Statistical Process Control

VERSION 6.5

Contents

Introduction

This document is intended as a user guide for importing and using the SPC (Statistical Process Control) accelerator developed by PTC. This accelerator provides ThingWorx entities that can be used and extended as needed when building SPC applications. It is intended only as an accelerator to provide a starting point and is not a commercial product or supported solution.

The accelerator provides a no code required method for monitoring the following SPC rules:

- Points above UCL or below LCL.
- *n* of *n* +1 points above/below 2 sigma
- *n* of *n* +1 points above/below 1 sigma
- *n* points in a row above or below the center line
- Trends of *n* points in a row increasing or decreasing
- *n* points within 1 standard deviation of the mean on either side of the mean
- *n* points in a row alternating up and down
- *n* points outside 1 standard deviation of the mean on either side of the mean
- *n* points above/below 1 sigma, 2 points one above, one below 2 sigma
- Range/StDev/Moving Range Out of Control
- Process outside of design limits
- CP/CPK < 1

This accelerator requires a minimum version of 9.1.6. Use with ThingWorx 9.0 or prior versions of 9.1 is untested and may not function as expected.

This accelerator also assumes some familiarity with SPC concepts. Links for further information about SPC Rules are provided at the end of this document.

1

Installation

Overview

The SPC Accelerator is installed as a ThingWorx extension, which is a collection of entities packaged together. These entities support the execution of numerous statistical calculations inside of ThingWorx. It also contains all the application entities, such as the mashups that display the insights. The name of the extension to be installed is SPC6.5.

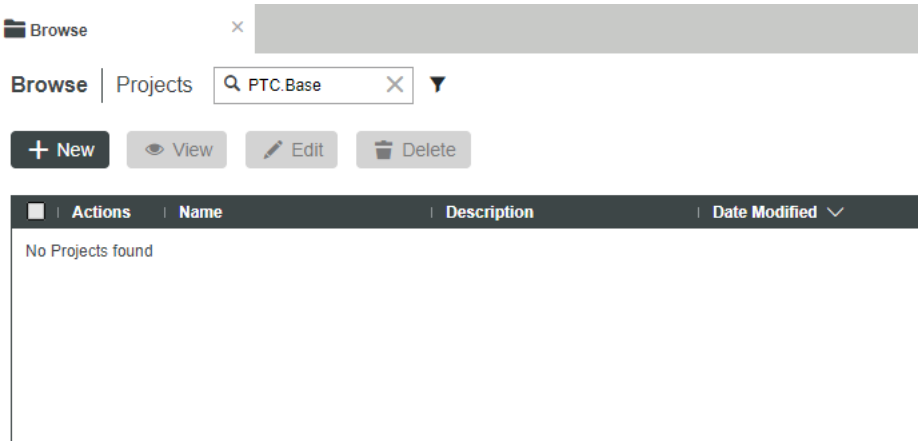
The installation will create a project named PTCDTS.SPC.
The project contains all the necessary mashups, Things, data shapes, styles and other entities required by the accelerator.

Importing the SPC Building Block

The latest SPC was developed with PTC's Building Block approach. As a result, the extension needs to be both imported and initialized before it can be used. There are two methods that can be used to initialize the extension.

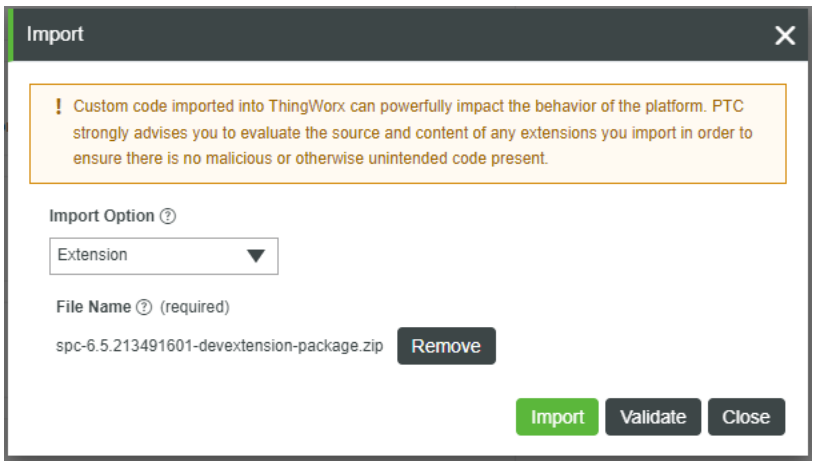
Method One: Use if other PTC Building Blocks are not installed
This is the preferred method of initialization, but it can only be used if there are no other ThingWorx accelerators or applications installed that use PTC Building Blocks.

To verify there are no other Building Blocks installed, select Projects from the left side ThingWorx menu and browse for a project called PTC.Base.



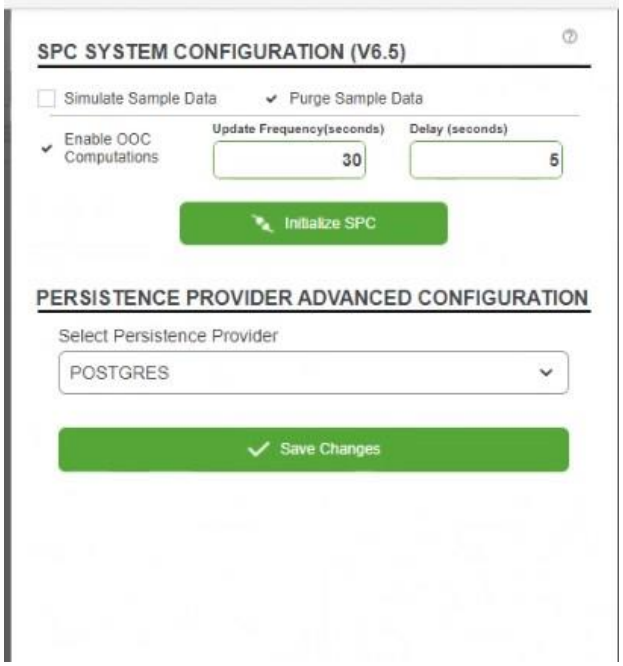
If a project with this name is found, please follow the instructions in outlined below in method two.

To install the accelerator, select the Import/Export option in the ThingWorx application. Select the option to import an extension and the location of the file containing the *SPC6.5 Package.zip* file. Select the green Import button to import to ThingWorx. A warning will appear asking to refresh Composer for newly installed objects to appear. Select Yes to refresh Composer.



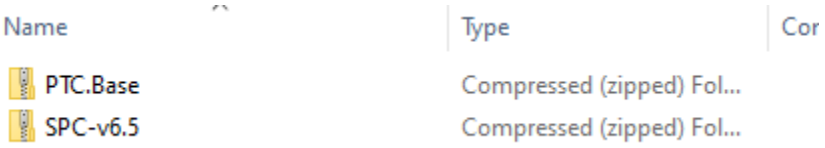
Open the *PTCDTS.SPC.Main_MU* Mashup and view the mashup. In the lower left corner, select the System Configuration icon. In the popup, click the green button labeled Initialize SPC. After clicking, this might

take a few seconds to perform the configurations in the background. If initialization works correctly, the button should disappear.



