

Condition monitoring solutions for hydroelectric power generation



Why the Bently Nevada product line?

We have earned your trust. For over six decades the Bently Nevada product line has supported the most demanding applications in multiple industries. And even as we protect and monitor your machinery, we constantly strive to refine and improve our offerings—and help enable your success.

We design and deliver solutions for all your monitoring needs—including sensors, distributed and rack-based monitors, software, and supporting services—with the following goals in mind:

- Increased availability and production
- Lowered maintenance costs
- Reduced risk in terms of safety, environmental, and asset upsets.

And we have impressive statistics to back up our extensive experience:

- More than 240 international patents issued, including over 150 in the U.S.
- More than 360 international patents pending, including over 95 in the U.S.
- Over 75,000 3500 Series monitoring systems installed globally
- Over 4 million sensor monitoring points
- Over 20 years of offering overspeed detection systems

Want to know more?

Detailed information, including product data sheets and application articles and guides, can be found at the Hydroelectric Power Generation page of our website.

We understand how to monitor your hydro machinery

Whether Kaplan, Pelton, Francis, bulb, or propeller—vertical or horizontal—generation-only or pump/storage, our hydro monitoring solutions are effective because we understand the measurements you need to detect the unique malfunctions that can affect hydro units. In addition to the traditional proximity, velocity, LVDT, and acceleration measurements, our solutions incorporate a wide array of sensors designed specifically for hydro power applications.

Over 60 years of condition monitoring leadership

330505 Low-Frequency Seismic Sensor

This sensor eliminates low frequency noise that other sensor technologies exhibit, and reliably detects vibration at bearing supports where vibration is often a sign of significant machine problems. It can also be applied at the stator core and frame, where vibration can damage winding insulation.



4000 Series Air Gap Sensor System

This system measures the distance between the rotor and stator. Early detection of air gap anomalies can help operators diagnose rotor-to-stator rub and decide whether to keep the distressed machine online until the next planned outage or remove it from service before serious damage occurs. Also, long term trending of gap and shapes can be correlated with operating conditions and used in operational and rehabilitation planning.



350300 Dynamic Pressure Sensor

The Hydro Dynamic Pressure Sensor uses piezoresistive sensing technology to measure both static and dynamic pressures. The sensor uses the 3500/46M Hydro Monitor and System 1 software to provide static trending and specialized dynamic plots for diagnostics. This allows the identification and management of vortexing and cavitation in the turbine and draft tube, and pulsations in the penstock. The static pressure measurements enable mapping and correlation of these phenomena across varying head conditions.



Comprehensive, globally available services

Project Design and Installation



Let our experienced project services team modify and retrofit your existing hydro turbines and generators for transducers, monitoring systems and condition monitoring software. By supplying services with our products, you're assured of getting a high-quality fully engineered and optimized solution tailored to your specific requirements. Services include mechanical modification and electrical design drawings, trades subcontracting and/or oversight, transducer installation, and system configuration and commissioning. You determine the scope, from best practice recommendations to full turnkey services to anything in between.

Maintenance and Support Agreements



A one-year renewable Maintenance and Support (M&S) Agreement is automatically included with every product we sell. Its structure consolidates all products installed at your site under a single agreement for ease of administration, and entitles you to phone, e-mail, and web-based support from our global network of experienced support experts.

Machinery Diagnostic Services



Our more than 70 machinery diagnostic engineers around the world are recognized globally for their expertise in gathering and analyzing data to document baseline conditions and troubleshoot even the most vexing machinery problems.

Remote Monitoring & Diagnostics and Remote Data Hosting



In many cases, traveling to the site to perform machinery diagnostics and assess machinery health is a thing of the past. We can even work with your IT department to engineer remote connectivity solutions that are fully compliant with your corporate data network requirements.

Supporting Services Agreements



A Supporting Services Agreement (SSA) is a custom-tailored combination of individual remote and site-based service offerings that addresses the unique needs of your site and your installation. We work with you as a partner to keep your instrumentation performing optimally at all times and to provide hands-on assistance that helps you realize the full potential of your condition monitoring system.

