

Orbit Newsletter Digital Publication

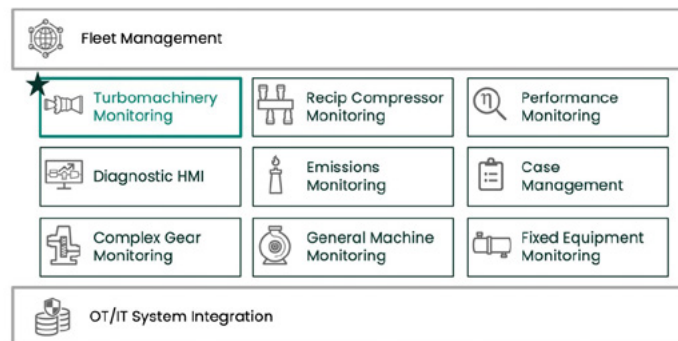
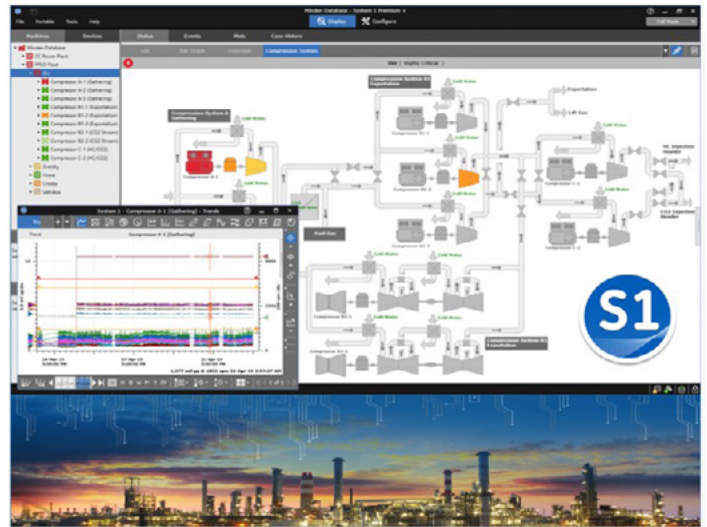
Q1 2021

System 1 use case: turbomachinery monitoring

Introduction

Process-intensive Industrial Operators are increasingly wading into the Digital Transformation revolution to streamline production in the face of globalization, a shifting workforce, and heightened cyber security threats. Delivering safe, reliable, and environmentally friendly operations while maintaining a competitive advantage over peers is virtually unachievable without intelligent adoption of technology and cultural acceptance of changes to long standing processes.

Bently Nevada has been partnering with customers to help solve these challenges. Through user research in 25 countries with more than 500 end users, we have studied our customers' team dynamics, site processes, and technology suites to determine how **System 1** can best support Plant-Wide Machinery Management. The resulting platform meets a variety of unique customer use cases, with each use case leveraging a subset of System 1's Connectivity, Analytics, and Visualization capabilities. This Orbit Article explores the **Turbomachinery Monitoring** use case and the application of System 1 for proactive, real-time, and reactive monitoring of this highly critical asset class.



Turbomachinery monitoring, a key use case of System 1

Challenge

Turbomachinery is often the most-critical rotating equipment within an industrial process. As such, this machine class has been instrumented and monitored as part of Condition Monitoring Programs for decades. Bently Nevada's System 1 Classic, with its rich set of tools for real-time and reactive vibration monitoring, has long been considered the best-in-class turbomachinery diagnostics application and is an essential tool for many industrial operators around the globe.

However, digital transformation has driven operators to seek out a single condition monitoring application that extends beyond vibration and real-time monitoring. They ask:

- How can we establish operating context for turbomachinery by combining vibration, process, and control system data within a single application?
- How can we consolidate our toolset to monitor and manage turbomachines alongside our other operating equipment?
- How can we parse through our rich (and overwhelming) data set to extract insights to proactively detect evolving machine conditions?
- How can we supplement a retiring, expert workforce to ensure that we maintain and improve upon our operating efficiency?

System 1 solution

System 1 Evo, the next generation System 1 offering, has maintained the deep diagnostic capability-set that made System 1 Classic so essential to monitoring turbomachinery. However, it has been greatly enhanced to meet the evolving digital transformation needs of our customers.

Today, System 1 has broadened its focus beyond its previously narrow "vibration" view and includes external interfaces for importing process and control system data, allowing users to have a comprehensive view of their turbomachinery health. The parallel evolution of Bently Nevada's plant-wide hardware offerings, such as Ranger Pro and SCOUT, ensures that the solution connects to and visualizes data for all Plant-Wide assets, providing health data on the supporting equipment within the industrial process.

Decision Support provides the analytic engine that parses the vast amount of vibration, process, and other operational data to extract insights and optimize work prioritization and asset management. The engine taps into the rich plant-wide historian of System 1, processes the data through a series of user-defined rules or Bently-defined InsightPak™ Analytics, and returns the results to System 1 for notification, visualization, and confirmation.