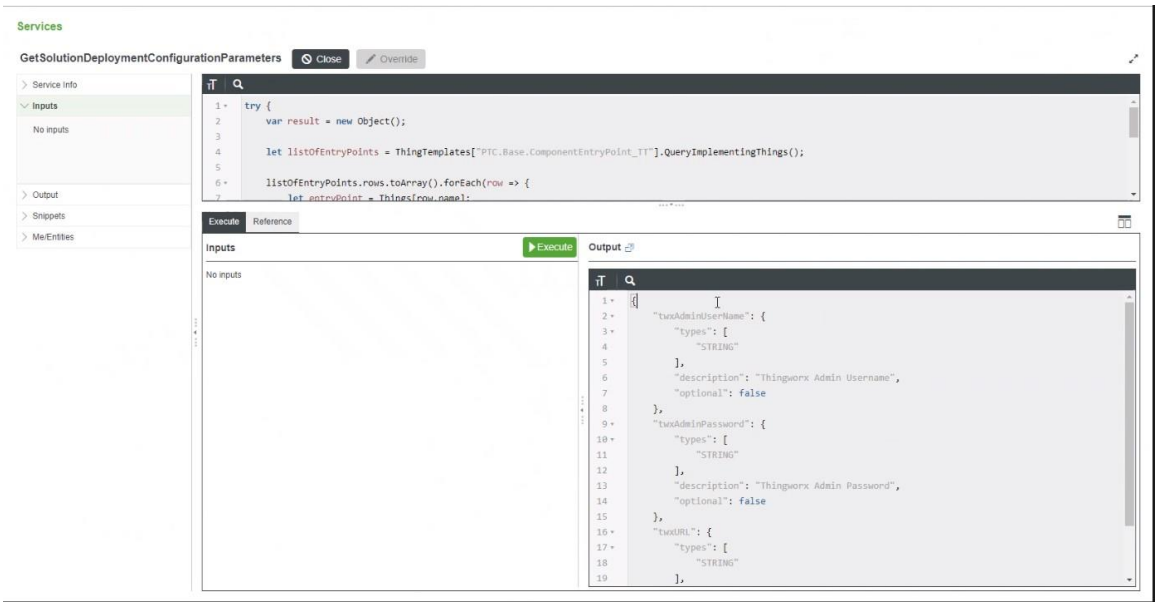
Method Two: Use if other PTC building blocks are installed

If PTC.Base is already installed in the environment, unzip the *SPC6.5 Package.zip* file. Select the Import/Export option in the ThingWorx application and import only the *SPC-v6.5.zip* file that was contained in the unzipped package file. Do not install the package zip file or the PTC.Base zip file that was included inside the package. Once imported a warning will appear asking to refresh Composer for newly installed objects to appear. Select Yes to refresh Composer.



Once installed, open the PTC.Base.Manager Thing and select Services. Open the GetSolutionDeploymentConfigurationParameters service and select the green execute button in the lower right hand corner. Copy

the JSON results that from the Output window, these will be used to initialize the building block.



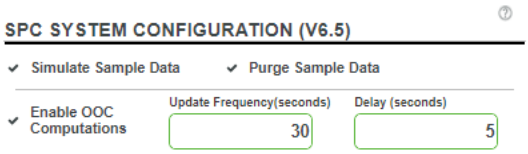
Click the black Close button and select the InitializeSolution service. Paste the output of the previous service into the deploymentConfig window and select the green execute button.

SPC Components

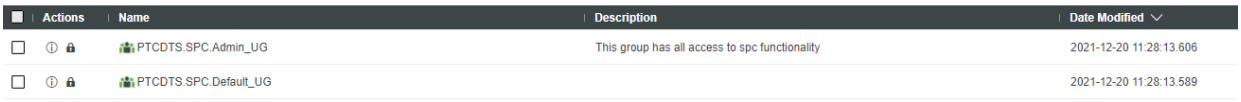
The PTCDTS.SPC.EntryPoint thing implements the PTCDTS.SPC.EntryPoint_TT thing template and contains the required services for component management, such as getting the component name and version.

The main entities that power the SPC accelerator are contained in a Thing named PTCDTS.SPC.Manager. An index of the services contained in this Thing are provided in Appendix A. The main entry point to the application is the mashup named PTCDTS.SPC.Main_MU. Viewing this mashup will provide access to all the functionality described within this document.

The System Configuration screen launched from the lower left side menu provides the option to set the Update Frequency for the application. SPC computations are 'near real-time' for performance considerations. By default, this value is set to compute every 30 seconds.



The SPC extension also provides user management to limit configuration access to only admin users. The problems, monitor and history pages are accessible to all users in the default user group. The problems, monitor, history, asset config, and system config pages are all accessible to SPC admin users. Note that SPC admins do not necessarily need to be ThingWorx admins.

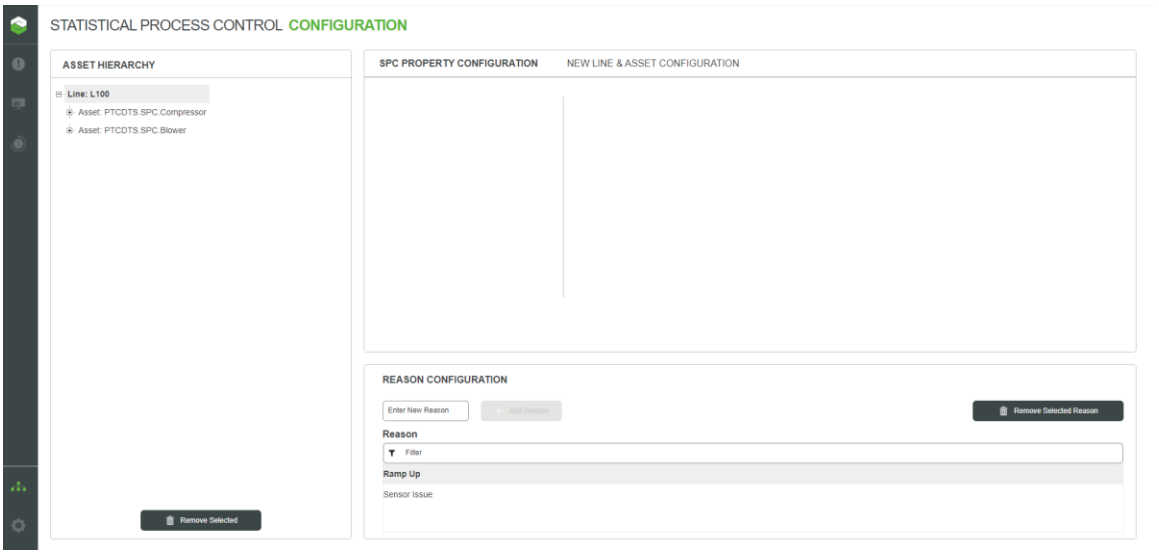


2

Configuration

Adding Lines and Assets

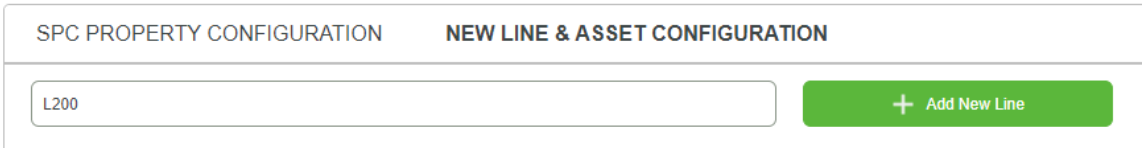
The user may configure SPC monitoring for multiple production lines, connected assets on those lines, and properties on those assets using the configuration mashup. This is done by the opening the PTCDTS.SPC.Main_MU mashup and selecting Asset Configuration from the bottom of the left menu bar.



How to Add Production Lines:

1. Click on the New Line & Asset Configuration link, enter a production line name in the text box prompting "Enter New Production Line Name".

2. Click the "Add New Line" button to add that line into the Asset Hierarchy tree shown in the Asset Hierarchy tree on the left.