Training



We provide in-depth technical training that is routinely praised by customers for its highly effective "learn by doing" labs coupled with classroom-style instruction. A comprehensive suite of product training courses is augmented by courses that teach the fundamentals of rotating machinery behavior and diagnostic techniques. Our courses can be provided at any of our global training centers or at your site.

Cybersecurity Services



We offer a comprehensive suite of Cyber Security Services, including: Cyber Asset Risk Assessments for compliance with industry standards; systems hardening that provides centralized security management and server health monitoring; security recommendations regarding network configurations, physical security, and change management.

Systems for every application

3500 Series machinery protection system

The 3500 platform has proven its value and dependability with customers everywhere, year after year. It features the industry's most extensive selection of machinery measurement parameters and utilizes software configuration for virtually all monitor options, providing unparalleled flexibility. Using the 3500 System's monitoring modules, vibration, bearing temperatures, thrust position, speed, air gap, process variables (electrical load, oil pressure, reservoir elevation, etc.) and other measurements can be configured to address the specific needs for correlation of data and analysis of each hydro unit in your facility. Hydroelectric turbine generators typically operate at low rotational speeds, usually from 60 to 600 rpm, and are often physically very large, sometimes with generator rotors that may be more than 50 feet in diameter and weigh more than 1,000 tons. Their physical mass and slow rotational speeds give rise to large vibration amplitudes and low vibration frequencies. This requires monitoring capabilities with special low-frequency response, filtering, and signal conditioning.



The 3500/46M Hydro Monitor module has been specifically developed to deliver these capabilities by providing the suite of radial vibration measurements used for guide bearing runout and seal ring position, and generator air gap measurements. The 3500/46M Hydro Monitor provides:

- Overall vibration (direct)
- 1X filtered vibration and phase
- NX filtered vibration and phase (where N is a user-selectable integer between 2 and 20)
- NOT 1X vibration amplitude
- Gap voltage (shaft radial position)
- Composite (shear pin failure indication)
- Instantaneous air gap
- Average air gap
- Minimum air gap
- Maximum air gap
- Minimum air gap pole number
- Maximum air gap pole number

The 3500/46M Hydro Monitor module provides users with up to eight configurable machine states for which independent alarm setpoints and time delays can be programmed. This supports a parametric monitoring strategy tailored to the individual operating modes of your hydro assets. The multi-mode feature works in concert with the State-Based Analysis option of our System 1 software.



System 1 software

Hydro turbine-generator plants present unique data acquisition and analysis challenges due to machine design, low rotational frequency, operating mode-specific dynamic behaviour, and failure mode characteristics common to these asset types. Bently Nevada's System 1 optimization and diagnostic software platform incorporates hydro-specific functionality, designed to dramatically improve your ability to proactively manage these units. Its exceptional data integration, analytic and diagnostic capabilities enable engineering and maintenance personnel to spend less time searching for problems and more time proactively managing and maintaining your most critical production assets. System 1 software also supports integration of process data from the diverse information systems throughout your plant, providing a common platform for data correlation, analysis and viewing. Packages designed specifically for hydro turbines and generators are available.

Hydro-specific condition monitoring and diagnostics

The Bently Nevada Hydro Turbine/Generator online management and diagnostics software package is designed to work with the Bently Nevada 3500 online monitoring system, collecting both static and dynamic high-resolution data including: vibration, partial discharge, air gap, position, speed, temperature, and more. This package can help you reduce operational risk caused by partial load and frequent cycling, improve asset reliability and productivity, and reduce maintenance costs.

Designed for multiple operating states

Machines that rotate bi-directionally (pumped storage units), or which routinely operate under differing hydraulic or load conditions, need a simple and robust method to identify and segregate the various operating modes for both protection and analysis. The Bently Nevada 3500/46M Hydro monitor supports multi-mode operation, allowing separate alarm setpoints to be defined for up to eight different operating modes. Within System 1, operating modes can be further defined with rule logic using any combination of available data, to enable accurate assessment of machine condition and change under consistent operating conditions.

Real-time analytic tools

Each deployment includes the System 1 Decision Support analytics environment, allowing any user to configure data evaluation rule logic so that proven knowledge and best practices can be applied and shared across a business in a repeatable and manageable process. Simple comparison logic, or complex mathematical operations, including spectral band extractions and array operations, can be

created in an intuitive GUI interface. Analytics operate on live data in real-time, enabling fast identification and notification of detected problems.

