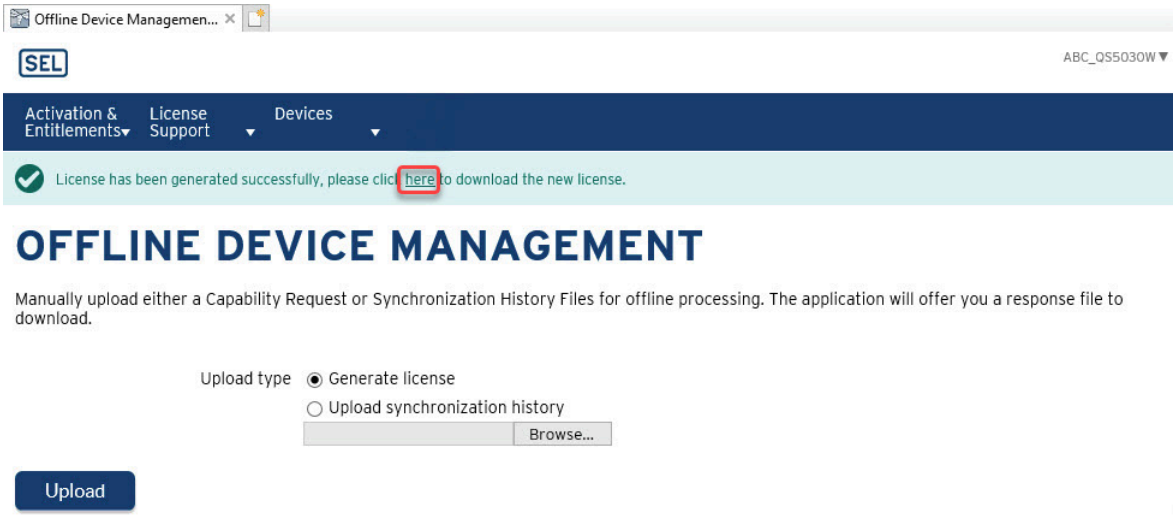


**Figure C.11 Link to Download Capability Response File**

Step 10. Click **Save** on the message similar to *Figure C.12*.

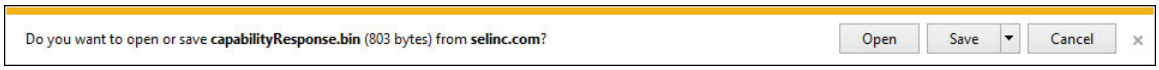


**Figure C.12 Save Capability Request File**

Step 11. With the **Capability Response** file saved in *Step 10*, return to the computer where the Synchrowave license is being deactivated.

Step 12. From the **Deactivate License** dialog box, click **Upload Capability Response File**.

Step 13. Browse to the location of the **Capability Response** file created in *Step 10* and click **Open**.

Step 14. Wait until the confirmation message that indicates success.

Step 15. Click the **Download Capability Response Confirmation** button.

Step 16. Provide a name and location for the **Capability Response Confirmation** file and click **Save**.

Step 17. From a computer that has internet access, go to **https://licensing.selinc.com** and log in with the activation ID you are deactivating.

Step 18. From the **License & Delivery Portal** page, click the **Devices** tab and click **Offline Device Management**.

Step 19. From the **Upload Capability Request** page, click **Browse**, click the **Capability Response Confirmation** file generated in *Step 16*, and click **Upload**. After you upload the confirmation file, the FlexNet software generates another response file. This additional response file is not required and does not need to be downloaded.

Step 20. Click **Finish** on the **Deactivate License** dialog box. The activation ID that was deactivated no longer appears in the Applied Activation IDs list.

# Rehosting an Existing License

To transfer a license from an existing Synchrowave Platform installation to another, you must first deactivate the license using one of the procedures described previously and then activate the license on the new installation.

**Important Note:** If the machine with the existing license is no longer available to perform the deactivation (e.g., due to hardware failure), please contact SEL at synchrowave@selinc.com to have it manually deactivated.

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APPENDIX D

# 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 15*).
- Authorization roles are configured.
- A trusted HTTPS certificate is configured (see *Configuration of HTTPS on page 13*).
- 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 102*.

### 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 16* 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 105*.

# 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.

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