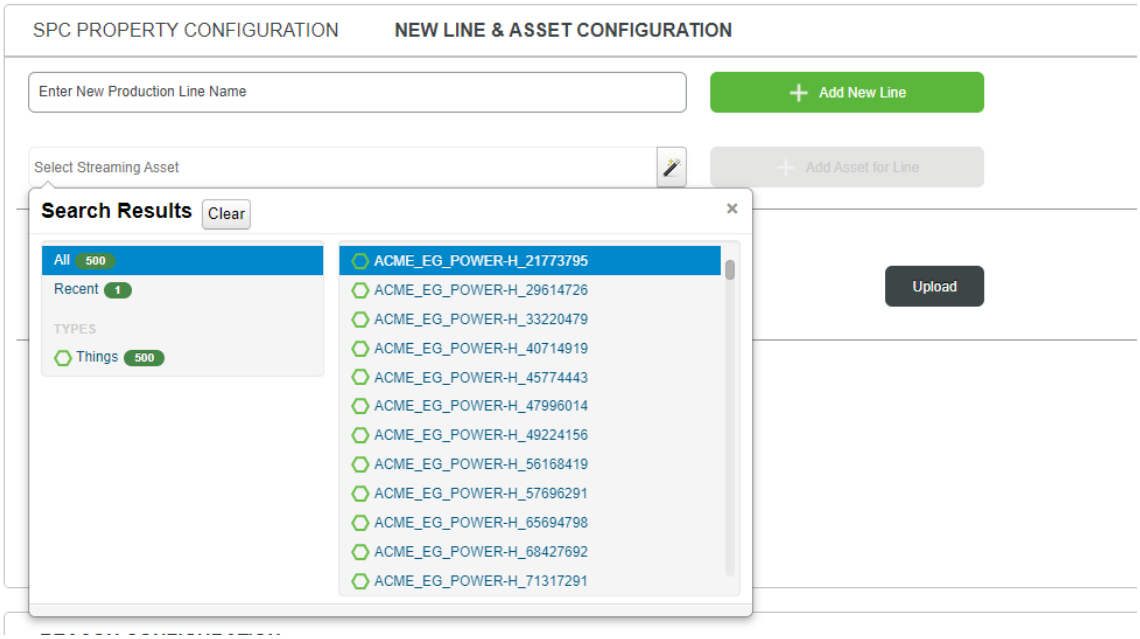


3. Select the newly created line from the Asset Hierarchy tree.

How to Add Assets to a Production Line:

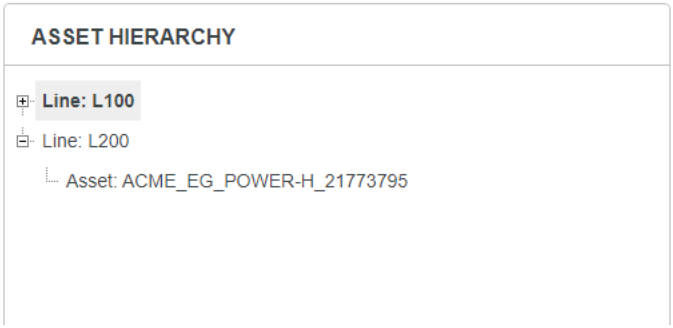
1. Select the production line that the new asset will be added to within the Asset Hierarchy tree.

2. Within the New Line & Asset Configuration area, enter the name of a connected streaming thing into the text box prompting "Select Streaming Asset". You can also use the Entity Picker to search and select an asset. Please note that if there an asset does not appear in the search results it is likely because the user does not have permissions to view or access that entity. A system administrator would need to provide access to that entity for that user to add the asset to SPC monitoring.



3. Click the "Add Asset for Line" button to add that streaming asset into the Asset Hierarchy tree.

4. Select the streaming asset from the Asset Hierarchy Tree to enable the SPC Property Configuration area. In this area you will see a list of Properties Eligible for SPC Monitoring



Note: If both the line and asset aren't selected, the button will be disabled

Adding Properties

The steps listed below will add or update monitoring of an SPC property for a line and asset combination.

1. In the SPC Property Configuration link, select the desired property from the list of Properties Eligible for SPC Monitoring. If the property is already being monitored, the current settings will be displayed in the boxes on the right. If the property is not currently being monitored, the default values for these settings will be shown.
2. Choose a chart type to be displayed on the SPC Monitoring Mashup. Available chart options are Xbar-R, IX-MR, Xbar-S, or np.

   Xbar-R – The Xbar and R chart is the most common SPC chart option. The Xbar chart shows the average value for each sample. The R chart displays variation in the sample by plotting the maximum value minus the minimum value each sample size.

   IX-MR – The IX-MR chart shows a moving range plot of individual points. Because individual values are displayed, the sample size must be set to 1 if creating this chart type.

   Xbar-S – The Xbar-S chart is similar to Xbar-R but plots the standard deviation of the sample size in the second grid instead of range.

   Np – The NP a type of control chart used to monitor the number of nonconforming units in a sample.

3. Modify any of the parameters within the SPC Property Configuration.

   Sample Size – This is the number of consecutive property values to be grouped together. For example, a Sample Size of 5 will tell the accelerator to group every 5 property values together and calculate their averages/standard deviations/ranges.

   XBar Points – Number of the most recent sample aggregations to display in the SPC Monitoring Mashup. This also affects SPC calculations.

   Capability Points – Number of the most recent sample aggregations to use when populating the Capability Histogram & CP,CPK in the SPC Monitoring Mashup.

Lower Design Spec – Value determined to be the lower design spec for that particular property on the asset. This is used for capability calculations.

Upper Design Spec – Value determined to be the upper design spec for that particular property on the asset. This is used for capability calculations.

Set Point – Value determined to be the set point for that particular property on the asset. Please note that this value is only used for visual reference in the capability histogram and not used in any SPC calculations.

4. Once the settings above have been provided, click the "Add or Update SPC Monitoring" button. This will add to property into the Asset Hierarchy Tree and begin SPC monitoring for new properties being added or will update the settings for an existing property being updated. If the property is selected from the hierarchy, you will see its currently configured properties in the configuration text boxes.
    a. The only assumption made for the SPC accelerator is that there exists a logged property in Thingworx.

When the "Add or Update SPC Monitoring" button is clicked, the SPC accelerator will automatically update an Infotable named "SPC_Properties" in the PTCDTS.SPC.ConfigurationHelper_TS Thing Shape. The accelerator will also add the asset to the AssetList Infotable in the same Thing Shape. The accelerator does not create copies of the data, but merely queries the data from the original logged property and applies calculations on top of that queried data.

The user may remove any line, asset, or property from the Asset Hierarchy tree by selecting it and clicking the "Remove Selected" button below the tree. If a line or asset are chosen, then all of its child elements in the Asset Hierarchy tree are also removed.

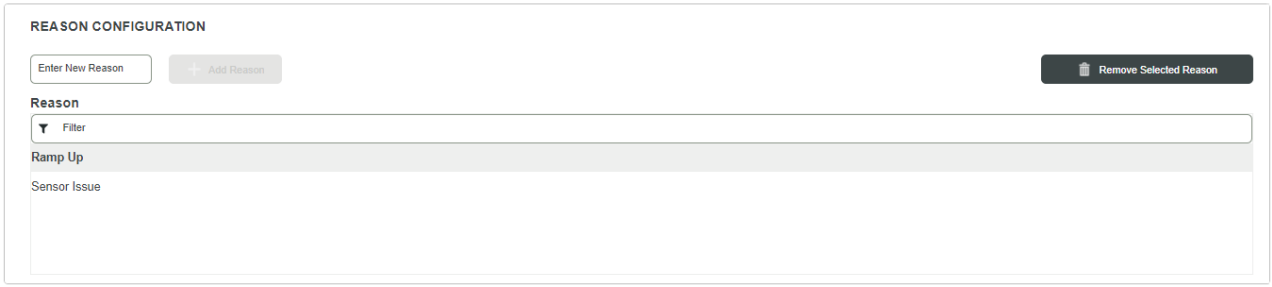
After SPC monitoring for a property begins, the Statistical Process Control Monitoring Mashup may contain red error bars until enough streaming data points have been collected to perform the required SPC monitoring calculations.