Software lifecycle support

System 1 software is continually developed and enhanced to imbed new functionality, maintain compatibility with interfaces and operating systems, and to incorporate the valuable feedback from our active end-users. Updates are released biannually, accessible to all users with a current Support Agreement.

Hydro-specific plot types

In addition to the comprehensive set of standard plot types¹, System 1 software provides the following plots specifically designed for diagnosing/analyzing hydro turbine-generator anomalies.

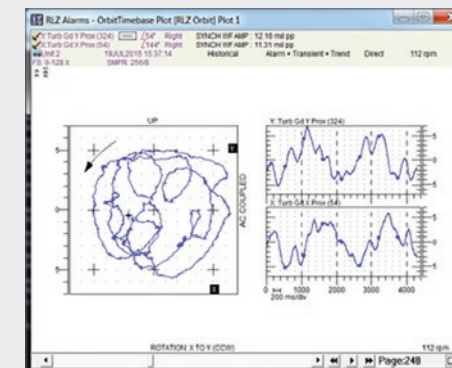
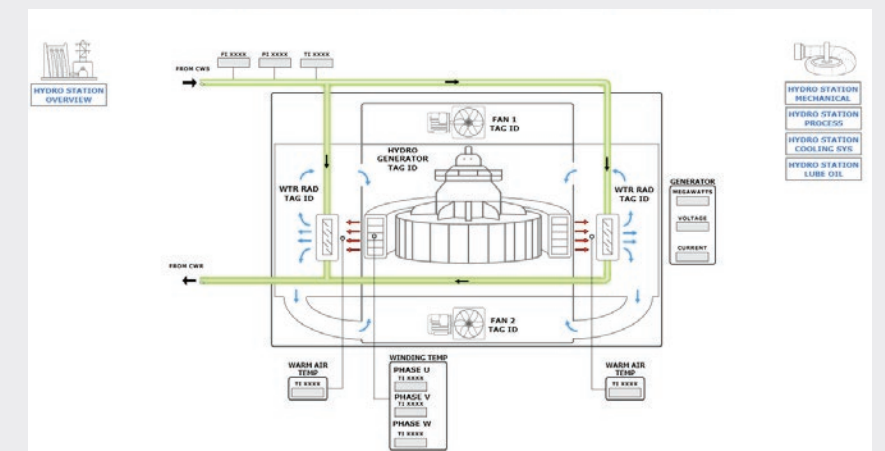
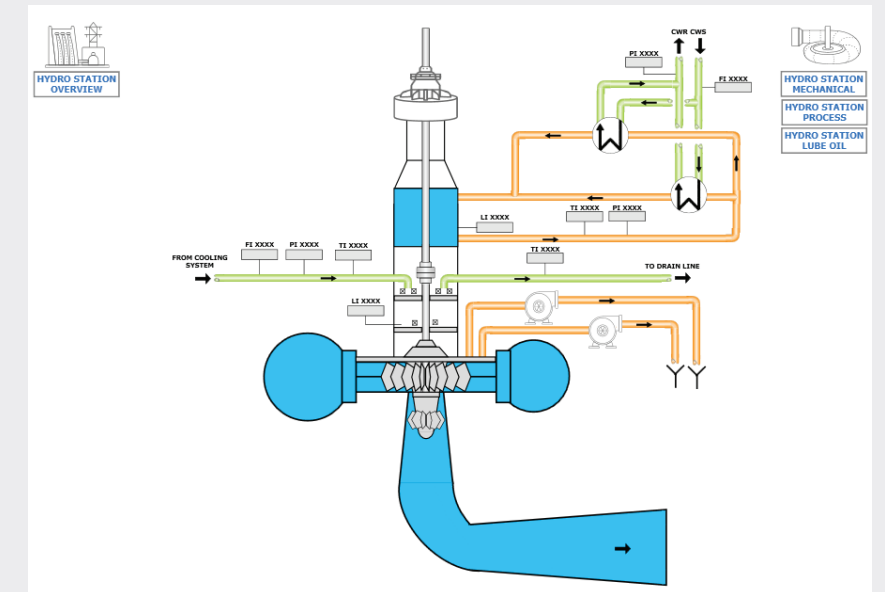
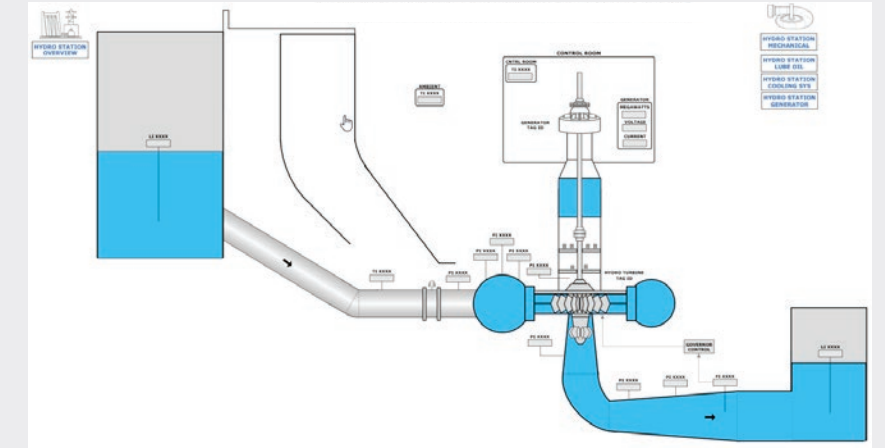
Hydro Asset Health HMI Dashboard View	The System 1 interface uses a rich graphical information screen layout to provide detailed machinery context of key operating information, alarm or fault status, and asset management performance indicators. This is a highly flexible and intuitive environment, configurable for a plantwide overview or detailed asset summary, enhancing the accessibility of machinery health data to all users. The navigable icons and data fields are color-coded according to alarm status, supporting drill down directly to diagnostic data formats.
Air Gap Plots	Displays the rotor poles versus the air gap for a single channel or the rotor poles versus the minimum air gap on all channels. Variables available include Average, Instantaneous, Max & Min Air Gap, and Max & Min Pole number.
Rotor Stator Plots	A multiple channel plot set showing the Stator Shape relative to the rotor shape, and the Rotor Shape and or Stator shape from one or more sensors or from the average of all sensors. These plots are derived from generator Air Gap measurements.
X versus Y	Plotting any X (such as vibration) versus any Y (such as unit load), provides powerful diagnostic tools. Cause-and-effect relationships and correlation can be easily visualized and understood. System 1 software has data historian capabilities allowing it to archive virtually any data, even if not condition-related. It can also interface to existing historian systems you may already have installed.
Performance Map Plot	Enhanced X versus Y plot displays a current value relative to multiple user-configurable characteristic curves which may represent, for example, unit operating limits or regions of undesirable operation. The overlay reference curve sets can be easily customized to represent clearance boundaries, in the case of shaft position plot formats, for example.
Multi-Parameter Plots	Multiple parameters can be displayed on the same plot. For example, plotting turbine flow, combined unit load, and bearing vibration provides the ability to immediately identify events associated with rough load zone. Changes in the duration and amplitude of these events can be an indication of excessive wear or impending failure.