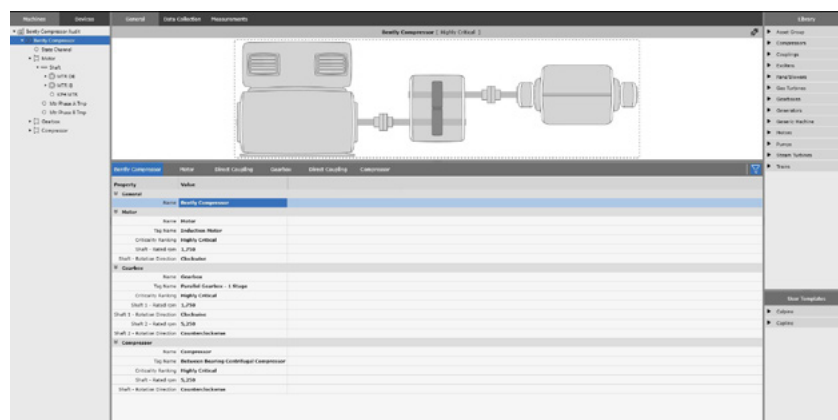
The System 1 Connectivity, Analytics, and Visualization capabilities that support Turbomachinery Monitoring and Management are detailed in the following sections.

Pillar 1: Connectivity

Machinery definition

An extensive library of turbomachinery asset models are available in the System 1 Configuration Library, including Centrifugal Compressors, Gas Turbines, and Steam Turbines. These models are outfitted with standard sub-components (e.g., Shaft, Section, Bearing) and machine properties, allowing users to quickly drag, drop, and build their highly critical rotating machines.

Machine properties, such as speed, rotation direction, and bearing clearance, are leveraged within the Plots workspace to aid in diagnostic analysis.

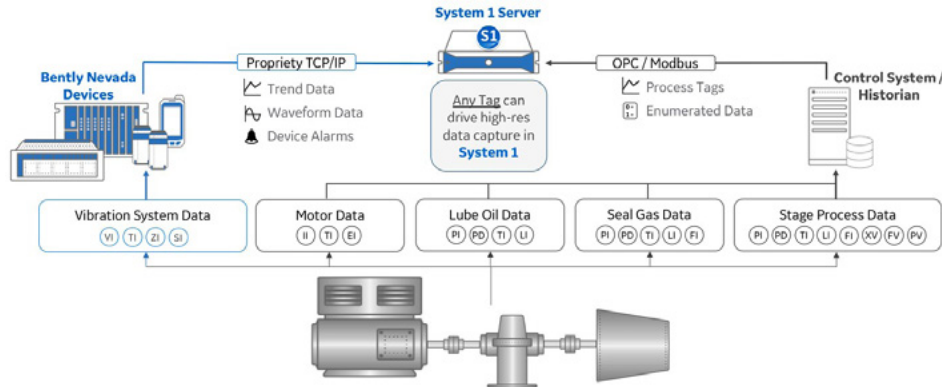


Motor-gearbox-compressor train with associated asset properties

Vibration + process data + control system data

System 1 provides comprehensive connectivity to all machine data sources on the edge and collects high resolution vibration, process, and control system data. This data can be collected from one or many Bently Nevada devices, such as [3500](#), [Orbit 60](#), [Ranger Pro](#), and/or [Scout](#) with Trend, Waveform, and Device-generated alarms all imported. In turn, process tags can be collected from a Programmable Logic Controller (PLC) or another historian. Up to 15,000 OPC or Modbus tags are supported per server, allowing customers to add all process, first-out, and permissive data to enhance the asset health data available to monitor, diagnose, and manage their critical turbomachines.

Once connected into System 1, these data points can be mapped to the associated location on the turbomachinery asset, establishing asset-context for the measurement value.



Comprehensive turbomachinery data into the System 1 historian

Operating state definition

Machine states enable users to define distinct operating conditions where asset behavior is unique. For turbomachinery, four Bently-defined states are available: Startup/Shutdown, Running, Slow Roll, and Machine Off. If a user has entered a rated RPM and mapped a speed data point to the machine, the trigger definition of each of these four states is automatically configured. In addition, 30 user-defined operating states can be configured. NOTE: Any data input can be used as part of state definition (e.g., Discharge Pressure, Bearing Temperature, Suction Flow, etc.).

Operating states enable more fine control over two aspects of [Condition Monitoring](#) programs:

1. Data Storage Rate: When machines are in critical operating states, higher density data can be collected and stored, enabling deep diagnostics into machine faults when required.
2. State-Based Alarming: Unique alarm thresholds can be configured for different operating states. In addition, alarming can be completely suppressed in certain states, like when the machine is off.