For example, if the default values of Sample Size = 5 and XBar Points = 30, then the Xbar chart will display an error until 3 x 50 = 150 datapoints have been collected. If the default values of Sample Size = 5 and Capability Points = 60, then the Capability chart will display an error until 5 x 60 = 300 data points have been collected.

Adding Reasons

Reasons are useful for adding explanations to explain or keep notes about out-of-control points that you wish to tag. You can add custom reasons for the selected line in the configuration screen. These reasons can be referenced when viewing the monitored properties for that line in the monitoring section, allowing the user to flag points with the explanations added on the configuration screen.

To create a new reason, type the reason in the Enter New Reason textbox and click Add Reason. There is also an option to remove selected reasons. Reasons that have already been created will appear in the list. A filter is available to view only reasons containing supplied text.



3

Problems

Overview

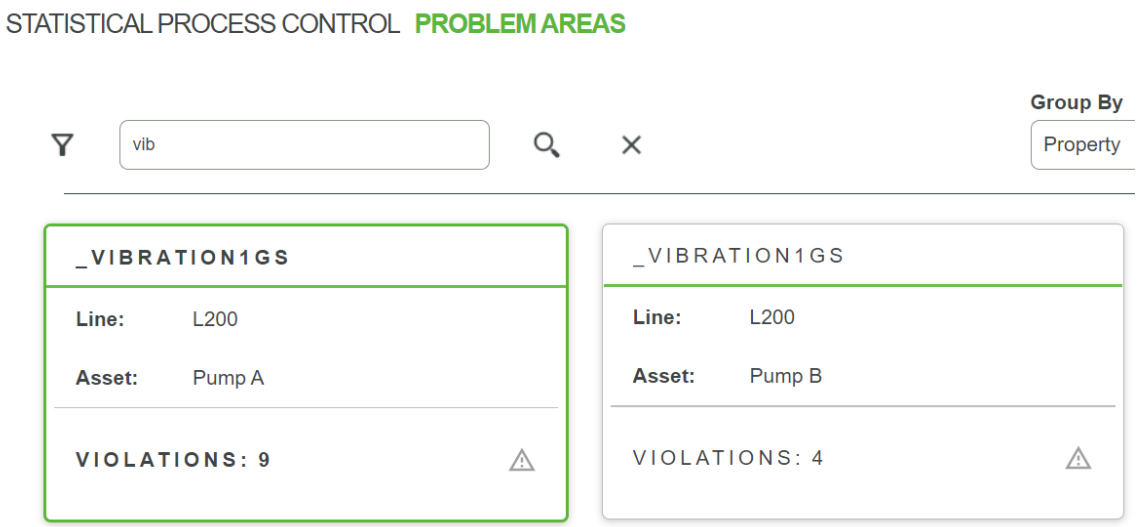
The problems screen provides an overview of the lines, assets, and properties with the most out of control behaviors. The summary cards are sorted with those cards that show the highest number of violations appearing at the top. The problem areas screen is an ideal first step to identify potentially problematic areas that need attention.

Usage

The menu bar at the top of the application page provides functionality to explore and consume insights from the identified problem areas.

The Group By dropdown provides a way to toggle between viewing by line, asset, or property.

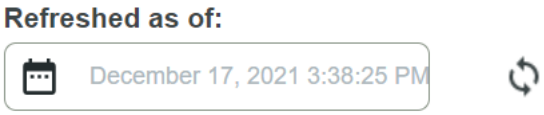
Adding text to the search text box and then clicking the magnifying glass icon will limit the cards shown below to match the provided search string. Note that the search will only work for the group that you are viewing. For example, if you are viewing problem areas by line and you search for an asset, no records will be returned.



Here is a sample of reading insights from the problems page:

If the asset/line card displays 9 violations, and 75% of properties have violations in it, that indicates that the total of 9 SPC violations on that asset/line and they are coming from 75% of the properties. If that asset has 4 properties being monitored, 3 out of those 4 properties have a total of 9 violations.

The date shown in the upper right side of the menu shows the date and time of the most recent data refresh. A manual refresh button is also available. In case the date field is empty, click on any card and that should populate the timestamp.



Monitoring Problem Areas

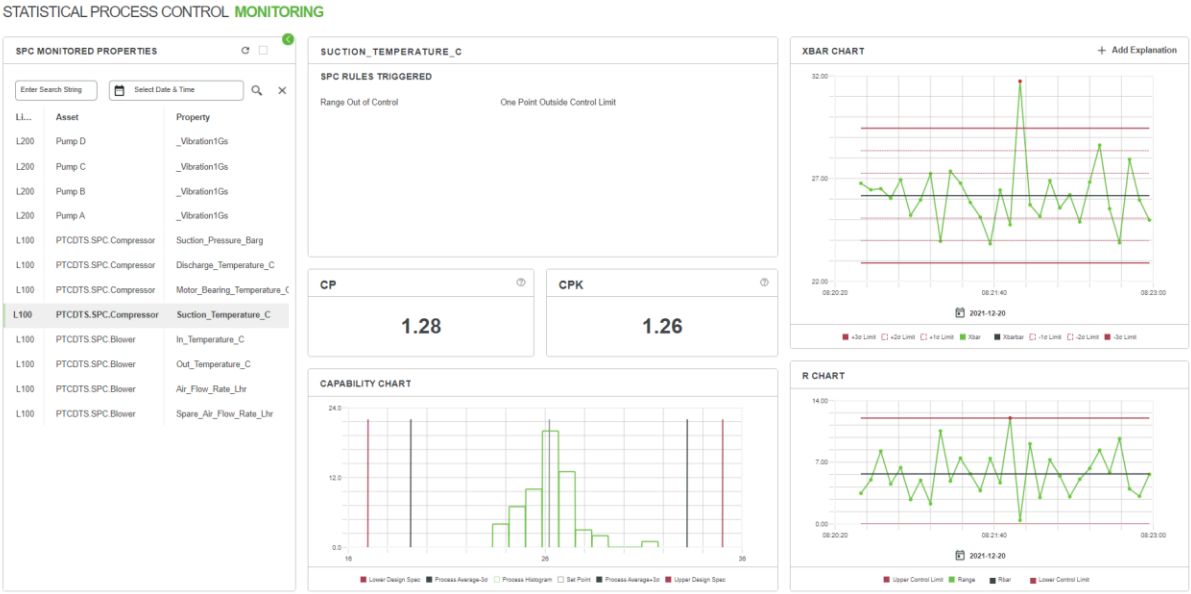
The Problem Areas screen can be used to drill into specific violations, once a particular line, asset or property has been identified for further investigation. Double clicking on any card will open the monitoring screen, where access to further details and historical charts is available.