¹ Vibration data can be displayed by System 1 software in the following standard plot types: Orbit, Timebase, Polar, Bode, Shaft Centerline, Cascade, Waterfall, Spectrum, Trend, Bargraph, and Tabular list.

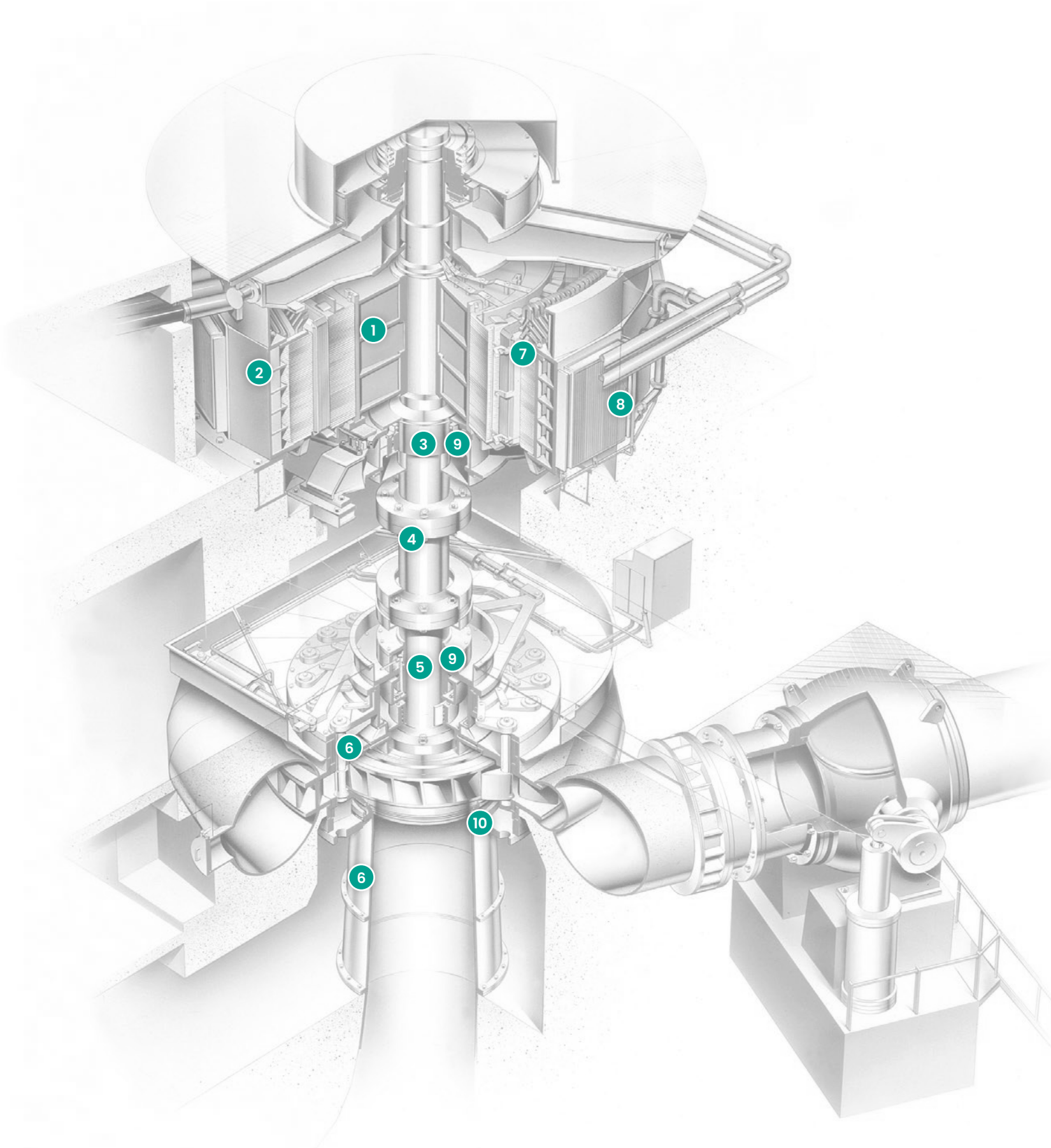
System 1's asset health dashboard identifies any areas that require further attention and embedded links allow users to move easily to the underlying data and diagnostics plots for problem spots for further analysis.

Any number of HMI screens can be created, typically featuring an initial landing page with plant-wide overview displaying key performance indicators for machine health and reliability. The drill-down pages reveal detail for major plant subsystems, including lubrication systems, generator cooling, generator electrical and mechanical monitoring, and turbine mechanical monitoring.

The System 1 HMI screens are intended to be intuitive and accessible to experienced and novice users alike, with imbedded navigation buttons, and color-coding to reflect the severity of any detected anomaly.



Hydro condition measurements



1. Generator Partial Discharge

Partial discharges are low-level electrical discharges that occur within the voids of high voltage insulation systems. By monitoring these partial discharges, a variety of winding related problems can be detected, allowing maintenance to be planned and serious failures to be avoided.