General	Data Collection	Measurements		
States	Points			
Property	Startup/Shutdown	Running	Slow Roll	Machine Off
General				
Name	Startup/Shutdown	Running	Slow Roll	Machine Off
State Type	Startup/Shutdown	Running	Slow Roll	Machine Off
Enable State	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Enable Storage	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Include Invalid Data	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Trigger Definition	Edit...	Edit...	Edit...	Edit...
Storage Rate	Edit...	Edit...	Edit...	Edit...
Alarming				
Protection Alarms	Standard	Standard	Standard	Standard
Condition Monitoring Alarms	State-Based	State-Based	Suppressed	Suppressed

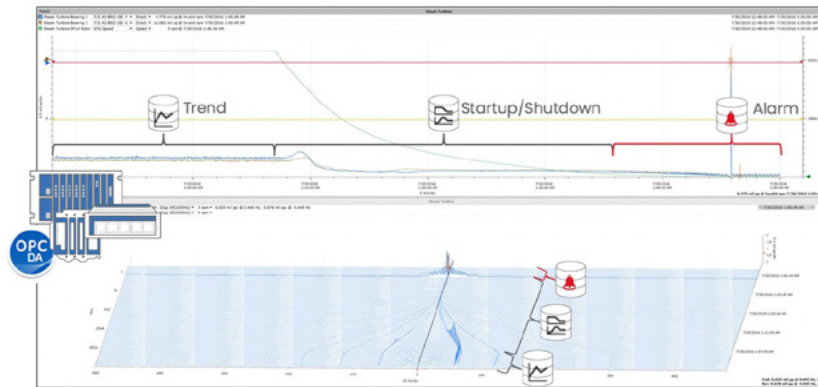
Bently-defined operating states

Data storage

Industrial Historians and System 1 Classic utilize change filtering for data summarization. This method requires expertise to set the storage rate thresholds for each measurement, periodic database storage optimization, and may lead to sparse data that is not time correlated.

With System 1 Evo, incoming trend data can be stored at up to once-per-second, with this data retained in the Short-Term Trend Store (NOTE: Modbus data can be stored at rates of up to 200ms). This guarantees that high density, time-correlated data will be available when a turbomachinery issue requires deep investigation. In addition to Trend Data, even higher resolution data is captured in the case of Alarm or Startup/Shutdown Events. When these events occur, high-resolution data is collected from any tag mapped to the machine train, with some Bently Devices supporting up to 100ms static data collection.

All stored data (e.g., Trend, Alarm, Startup/Shutdown) can be replicated from the Process Network to the Business Network, enabling users to conveniently perform proactive and real-time management of their turbomachinery from many locations: alongside the Operations team, from their office, or from centralized monitoring centers.



Trend, startup/shutdown, and alarm data visualized in System 1

Pillar 2: Analytics

Condition monitoring alarm

The analytic foundation of any [condition monitoring system](#) is threshold-based alarms. Within System 1, threshold alarms can be configured per machine operating state, with adjustable settings for time delay, latching, and suppression. Four levels of alarm setpoints can be configured per measurement, regardless of the source of the data (e.g., Bently Device, OPC).

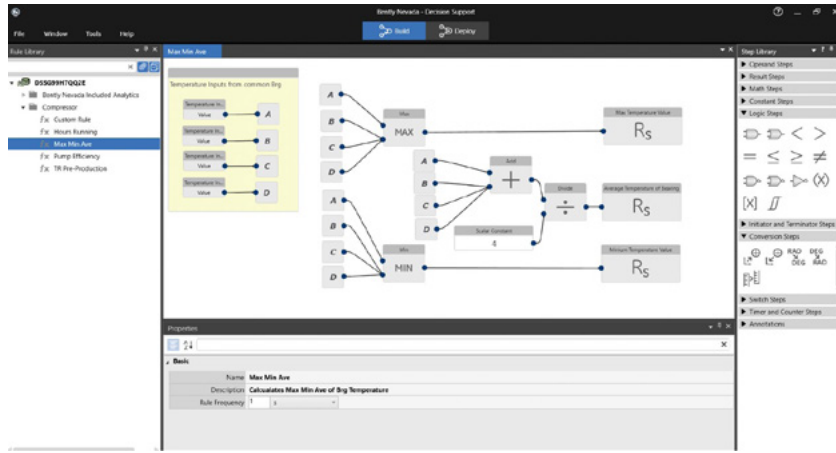
In addition, users can also configure OPC or Modbus import tags representing external system setpoints, with a maximum of 60,000 tags supported per System 1 server. These tags automatically update with the source system (e.g., PLC, DCS), ensuring that users leveraging System 1 for holistic machinery monitoring are always seeing the same setpoints as Operations.

Decision support developer

Turbomachinery management can be enhanced through the utilization of Decision Support Developer. This analytic application natively integrates with System 1, enabling turbomachinery engineers to tap into the rich dataset of System 1 and write custom rules that codify their machinery expertise. The results of these rules are populated within System 1, where they can trigger alarm notifications and events, be visualized alongside supporting data within the Plots workspace, and verified by utilizing the rich diagnostic toolset.

This codification of machinery knowledge captures the expertise of engineers that have been monitoring turbomachinery for decades, ensuring that this knowledge does not retire alongside the personnel. In addition, created rules can be shared between sites, allowing operators to take advantage of these insights across their asset fleet.

Bently Nevada's [Decision Support](#) includes an extensive library of extraction rules allowing engineers to gain new insights related to the health of auxiliary systems and process systems associated to turbomachinery.



Decision support custom rule for measuring bearing min, max, and average temperature

Decision support InsightPak™ analytics

InsightPak Analytics can be applied to specific machines within System 1 to perform continuous real-time data analysis to detect early changes in machine behavior and identify targeted failure modes. While Decision Support Developer equips end users to create their own rules, InsightPaks are Bently-defined rules that diagnose malfunctions by using machine configuration information, real-time data, and asset operating states. InsightPaks are based on Bently Nevada’s decades of experience monitoring turbomachinery.