4

Monitoring

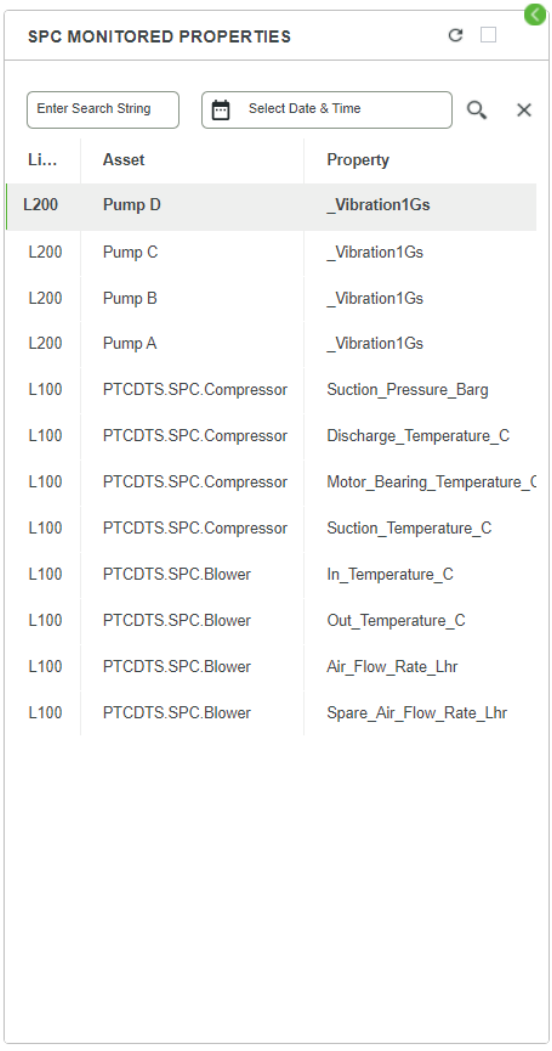
Overview

The monitoring screen shows a list of monitored properties for multiple production lines and connected assets on those lines along with visualizations of the distribution for recently collected data points. The main entry point to the monitoring screen is the mashup named PTCDTS.SPC.Main_MU.



Usage

Once the user has configured an SPC property using the SPC Configuration screen, that property is automatically added to the SPC Monitored Properties grid shown below. Also displayed in this grid are the line and asset the property belongs to.

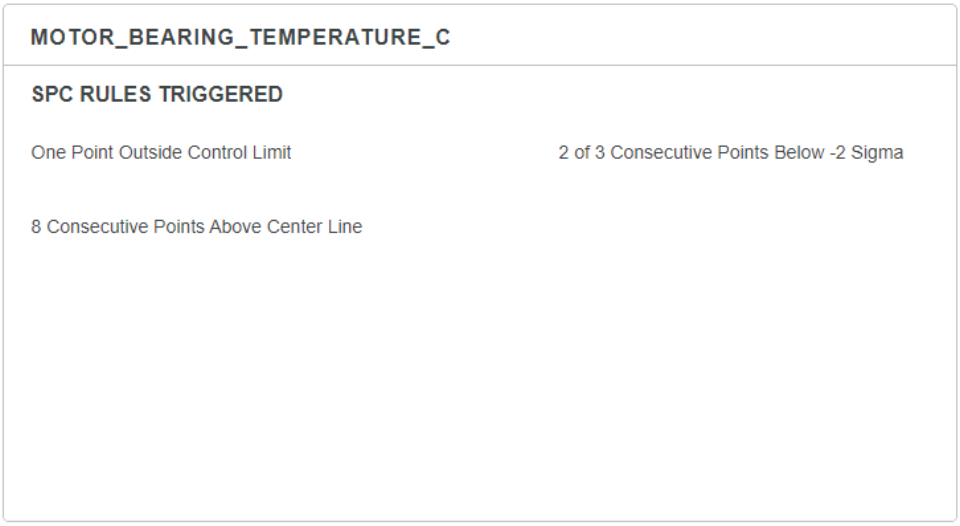


Li...	Asset	Property
L200	Pump D	_Vibration1Gs
L200	Pump C	_Vibration1Gs
L200	Pump B	_Vibration1Gs
L200	Pump A	_Vibration1Gs
L100	PTCDTS.SPC.Compressor	Suction_Pressure_Barg
L100	PTCDTS.SPC.Compressor	Discharge_Temperature_C
L100	PTCDTS.SPC.Compressor	Motor_Bearing_Temperature_C
L100	PTCDTS.SPC.Compressor	Suction_Temperature_C
L100	PTCDTS.SPC.Blower	In_Temperature_C
L100	PTCDTS.SPC.Blower	Out_Temperature_C
L100	PTCDTS.SPC.Blower	Air_Flow_Rate_Lhr
L100	PTCDTS.SPC.Blower	Spare_Air_Flow_Rate_Lhr

A search box is available to filter properties by a provided string. The date picker can be used to select a date and time from the past using the date picker. The charts on the SPC Monitoring Mashup will then update to reflect their respective values ending at that point in time. Any OOC rules that may have been violated at that time will also be updated. There is also a refresh button to manually refresh property values.

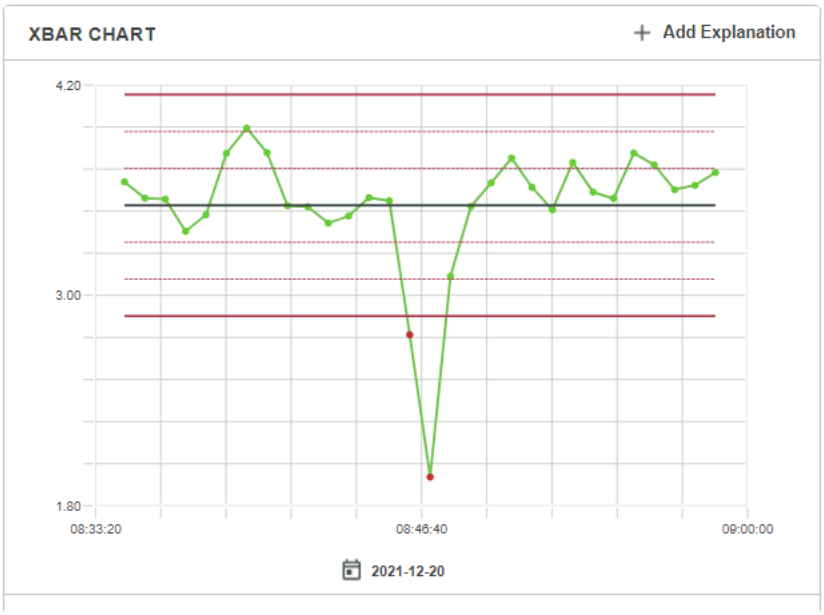
By default, the SPC Monitoring Mashup needs to be refreshed manually by clicking the "Refresh Now" button. The toggle to the left of it may be clicked to have the Mashup automatically update every 30 seconds

To the right of the SPC Monitored Properties list is the Out-of-Control Rules list, which shows the Out of Control (OOC) rules that the property is currently violating. If no rules are currently being violated this box will be empty. When a new property is added this area will show a message that SPC values are being collected. This is to be expected, as the SPC accelerator is currently collecting enough property values to satisfy the SPC configuration for that property.

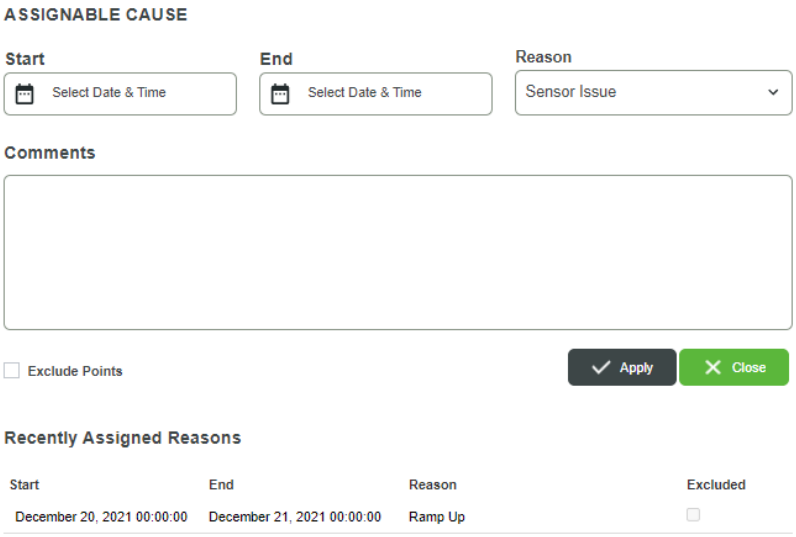


After enough property values have been collected for SPC monitoring, the rest of the graphs on the SPC Monitoring Mashup will fill with data.