- Continuous PD Monitor
- Capacitive PD Couplers

2. Stator Frame Vibration

Vibrations of the stator core can increase after many temperature cycles, resulting in loose stator components. By mounting an appropriate seismic vibration transducer on the stator core/frame, such problems can be detected before serious damage occurs.

- 3500/46M Hydro Monitor
- 330505 Low-Frequency Seismic Sensor, Velomitor or Velomitor CT
- Orbit 60 Monitoring System

3. Thrust Bearing Oil Film Thickness/Rotor Position

An absence or reduction in oil film thickness at the thrust pads results in rapid breakdown of the bearing babbit and can result in rotor/bearing damage if not corrected. On hydro units, the thrust bearing shoes are fitted with proximity probes observing the thrust collar, providing a measurement of oil film thickness.

- 3500/46M or 3500/45 Position Monitor
- 3300 XL Series Proximity Transducer
- Orbit 60 Monitoring System

4. Keyphasor* Signal

A proximity probe observing a once-per-turn notch or protrusion on the machine's shaft provides a precise reference signal used for indicating rotational speed, filtering vibration to multiples of running speed (such as 1X, NX, and NOT 1X), providing vibration phase information and allowing air gap profile data, rotor pole temperatures, etc. Two probes and a 3500/50 tachometer can provide direction of rotation detection. The Keyphasor signal is required for synchronous values and sampling in the 3500/46M and 3701/46 monitors.

- 3500/50M Tachometer or 3500/25 Keyphasor Module
- 3300 XL Series Proximity Transducer
- Orbit 60 Monitoring System

5. Rotor Vibration and Position

Detects a variety of important malfunctions such as rough load zone, various sources of unbalance, shear pin failure, bearing problems, and wicket gate problems. Each channel of the 3500/46M module can simultaneously monitor direct, 1X vector, NX vector, NOT 1X, shaft radial position (gap voltage), and composite amplitude (gap voltage change multiplied by NX amplitude).

- 3500/46M Hydro Monitor
- 3300 XL Series Proximity Transducer
- Orbit 60 Monitoring System

6. Head Cover/Draft Tube Vibration and Dynamic Pressure

Cavitation can damage the turbine, eroding metal, affecting efficiency, and eventually forcing a shutdown and dewatering for repair of affected parts. Improper clearances can cause vibration of the head cover. By monitoring the draft tube or head cover with accelerometers and/or dynamic pressure sensors, these conditions can be detected and adjustments made to avoid operating in undesirable regions.

- 3500/46M Hydro or 3500/42M Proximitor*/Seismic Monitor
- 330425/330400 Accelerometer
- Orbit 60 Monitoring System
- 350300 Dynamic Pressure Sensor

7. Generator Air Gap

Air gap measurement is important because the stator is a flexible assembly that can become non-concentric and/or out of round. The monitor is able to provide instantaneous, minimum, maximum, and average air gap measurements along with the rotor pole to which min and max measurements coincide. Connecting to the System 1* software enables interpolation between sensors, providing calculated stator shape plots.

- 3500/46M Hydro Monitor
- 4000 Series Air Gap Sensors

8. Generator Temperatures

Temperature sensors installed in locations such as in stator slots, air cooler inlet and outlet, water inlet and outlet rotor poles, etc., provide important information on generator condition. The monitor provides alarming functions, alerting operators when temperatures are outside of acceptable limits. The monitor can also supply temperature information to System 1 software where it can be trended and correlated with other measurements for a more complete picture of unit health.

- 3500/60, /61, or /65 Temperature Monitor
- RTD or Thermocouple
- Orbit 60 Monitoring System

9. Thrust and Guide Bearing Temperatures

Bearing temperature can indicate problems related to fluid-film bearings, including overload, bearing fatigue, or insufficient lubrication.

- 3500/60, /61, or /65 Temperature Monitor
- RTD or Thermocouple
- Orbit 60 Monitoring System

10. Seal Ring Condition/Blade Tip Clearance

Francis turbines employ seal rings to prevent unwanted leakage of water past the runner, influencing efficiency. Kaplan and propeller type turbines experience changes in blade tip clearances or chamber deformation. Transducers mounted to observe/monitor these clearances can detect problems as they develop.