A list of detectable turbomachinery faults are included below, with new InsightPak analytics continuously being developed and released.

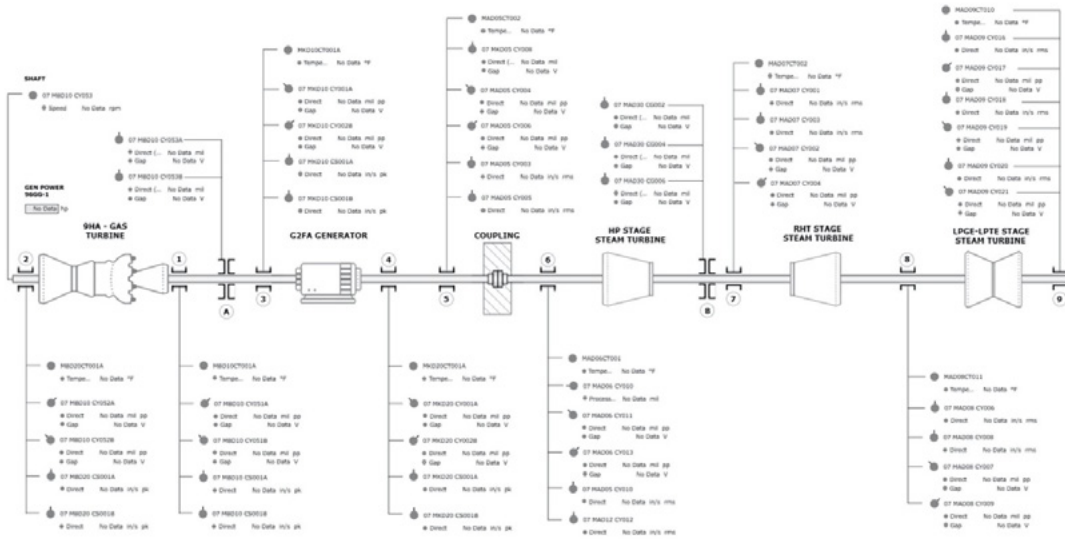
	Fluid Induce Instability Whirl/Whip	General Radial Preload	High Synchronous Vibration	Rotor IX runout	Sub-Synchronous Rub	Super Synchronous Rub	Misalignment	Rotor Bow	Gear Mesh	Compressor near Surge	Compressor Surge & Stall	High Exhaust Temperature	High Differential Exhaust Temperature	Electric Motor Non-uniform AirGap	Blade Pass	Compressor Rumble-Industrial GT	Compressor Rumble-Aeroderivative GT	Pump Cavitation	Radial Preload ISC
Industrial GT (Power Generation or Mechanical Drive) FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Aeroderivative GT (Power Generation or Mechanical Drive) REB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Power Turbine FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Centrifugal Pump FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Electric Motor FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Axial & Centrifugal Compressor FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Axial & Centrifugal Fan / Blower FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Gear box FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Generator FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Integral Gear Compressor FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Steam Turbine FFB	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

InsightPak analytics for turbomachinery

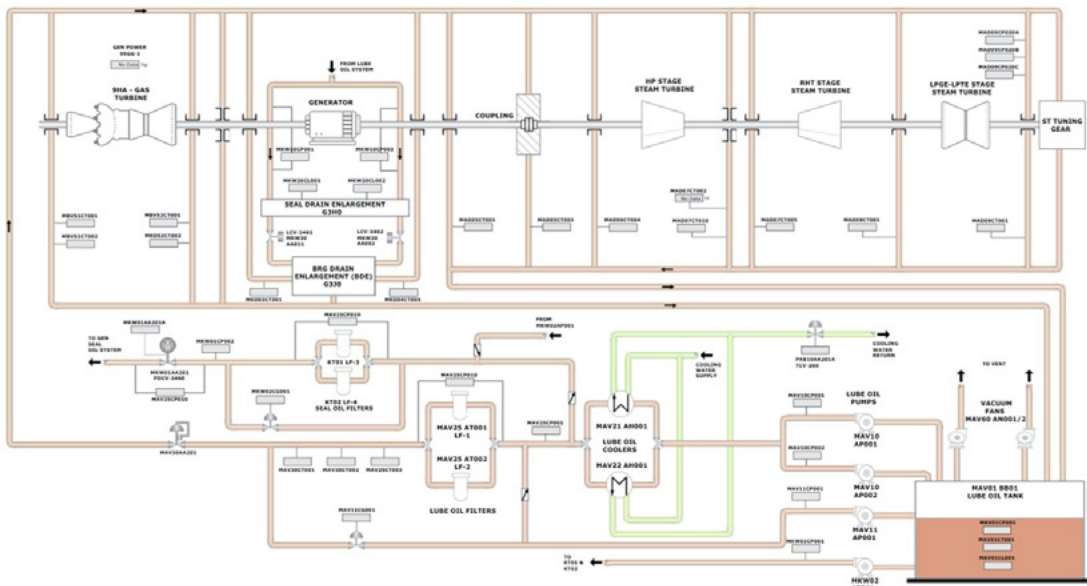
Pillar 3: Visualization

HMI mechanical and process views

The HMI workspace enables customers to visually represent turbomachine health by graphically depicting machine layout, current measurement values, and alarm status for both the machine, its sister assets, and supporting sub-systems. Navigational links can be added to any HMI view within the database; advanced users may elect to jump from HMI-based screens right into diagnostic plots, while higher-level users may elect to jump to sub HMI views or trends.