In the XBar Chart, the user can see the latest *n* number of XBar points, where *n* is the XBar Points value the user entered in configuration mashup. These points are plotted along with the +/- 1Sigma, 2Sigma, and 3Sigma values for that property. If there are any points that fall outside of +/- 3Sigma, they will be highlighted in red.

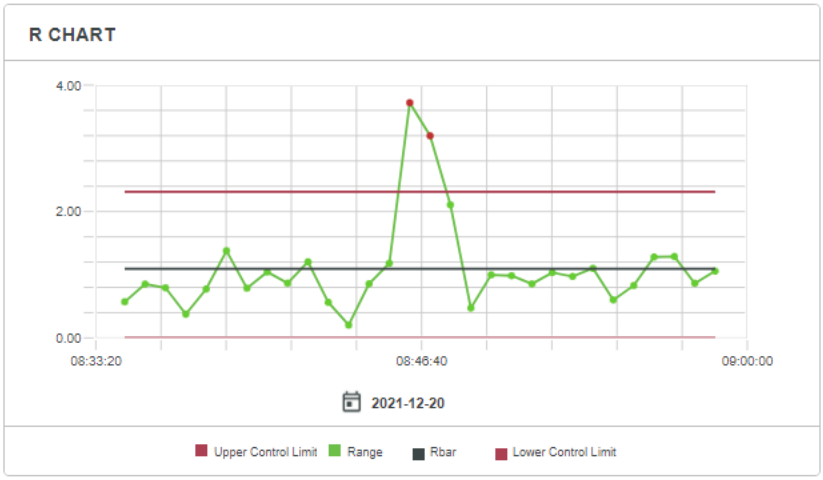


Clicking Add Explanation in the upper right of the XBar chart will open a popup that allows you to configure reasons (pre-configured in the configuration page) tagged to these instances of points. The reasons are time based – so choose a time period, assign a reason (setup earlier in the config page), add relevant comments and click Apply. If you want to exclude the point from the OOC reporting, select the Exclude Points check box. Previously assigned reasons will also appear in this screen. Reasons for assignable causes can be reviewed in the history page later.



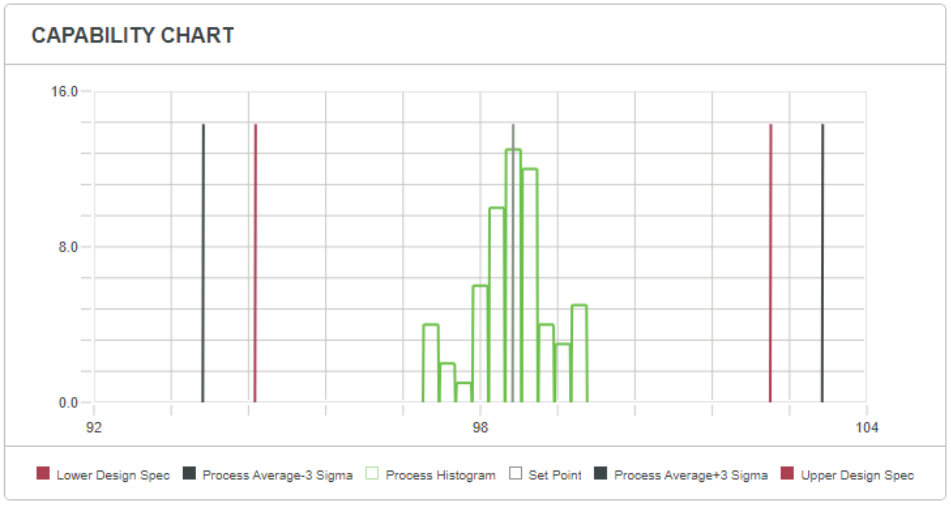
The R Chart in the lower right displays the range of values for each of the XBar Point subgroups. These values are displayed along with the upper and lower control limits that were calculated by the SPC accelerator. There are some SPC standard constants that are applied to compute limits. The bottom chart can be of 3 types – R/S/IX-MR:

- The R chart calculates the range values (Max - Min) in the XBar Point subgroups
- The S chart calculates the standard deviation of values of the XBar Point subgroups.
- The IX-MR will calculate the moving range between two consecutive points.



The CPK and CP displays show the current values at ending at the chosen timestamp from the top left. These are calculated by the SPC accelerator using the values that the user entered for set point, and upper and lower design specifications and # of points for capability during configuration.

The Capability Chart displays a histogram of the capability using the last n number of points from the chosen timestamp, where n is the Capability Points value the user entered during configuration. This is displayed along with the upper and lower design specifications, set point, and +/- 3Sigma values for that property.

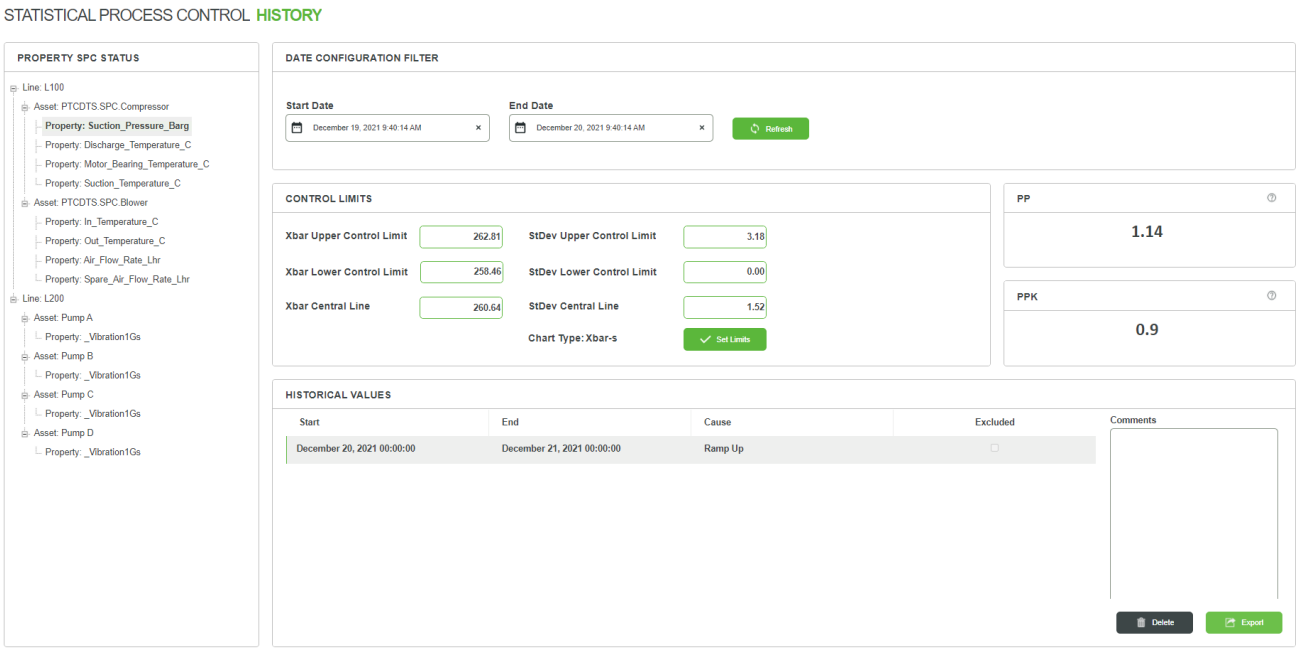


5

History

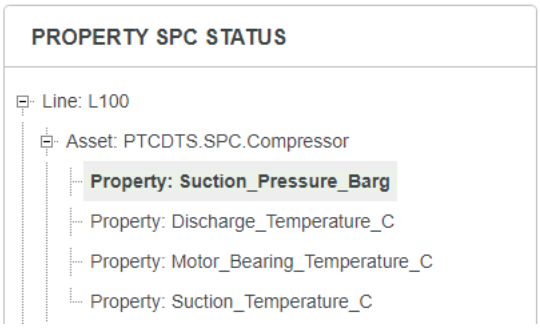
Overview

The History page offers the user option to understand past behavior of the system using process parameters like PP and PPK computed using SPC data of the past, as well as identifying optimal control parameters based on the date range selected.

