System 1 use case: thermodynamic performance 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, efficient, 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 20 countries with more than 400 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 eleven 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 Bently Performance use case and the application of System 1 for real-time and reactive machine monitoring.
Challenge
Managing sophisticated equipment is a complex task; many factors must be considered when assembling and implementing a strategy to properly maintain and operate equipment. Industrial operators with gas turbines, steam turbines, centrifugal compressors, pumps, generators, and other rotary equipment often include thermodynamic performance monitoring within their asset strategy, helping them to answer the following questions:

1. How efficient is my equipment?
2. How has my equipment efficiency changed over time?
3. How has a change in my equipment performance impacted plant or unit productivity?
4. Why have my equipment fuel costs increased while output has remained consistent?
5. When should I conduct equipment maintenance to recover production losses?

System 1 solution
To answer the above questions and provide greater insight into equipment health, Bently Nevada offers System 1 Bently Performance. The Bently Performance software module extends the functionality of System 1 to include online monitoring of thermodynamic performance. Bently Performance executes calculations based on ASME PTC codes, producing key performance indicators:

**Actual performance**: Actual output for current ambient and operating conditions. Actual performance data provides current performance information for a machine related to the current operating point compared to the best operating point recommended by the OEM. This information also indicates the effect of deviation of machine operation from design condition.

**Expected performance**: Expected output as per OEM curves at design conditions. Indicates the expected performance of the machine if the machine has not degraded and is operating at design conditions. These values can be compared with actual performance if the machine is operating at the design condition specified by the OEM.

**Corrected actual performance**: Actual output transposed to standard day conditions (ISO or site-specific rating). Typically used for gas turbines, these corrected / transposed outputs can be compared with the rated or guaranteed values of the machine to find the absolute degradation. When trended, they depict the relative degradation with respect to time.

**Corrected expected performance**: Expected output transposed to actual operating conditions. This is generally used for process gas compressors, which operate away from design conditions. The expected value after correction can be compared to actual performance to understand the degradation of the machine at actual conditions.

These values can indicate conditions like surge or stall.

A significant benefit to integrating thermodynamic performance monitoring within System 1 is the access to mechanical and thermodynamic machine-condition information within a single platform. By correlating and comparing performance, process, vibration, and mechanical data within System 1, users have a more comprehensive understanding of the overall health of their machinery.

Pillar 1: Connectivity
**Vibration + process data + control system data**

The System 1 platform provides comprehensive connectivity to machine data sources on the edge and collects high resolution vibration, process, and control system data. This data can be collected from a Bently Nevada device, 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 a historian. Up to 12,000 OPC tags are supported per server, allowing customers to add all process, first-out, and permissive data to enhance their machinery management programs.

In the v20.1 release, the modbus industrial protocol will be added, enhancing the flexibility of data import into System 1.

Bently Performance will often consume data values from the PLC, with common inputs including:

1. Suction temperature
2. Suction pressure
3. Discharge temperature
4. Discharge pressure  
5. Suction or discharge flow  
6. Speed  
7. Driver power  
8. Gas composition

In addition, Bently Performance may leverage gas composition to increase the accuracy of the performance calculations. If an on-line gas chromatograph is installed, System 1 can consume those values (via OPC) for use in performance calculations. If an on-line gas chromatograph is not available, System 1 allows manual input for the gas composition values.

**Trend data storage**

With System 1, incoming trend data can be stored at up to once-per-second, with this high-resolution data retained in the short-term trend store for a configurable time span. This guarantees that high density, time-correlated data will be available when a machinery issue requires deep investigation. Bently Performance will run calculations on the incoming data and store the calculated values at a 30 second update rate (update rates are configurable).

**Deployment architectures**

System 1 supports two architectures for the deployment of Bently Performance. In the first architecture Bently Performance is installed on the System 1 server located on level 3 of the customers network. In this scenario, the required Bently Performance inputs are sent to the System 1 server and processed via the Bently Performance engine.