Mechanical HMI view of a power generation train



Supporting lube oil system HMI view of a power generation train

Alarm events with supporting data

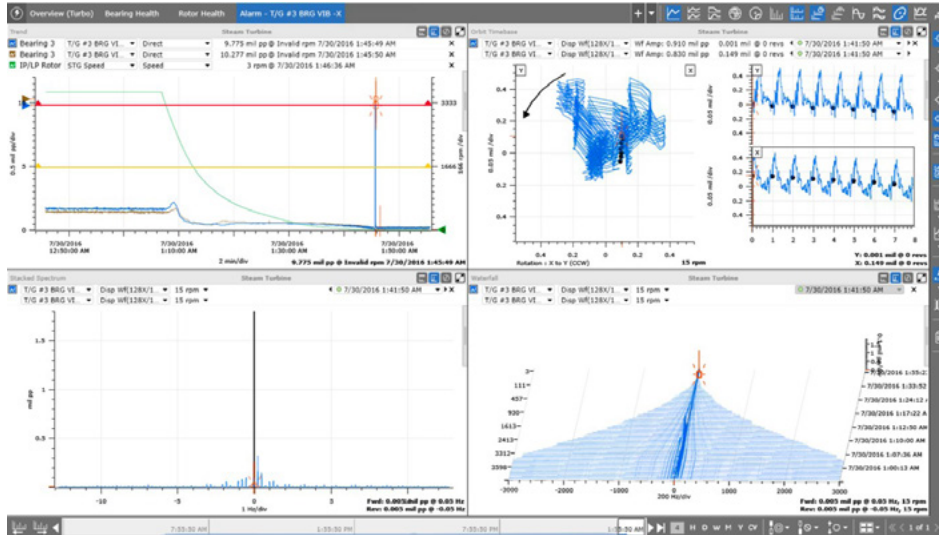
The System 1 Events workspace logs all device-generated events, along with any alarm triggered from a configured setpoint in System 1 or an integrated rule from Decision Support. These setpoints can be configured on any measurement within the application, including vibration, process, and control data. Setpoints can be synchronized with external systems to ensure a harmonized view for Operations and the Machinery Team.

When alarms trigger, Email or Mobile notifications can be sent to one or more stakeholders, containing supporting information, such as Tag Name, Configured Setpoint, and Measurement Trigger Value. Within System 1, the workspace visualization updates to reflect the presence of the alarm event, with color propagating within the hierarchy and status views.

The Events List displays the logged alarm event. Upon double-click of this alarm, a supporting Alarm Plot Set allows Machinery Engineers to view supporting data around the time that the event fired. For turbomachinery vibration alarms, the alarm plot set includes:

- Trend plot with Bearing X/Y Direct Measurements + Speed, with the cursor defaulted to the entered timestamp of the alarm event

- Orbit Timebase plot of Bearing X/Y Synchronous Waveforms, with the sample defaulted to that closest to the timestamp of the alarm event
- Full Spectrum plot of Bearing X/Y Asynchronous Waveforms, with the sample defaulted to that closest to the timestamp of the alarm event
- Full Waterfall plot of Bearing X/Y Asynchronous Waveforms

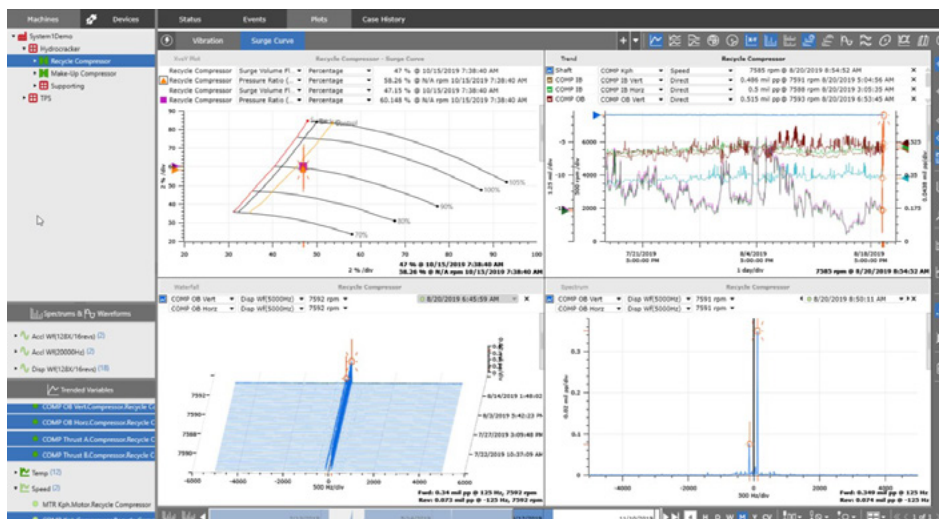


Alarm plot set for turbomachinery vibration point

Correlated data analysis

System 1 allows users to view all vibration, process, and control data within a single plotting workspace, with a multitude of plotting formats available. As all data is stored at up to 1-second rates, measurement values can be easily correlated. This enables users to mix and match data presentations to get a complete picture of machine behavior.