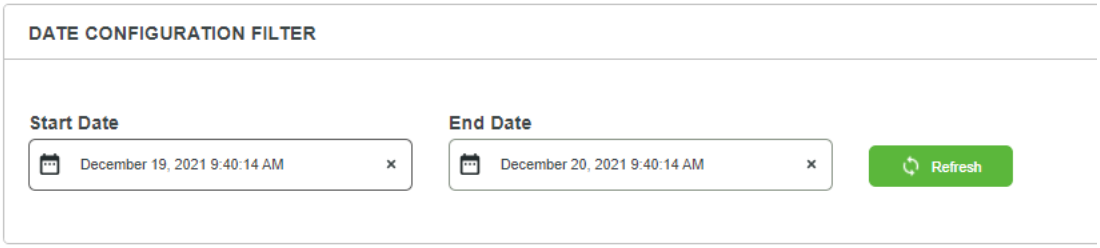


Usage

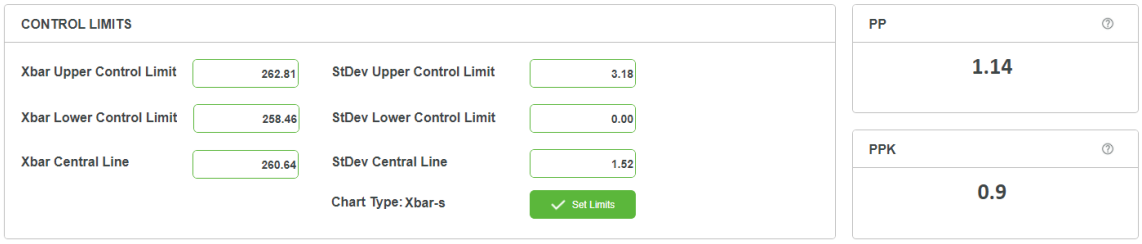
Begin by selecting the property from the Property SPC Status grid. This will invoke the SPC calculations based on the date range shown in the Date Configuration Filter.



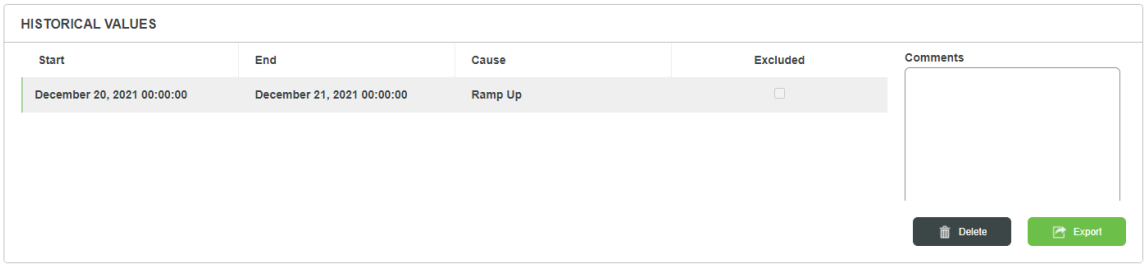
The date range from the Date Configuration Filter can be changed to a user supplied range. Changing the values in the filter will trigger the SPC Accelerator to calculate the appropriate control limits as well as process parameters based on the data seen within that date range.



The control limits, PP, and PPK for the supplied property and date range will appear in the Control Limits section. Clicking on the Set Control Limits button, will trigger an update to the set points of the selected property based on the values provided by the computation from the historical data.



Any added explanations assigned in the monitoring screen will appear in the Historical Values section. Double clicking on any row in the historical values grid will bring up the Assignable Cause window to edit the supplied values, such as reason and comments, for that explanation. Clicking on the Export button on the bottom right will trigger a .csv export of the historical values table for further analysis.

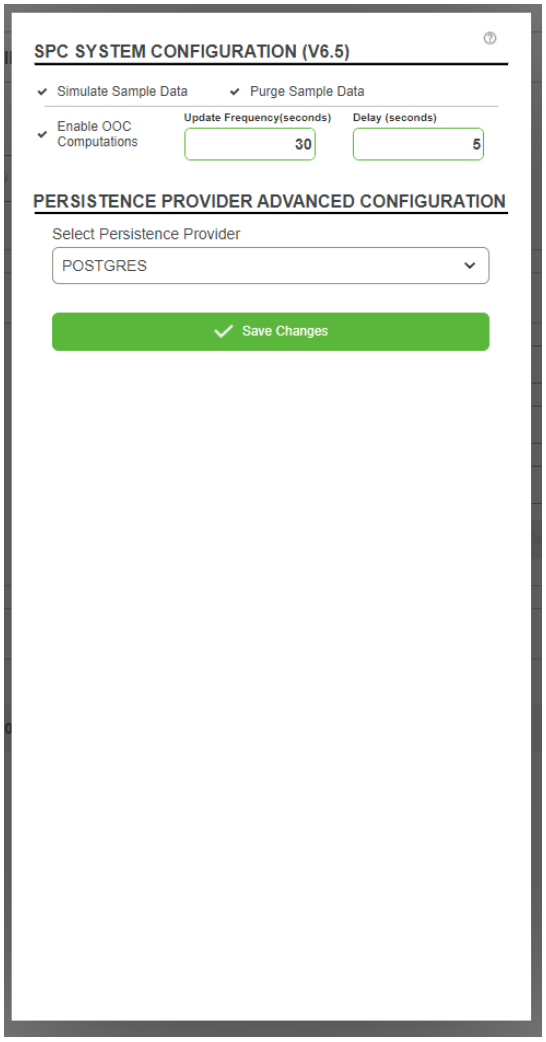


6

System Settings

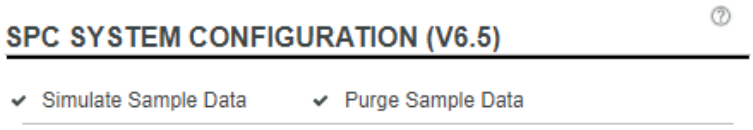
Overview

The System settings screen is used to configure system wide settings for the application. This includes sample data simulation, background computations and advanced persistence provider settings.

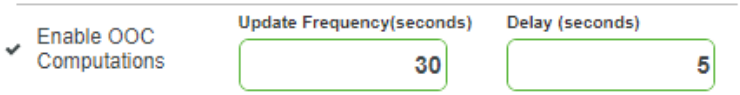


Usage

The simulate sample data check box enables simulated data from to demo assets – the Blower (*PTCDTS.SPC.Blower) and the Compressor (PTCDTS.SPC.Compressor)*. By default, the *purge sample data* is enabled, to not flood the database with demo data.