The second architecture leverages System 1 replication. The replicated architecture allows one or multiple System 1 databases located on level 3 to be “replicated” and placed on a server located on the business network. The replicated architecture offers improved data access for end users on the business network and simplifies maintenance activities associated to Bently Performance (due to improved accessibility).
Pillar 2: Analytics

Bently performance calculations

The Bently Performance Engine uses process data acquired by System 1 to execute calculations, sending the data back into the same System 1 database for visualization. Below are the high-level steps followed for proper calculations:

- **Data processing:** The health of the tag is assessed, validating the numeric value and performing any required unit conversions.
- **Application of equation of state:** Depending upon the machine, gas properties, and end user requirements, Bently Performance will utilize one of several Equation of State (e.g., Lee-Kesler, SRK, BWR, BWRS) to generate specific volume flow for Bently Performance KPI’s.
- **Calculation of actual values:** Once gas properties are available at various stages of the process (e.g., Stage 1, Stage 2), Bently Performance will calculate the KPIs required to evaluate machine performance (e.g., efficiency, head, gas power).
- **Calculation of expected values:** Bently Performance will then calculate expected values by comparing with the OEM curves and applying correction factors. In addition, Bently Performance will perform additional calculations such as energy balance and stoichiometry calculations.
- **Output Processing:** Bently Performance outputs are processed (range check, unit conversion etc.) and then sent to the System 1 database.

Additional analytics with decision support

Additional analytics may then be applied to the Bently Performance data by using tools such as System 1 Decision Support. The Decision Support module for System 1 will be released in August 2020 and will operate with System 1 version 20.1 and forward. Decision Support will allow users to develop custom analytics KPI’s as well as apply rules created by Bently Nevada to detect failure modes for mechanical assets, auxiliary systems, and process systems.

Decision Support will be highlighted in a future Orbit article later in 2020.

Threshold alarming

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, or calculated values derived from Bently Performance).

Pillar 3: Visualizations

Diagnostic HMI views

With System 1’s HMI views, customers can visually represent machine health across an entire facility, within the context of its sister machines and supporting sub-systems. Users can define navigational links within the HMI workspace to customize their workflow throughout the application. The following examples highlight key benefits of System 1 and Bently Performance for visualization of data.

![Graphical depiction of a hydrocracker unit built in System 1](Image)
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.
This rich, comprehensive data set unlocks new real-time monitoring opportunities for machinery engineers, not previously possible when utilizing a control system HMI, industrial historian HMI, or legacy vibration monitoring systems. This allows the machinery team to work alongside operations, for compressor surge testing, flow adjustments, and field leak identification.

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

Historical view of operating points (blue) and expected operating points (purple)

Plot workspace with multiple performance plots in a single view
How have customers benefited from Bently Performance?

In an ethylene plant where System 1 was used as machine condition monitoring platform for five highly critical trains (charge gas compressor, charge gas booster compressor, methane compressor, propylene compressor and ethylene refrigeration compressor), Bently Performance gave clear indications on steam turbine fouling via KPIs such as reduced steam efficiency and power while steam flow rate increased. This was later confirmed and related to bad water chemistry and formation of mineral deposits on the turbine blades. After the maintenance activity was completed, the recovered performance was observed on System 1 confirming the effectiveness of the maintenance action. The effect of the Steam Turbine degradation was also seen on the compressor section discharge mass flow and speed.

In another case on an ethylene compressor which had an anti-fouling coating applied, sudden spikes in vibration were observed. Plant personal investigated and found clear indications of fouling from Bently Performance data. They scheduled an outage, opened the machine, and found fouling deposits on stages 2 and 3 despite the presence of an anti-fouling coating. This is a great example of how vibration monitoring along with performance monitoring can add value to find issues in a machine and resolve them in timely manner.

Connectivity + analytics + visualization = a complete solution!

By combining its connectivity, analytics, and visualization capabilities, System 1 is positioned to be the premier edge historian and condition monitoring platform of all industrial operators. To recap:

System 1 collects data from any asset within a facility. Collection rates of up to once per second are achievable during steady-state operations, while sub-second data can be stored during alarm and startup/shutdown events (when available from the device).

The stored data can be analyzed to derive insights using a rich set of tools. The core SI application can configure threshold-based alarms, while decision support and Bently Performance layer on additional analytic capabilities for earlier detection of issues.

Replication frees data from the secure confines of the plant network, allowing users easy access to SI. Up to eight transmitter databases can be replicated to one receiver database on the business network.

Once on the business network, users can access SI’s extensive visualization capabilities, allowing for efficient investigation of abnormal machine conditions.

Finally, interfaces (i.e., OPC UA) serve up the rich System 1 data to external systems, populating data lakes and feeding machine learning algorithms.

What’s New for v20.1

System 1 v20.1 will be released in May 2020. A complete list of included capabilities is captured below.
Learn more about System 1

Website
Data sheet
Video
Brochure
Fact sheet
Infographic

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:

• **Q2 2020**: The Evolution of System 1 – A Celebration of 20 Years
• **Q3 2020**: (Re)Introducing System 1 Decision Support
• **Q4 2020**: System 1 – Turbomachinery Monitoring

With many more to come…

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