All of the rich plot types and tools required for turbomachinery diagnostics are available. Machinery Engineers can combine plot types within a single view to compare machine behavior across different plotting formats, apply compensation to eliminate run-out, and overlay reference baselines to compare current machine condition to a past time when it was operating normally.



Mixture of vibration and process data visualized on XY, trend, waterfall, and spectrum plot types

Case management

As part of their digital transformation journey, Industrial Operators are striving to aggregate all data into a single and connected ecosystem. While this includes the sensor data that is measuring real-time vibration and process values, it also includes the fault analyses, notes, and other case artifacts that document asset health over time.

Within System 1, Machinery Engineers can capture these case details and store them as part of the central database. Machine Fault Reviews, Plot Records (which visually capture asset condition), and observation notes can be tagged to turbomachines or any other assets within the System 1 Database and are available for review by all users, enabling more effective collaboration.

Connectivity + analytics + visualization = the solution in action!

The following scenario presents a real-world turbomachine fault condition. It demonstrates how the System 1 Capabilities of Connectivity, Analytics, and Visualization combine to support early fault detection, fault confirmation, and corrective action.

At an LNG production site, refrigeration compressors and their drivers are some of the most critical equipment within the facility. Compressor asset health data is connected to System 1, with high-resolution vibration and process data stored in a central historian, alongside the asset health data of auxiliary equipment. In addition, System 1's Decision Support engine is constantly processing data from the System 1 historian, performing real time calculations, analytics, and diagnostics.

Late in the morning, an InsightPak analytic alarm is fired, indicating that there is a rub condition on the refrigeration compressor. To generate a positive fault detection, the InsightPak analytic confirmed a number of machine behaviors, including vibration amplitude, eccentricity ratio, orbit shape, and persistence.

- Relative shaft vibration higher than Level 2 threshold
- Sub-synchronous component
- Value of sub-synchronous component
- Eccentricity ratio and position of shaft in bearing
- Orbit shape, precession
- Speed to critical speed ratio
- Time persistence

Conditions evaluated as part of compressor rub InsightPak analytic

The Machinery Engineer responsible for the asset receives an email notification, highlighting the problem asset, alarm level, failure mode, and date and time stamp of the event. Upon receipt of the message, the Machinery Engineer launches System 1 to evaluate the condition.

S1 Alarm Notification

Level: **2**

Database: APOLLO-11

Machine: Steam Turbine Compressor

Point: SubSynchronousRubB

Measurement: SubSynchronousRubbingB

Type: Over

Value: **1.000**

Trigger: 0.900

Source: Condition Monitoring

Alarm Set: Standard

Activity: Active

Entered: 10/4/2020 11:09:38 AM

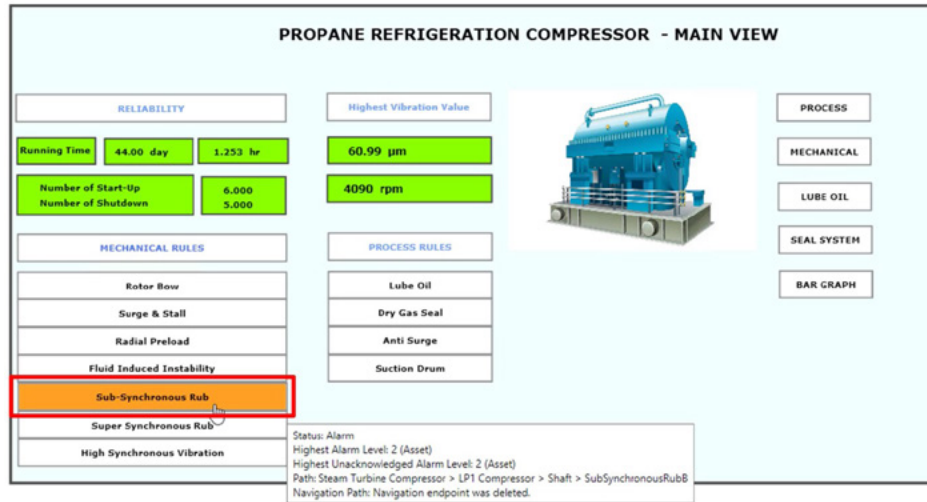
Exited: -

Path: APOLLO-11 > Steam Turbine Compressor > LP1 Compressor > Shaft > SubSynchronousRubB