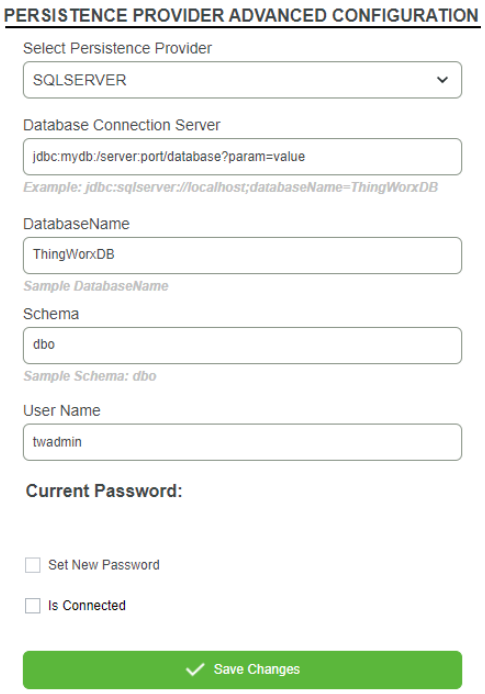


The OOC Computation section configures the timer in the background, to perform the OOC computations asynchronously. This is for performance considerations. The frequency sets the rate at which these background computations are performed. Sometimes, writes to the database can get queued and there may be delays in write completions, the delay parameter is designed to account for this delay.



The advanced persistence Provider settings are designed to be able to query the database directly instead of querying through Thingworx. Currently, there are 3 persistence providers supported: Postgres, SQL Server & InfluxDB. Custom configurations might help for larger number of properties being monitored.

- Postgres: No custom settings available
- SQL Server: SQL User needed on the database
- InfluxDB: Queries based on REST requests, user/password required.



Appendix A: SPC Services

PTCDTS.SPC.SPCCalculations_TS

The calculations used within the SPC mashups are contained within the PTCDTS.SPC.SPCCalculations_TS Thing Shape. OOC violations are contained in an infotable property in this Thing Shape (Implemented by the PTCDTS.SPC.Manager thing). A description of the services that perform statistical calculations for a set of points within this Thing Shape is provided below.

- CalculateDateFromTimestamp – returns the most recent datetime for a supplied infotable of timed values
- CalculateLongTermSPCLimits – establishes long term control limits based on a provided set of SPC points on the history page
- CalculateProcessCapability – returns an infotable containing the CPK and CP calculation results
- CalculateProcessPerformance – computes process performance
- CalculateSPCStatsAndLimits – returns metrics such as UCL, LCL, 1 and 2 Sigma from a supplied set of points for a specific property
- ComputeSPCPoints - returns an infotable containing XBar and XVar points
- GetCapabilityChart – returns an infotable of values for the capability chart
- GetChartLimitLines – returns an infotable of computed chart limits to display on the mashups
- GetOOCStatus - returns an infotable containing the list of OOC rules that were violated by that monitored property
- GetXBarChartPoints - returns an infotable of XBar time, values and a Boolean indicating if the value is OOC for a supplied property
- GetXVarChartPoints - returns an infotable of XVar time, values and a Boolean indicating if the value is OOC for a supplied property
- QueryDataFromMultiplePersistenceProviders – queries values from Postgres, SQL Server and InfluxDB databases based on whether custom persistence providers were configured to be used
- RetrieveOOCProperties – retrieves values from the OOCViolations property infotable
- ReturnActiveSPCPoints – returns an infotable of time and values for a supplied property

PTCDTS.SPC.ConfigurationHelper_TS

The PTCDTS.SPC.ConfigurationHelper_TS Thing Shape is what powers both the PTC.SPC.Configuration_MU and PTC.SPC.Monitoring_MU Mashups. This thing has several infotable properties that contain the names of the lines, assets, and properties that have been configured for SPC monitoring, as well as the chart types that can be displayed in the PTC.SPC.Monitoring_MU Mashup. When the user configures an SPC property to monitor, these properties are updated.

- AddNewAsset – takes a production line name and asset name and adds those to the properties on the PTC.SPC.ConfigurationHelper.
- AddNewProductionLine – takes a production line name and adds it to the properties on the PTC.SPC.ConfigurationHelper.
- AddNewReason –adds a new reason to the Reasons property infotable for a specified production line
- AddOrUpdateSPCTrackingOnProperty – Adds the chosen property along with its specifications into the SPC_Properties infotable
- CreateSPCTrackingFromCSV – creates SPC production lines, assets and simulated data from a csv located in the PTCDTS.SPC.FileRepo. The file can also be uploaded through the Asset Configuration mashup in the SPC application.
- DeleteExplanation – deletes a previously created explanation for an SPC property
- GetAssetProperties – returns an infotable containing a list of properties that exist on a connected streaming asset that are eligible for SPC monitoring. This list is displayed in SPC Configuration Mashup. Eligible properties are ones that are numeric data types.
    - If you expect a property to show up but it isn't, verify that the datatype of the property is numeric on the thing being monitored.
- GetProductionLineList – returns an infotable containing a list of production line names that have been configured.
- GetSystemSetup – used for retrieving the default SPC System settings, seen on the System Settings page in the UI
- InfotableRowcount – returns the record count for a supplied infotable
- IsPropertySelectionValid – used internally to manage grid/button refreshes. Do not alter.

- RemoveAssetHierarchyItem – removes the name of a line, asset, or property that has been configured for SPC Monitoring from the PTC.SPC.ConfigurationHelper. It also deletes any children of the selected level of the hierarchy, if any.
- RemoveReason – removes a reason from the reasons property infotable for a specified production line
- RetrieveAssetHierarchy – returns an infotable that is used to populate the Asset Hierarchy tree, the list of Properties Eligible for SPC Monitoring, all the numeric entry fields, and the chart type picker on the SPC Configuration Mashup.
- RetrieveAssignedCauses - returns an infotable of all assigned causes and comments. The buffer days input can be used to additional days before and after the selected time interval
- RetrieveChartTypes – returns an infotable containing a list of possible chart types that the user may select when configuring an SPC property. This selected chart type is then displayed in the SPC Monitoring Mashup.
- RetrieveDefaultSelectionForMonitoredProperty – returns an infotable that allows the SPC Monitoring Mashup to automatically select the top row of the Property SPC Status grid when loading.
- RetrieveDefaultSelectionForReasonList – returns an item list from a supplied infotable
- RetrieveMonitoredProperties – retrieves a distinct list of production line, asset and properties being monitored
- RetrieveMonitoredPropertiesPage – returns monitored properties by page
- RetrievePersistenceProviders – Returns Persistence Providers available in thingworx
- RetrieveReasons – Retrieves records from the reasons property infotable for a selected production line
- RetrieveSupportedPersistenceProviders - retrieves records from the SupportedPersistenceProviders property infotable
- ReturnCurrentTime – returns the current date, which is used to properly display the charts in the SPC Monitoring Mashup.
- ReturnCurrentTimeMinusOffset - returns the current date a with a supplied minutes offset applied
- ReturnDefaultSearchString – returns an empty string. Can be modified to supply a custom default search string. This search string gets applied to the monitoring mashup

- ReturnFilteredQuery – returns an empty string if not custom query is supplied
- ReturnMonitoringTime – Returns current time or a supplied timestamp
- ReturnOOCPropertyID – Returns the lines, assets and related unique ID of the selected property being monitored (from the monitoring page)
- SetControlLimits – Writes supplied control limits to the CustomControlLimits property infotable
- SetExplanation – Writes an assignable cause to the AssignedReasonsAndComments property infotable
- SetSystemSetup – This service will save all system settings configured in the System Settings of the SPC application.

Appendix B: SPC Rules Reference

- **Western Electric Rules -** https://en.wikipedia.org/wiki/Western_Electric_rules
- **Capability -** https://en.wikipedia.org/wiki/Process_capability
- **Process Performance** - https://en.wikipedia.org/wiki/Process_performance_index