- 3500/46M Hydro Monitor
- 3300 XL Series 11 mm underwater Proximity Transducer
- Orbit 60 Monitoring System

Process and Environmental Variables

Load, reactive load, exciter voltage and current, generator voltage and current, lube oil pressure, wicket gate position, and reservoir elevation are just a few of the parameters that may be available in the unit's or plant's control and automation system. These variables are often correlated with the condition monitoring measurements for enhancing the diagnostic capabilities of the system. If these variables cannot be imported directly into the condition monitoring software, they can be obtained via the 3500 System.

- 3500/62 Process Variable Monitor
- Orbit 60 Monitoring System
- System 1 OPC UA and/or Modbus data import

Operating hydro in challenging conditions

Hydro turbines are facing a broader set of operating conditions that increase the risk and wear. System operators would base load these units, only reducing load or removing the units from service when maintenance was required, the power was not needed, or stream flow conditions dictated. In this base-load mode, a typical hydro machine could operate successfully for over 40 years with only routine scheduled maintenance and minimal condition monitoring.

In today's world of partially deregulated utilities and grid systems where fish and water issues often eclipse energy issues, the operating flexibility of hydro machines has often led them to be load-follow units with continuous load changes and partial-load operation. Running a unit at partial load brings into play considerations like rough load zone and cavitation, along with operation that is far from the unit's peak efficiency. Further, continuous load cycling introduces thermal, mechanical, and electrical stresses on the machinery that may not have even been considered in the original design. In some cases, such machines are cycled on- and off-line multiple times per day. And pumped storage applications can experience even more starts and stops, often representing the most extreme operating conditions of all hydro units. At the same time, normal scheduled maintenance outages

are being reduced or eliminated. The circumstances that once resulted in virtually trouble-free operation for decades simply don't apply any more. Clearly, the need for condition monitoring on hydro units has never been more important.

For over six decades, the Bently Nevada condition monitoring portfolio has been synonymous with the highest quality, most reliable choice available for critical machinery. With a name that is trusted worldwide for machinery protection, over four million transducers and monitoring channels have been installed around the globe. Our comprehensive selection of hydro-specific transducers, monitors, diagnostic software, and of course, services, has been designed with the unique needs of hydro operators in mind.

Benefits

- Lower life-cycle costs
- Improved efficiency
- Avoidance of load zones with damaging vibration or cavitation conditions
- Early warning of impending failures
- Proactive maintenance planning and intervention
- Reduced maintenance costs
- Increased availability and reliability
- Longer intervals between outages
- Lower insurance premiums

The business case

Machinery protection and asset condition monitoring systems are an investment that pays back quickly and in numerous ways. Today, such systems have moved from simply "good engineering practice" to "good business practice" in hydro power generation as well as many other industries. These systems have proven and continue to prove their value time and again.

Payback through Protection

Our solutions help protect your machinery from catastrophic failures and their costs.



For more than 60 years, the Bently Nevada name has been recognized for its industry leadership in machinery protection and condition monitoring. Today, with more than one million channels of machinery protection installed worldwide, customers have made us the proven choice for machine protection. We not only protect your machinery, but our legendary product quality, deep application expertise, and highly competent locally available service help protect your condition monitoring investment as well.

Payback through Mechanical Validation

Our solutions let you capture baseline machinery conditions, pre- and post-maintenance, giving you a reference for optimal decision making.



One of the most crucial times in the life of a machine is immediately after maintenance has been performed. We can tell you if "all is well" with systems that capture relevant data both before and after maintenance. You can instantly see if problems are present and make decisions accordingly. For many customers, the ability to knowledgeably continue with or abort the startup of a hydro turbine-generator unit can more than pay for their entire system in a single event.

Payback through Asset Performance Management (APM)

Our solutions provide the data necessary to optimize machinery operations and maintenance for financial and market conditions.



Hydro power assets are increasingly asked to compensate for the effects of a more diverse mix of generating assets, which often forces them into operating regimes that cause increased machine stress and wear. As industry digitizes to more effectively monitor, monetize, and optimize its assets, the ability to incorporate rich asset health data from a condition monitoring system becomes essential for accurate analysis and decisions.