InsightPak alarm notification for sub-synchronous rub condition

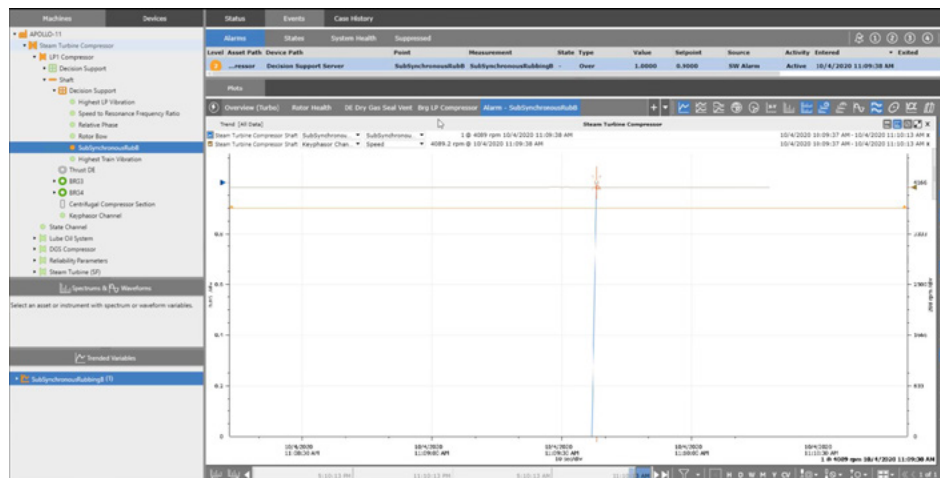
Using System 1, the Machinery Engineer confirms the identified compressor is in alarm and quickly scans the HMI screen to see if other alarms are present. While there are no other active alarms, the Engineer can see Key Performance Indicators (KPIs) that the Machinery & Reliability Team created in System 1's Decision Support, including:

- Running time of the compressor
- Number of machine startups and trips
- Highest vibration from all vibration transducers on the Refrigeration Compressor



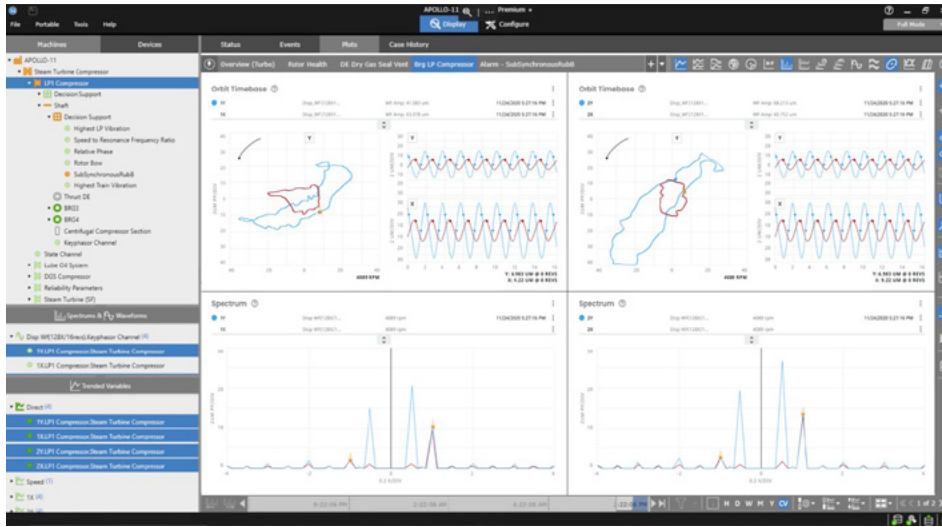
Refrigeration compressor HMI view

The Machinery Engineer navigates to the Events workspace and double-clicks on the InsightPak alarm, which launches the Alarm Plot set for the event. The Engineer notes that the operating state has not changed and the speed has remained consistent, indicating that the event was not associated with a changing machine state.



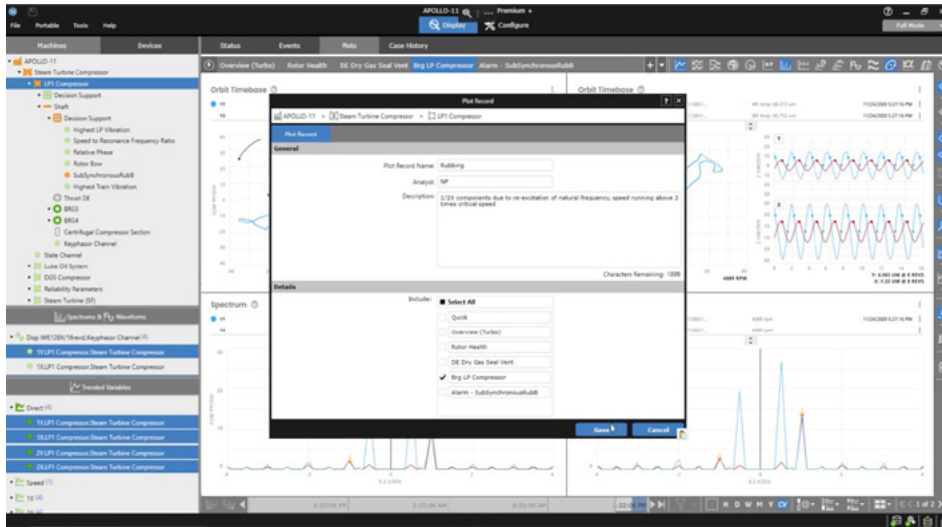
Alarm plot set for sub-synchronous rub InsightPak analytic

The Machinery Engineer launches the Orbit-Timebase and Full Spectrum plots to do a deeper analysis of the dataset collected during the alarm event. He overlays the reference baseline that was collected when the machine was commissioned and can clearly see a difference in behavior between current condition (blue) and baseline data (maroon).



