Condition monitoring solutions for hydroelectric power generation
Why the Bently Nevada product line?

We have earned your trust. For over five 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 upset.

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.

Over 50 years of condition monitoring leadership

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.

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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.

Hydro Stator End Winding Accelerometer (SEW Accel)
The Hydro SEW Accel system monitors the vibration of select stator end windings. This can help you determine proper maintenance cycles, and detect worn insulation, which may lead to a catastrophic failure. Designed to resist electrical tracking corona damage, partial discharge, magnetic field interference and electric field interference, this system is well suited for the electrical environment in hydro generators.

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.

Cyber Security 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

ADAPT Hydro monitor
The ADAPT Hydro monitor is ideally suited for a wide variety of hydro turbine types where mechanical and hydraulic vibrations are of primary concern, and where generator air gap measurements are not required. ADAPT Hydro features hydro-turbine-specific signal processing and measurements designed to detect rough load zone, propeller, blade, or bucket nX frequencies and cavitation as well as shaft radial position, vibration, thrust position, and dynamic pressure pulsations. In addition, ADAPT Hydro offers multiple customizable measurements configurable on a single sensor to optimize early detection of failure modes. As with all 3701 products, ADAPT Hydro’s small but robust package can be mounted near the hydro turbine reducing the wiring and cost of installation.

The ADAPT 3710 is configured and validated with Bently Nevada Monitor Configuration (BNMC) software. BNMC offers a simple and powerful configuration and validation environment resulting from extensive user interaction studies with end-users, OEMs, and the Bently Nevada field service teams.

ADAPT Hydro connects to System 1 software for condition monitoring and machinery diagnostics. Current values and alarms from ADAPT Hydro can be displayed in third-party panels and systems using the Modbus interface, or using System 1 Basic, a low cost entry-level application that serves as an operator display and troubleshooting tool.

Key Features
- Hydro turbine specific signal processing and measurements.
- One or two six-channel monitor modules, each with a seventh Keyphasor/Speed Input channel.
- Redundant 24 VDC Power Inputs.
- 24-bit A/D conversion and signal processing.
- Synchronized parallel sampling on all channels.
- 110 dB dynamic range.
- Two 10Base-1/100Base-TX Autosensing Ethernet RJ-45 connections.
- Hardware configuration lock prevents changes when in run mode.
- One Protection Fault SPD1 Relay Output.
- Eight Programmable SPD1 Relay Outputs.
- Modbus TCP communication.
- Ethernet Global Data (EGD) communication.

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 620 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 3500/49 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 3500/49 Hydro Monitor provides:

- Overall vibration (direct).
- TX filtered vibration and phase.
- NX filtered vibration and phase (where N is a user-selectable integer between 2 and 20).
- NOT TX 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 3500/49 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 multiple mode feature works in concert with the State-Based Analysis option of our System 1 software.
Starting with its enterprise view, System 1 identifies the location in your hydroelectric generating unit that needs to be investigated. The Event Manager and/or automated HydroX notifications link you to trend and dynamic data analysis plots that facilitate diagnosis or confirmation of a deteriorating condition or malfunction. Data from the HydroTracII Partial Discharge System provided by Iris Power Engineering, a leader in this technology, enables continuous online monitoring of partial discharge activity and correlation with other related data on a common platform.

### System 1 Software

The System 1 optimization and diagnostic software platform can dramatically improve your ability to proactively manage your hydro units. Its exceptional data integration, analysis and diagnostic capabilities enable engineering and maintenance personnel to spend less time searching for problems and more time proactively managing and maintaining your hydro units. System 1 software also supports integration of data from the diverse 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 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.

#### Embedded hydro machinery expertise

The knowledge-based technology in Bently Nevada’s HydroX™ RulePak automatically performs real-time audits of the data collected by System 1. Pre-configured, proven rule sets combine the incoming data with machine properties and models to detect the most common problems related to Partial Discharge, Air Gap, Vibration, and Auxiliary Processes. Advisories notify you of the pertinent details of a potential problem via computer workstation, e-mail, smart phone, and/or control system HMI. In recognition of an operator’s own machinery knowledge and experience, failure mode detection can be enhanced through custom rules you generate yourself using the rule engine studio.

#### Enterprise impact

A Predix-enabled data connectivity solution, Enterprise Impact increases accessibility and capability across multiple units and power houses. It aggregates and provides a single visualization workspace for data from System 1 and other asset management applications (SmartSignal), and can link these machinery data sources with Baker Hughes Asset Performance Management (APM) or legacy Meridium APM. Enterprise Impact enables robust prioritization, apparent causes, risk classifications, and failure risk specifics to enhance APM strategies both on premise and in the cloud.

### Overall Hydro Plant View

Displays an overview of plant condition with normal parameters in green and alarm parameters in colors designating severity of the alarm.

### Air Gap Plots

- **Gap versus Pole** Displays the gap for each sensor versus pole number for one rotor revolution.
- **(Rotor Shape)** Displays measured rotor shape as observed from each air gap probe.

### Air Gap Plots (Combined Rotor and Stator Shape)

Displays stator and rotor roundness and concentricity by combining measured rotor shape with calculated stator shape.

### Partial Discharge Plot

PLOTS Partial Discharge voltage frequency versus magnitude where an increase in either may indicate that insulation deterioration has increased.

### X versus Y

- **(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.
- **(Combined Rotor and Stator Shaping)** Displays the gap for each sensor versus pole number, for one rotor revolution.

### 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.

### 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.

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1. **Hydro-specific plot types**

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

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

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

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
- ADAPT 370/46 Hydro Monitor

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 orbit and can result in rotor/bearing damage if not corrected. On hydro units, the thrust bearing pads 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
- ADAPT 370/46 Hydro Monitor

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 3700/46 monitors.
- 3500/50M Tachometer or 3500/25 Keyphasor Module
- 3300 XL Series Proximity Transducer
- ADAPT 370/46 Hydro Monitor

Rotor Vibration and Position
Detects a variety of important malfunctions such as rough load zone, various sources of unbalance, shaft pin failures, bearing problems, and seal 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
- ADAPT 370/46 Hydro Monitor

Head Cover/Draft Tube Vibration and Dynamic Pressure
Vibration 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 and/or 3500/42M Proximity/Seismic Monitor
- 330420/330400 Accelerometer
- ADAPT 370/46 Hydro Monitor
- 350300 Dynamic Pressure Sensor

Rotor Tip Clearances
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
- 330447 Stator End Winding Accelerometer Sensor
- 330447 Stator End Winding Accelerometer Probe
- ADAPT 370/46 Hydro Monitor

Stator End Winding Vibration
Stator end windings are susceptible to vibration induced by electromagnetic, mechanical, and gravitational forces. High vibration can lead to deterioration and failure of support and the insulation systems, often resulting in forced outages and long out-of-service repairs.
- 3500/46M Hydro Monitor
- 330446 Stator End Winding Accelerometer Sensor
- 330447 Stator End Winding Accelerometer Probe
- ADAPT 370/46 Hydro Monitor

Thrust and Guide Bearing Temperatures
Thrust bearing 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

Seal Ring Condition/Blade Tip Clearance
Process 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

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 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

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 interrogation between sensors, providing calculated stator shape plots.
- 3500/46M Hydro Monitor
- 4000 Series Air Gap Sensors

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

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- 3500/62 Process Variable Monitor
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 five 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 50 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 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.

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.