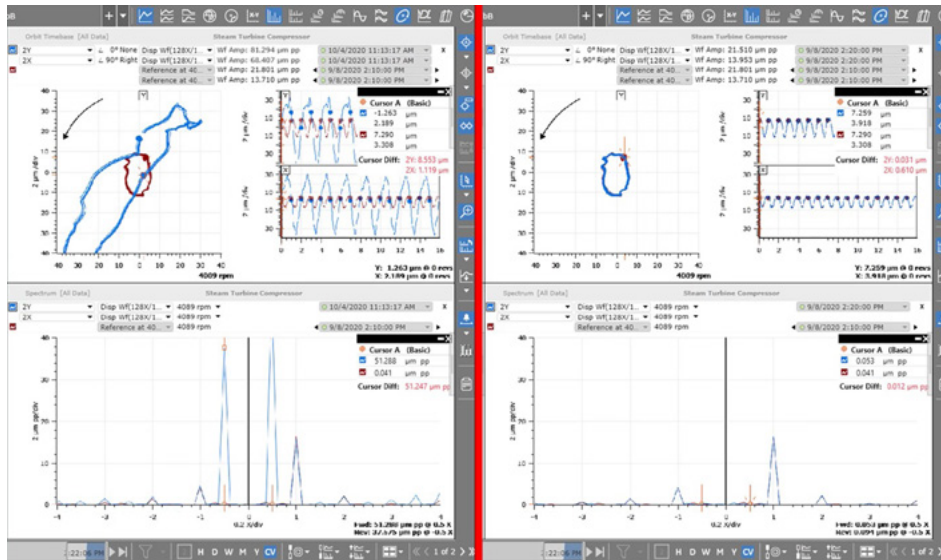
Orbit-timebase and full spectrum LP plot with reference baseline overlays

The Machinery Engineer documents the rub condition in System 1, saving the plot view as a Plot Record that can be viewed by him and his teammates in the future. He then instructs the Operations Team to achieve a stable thermal condition to eliminate the rub condition.



Plot record documenting rub condition of refrigeration compressor

Acting on the recommendation of the Engineer, Operations is able to achieve thermal stabilization of the compressor train, and the rub condition is resolved, returning the rotor response to normal.



Comparison of compressor data with rub (left) and post thermal stabilization without rub (right)

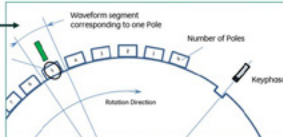
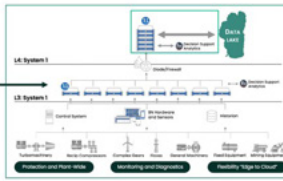
What's planned for v21.1

System 1 v21.1 will be released in late May 2021. This release will deliver major new capabilities to the Hydro Monitoring, OT/IT System Integration, and General Machinery Monitoring use cases provided by System 1. A list of included capabilities is captured below.

System 1 v21.1 – Features (Target ATS: 31 May)

High-Level Features

- **Hydro Use Case Enablement** – Machine Configuration; Air Gap and Profile Plots
- **Ranger Pro Scalability** – Connectivity for 20 GWs & 2000 Wireless Sensors per S1 Database
- **vbOnline Pro Enhancements** – Adds Software States & MODBUS Client Capability
- **SCOUT Enhancements** – route preview, triaxial sensors, PTT measurements, low-speed tach, manual IP and enhanced route reports
- **Replication Extensibility** – Enables Future Releases of Decision Support to Run on RX (Layer 3) DBs
- **PEMS & Database Management** – PEMS Enhancements, Audit file creation at different database levels
- **OPC UA Import** – Static Data
- **Fleet Connectivity** – Connect S1 DBs to SIE

System 1 v21.1 planned capabilities

Learn more about System 1

- [Website](#)
- [Data sheet](#)
- [Video](#)
- [Brochure](#)
- [Fact sheet](#)
- [Infographic](#)

Prior Orbit articles

- [System 1: Plant-wide monitoring with clarity and context](#)
- [Celebrating 20 years of System 1](#)
- [System 1 decision support](#)
- [Use case: diagnostic HMI](#)
- [Use case: gearbox monitoring](#)
- [Use case: thermodynamic performance monitoring](#)
- [Portable & System 1](#)

Upcoming System 1 Orbit articles

The deep capabilities of the System 1 Platform will be explored in upcoming releases of Orbit magazine. Planned articles include:

Q1 2021: Reciprocating Compressor InsightPaks

Q2 2021: Monitoring Hydro Generation Assets with System 1

Q3 2021: The System 1 Ecosystem – Connected Asset Management from Breadth to Depth

Q3 2021: Roll Monitoring in Pulp & Paper and Steel Manufacturing with System 1

Q4 2021: Introducing System 1 Enterprise

Q4 2021: System 1 Advanced Analytics

With many more to come...



Jackie Tappan

Senior Product Success Manager
Bently Nevada, a Baker Hughes company.

E jackie.tappan@bakerhughes.com