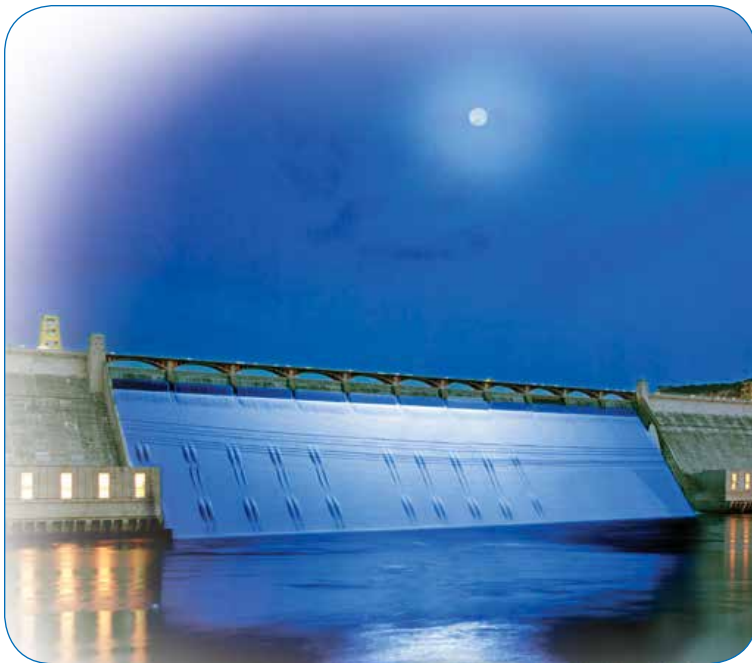


GE
Measurement & Control

Condition Monitoring Solutions for Hydro

Bently Nevada* Asset Condition Monitoring



imagination at work

Your Challenges

Hydro machines have historically had the lowest cost per MW on the grid. 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.

But that was then. 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 the 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 pump/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.

You can confidently turn to GE Measurement & Control for the solution. For over four decades, our 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 two 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.

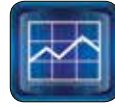


Payback through Mechanical Validation

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

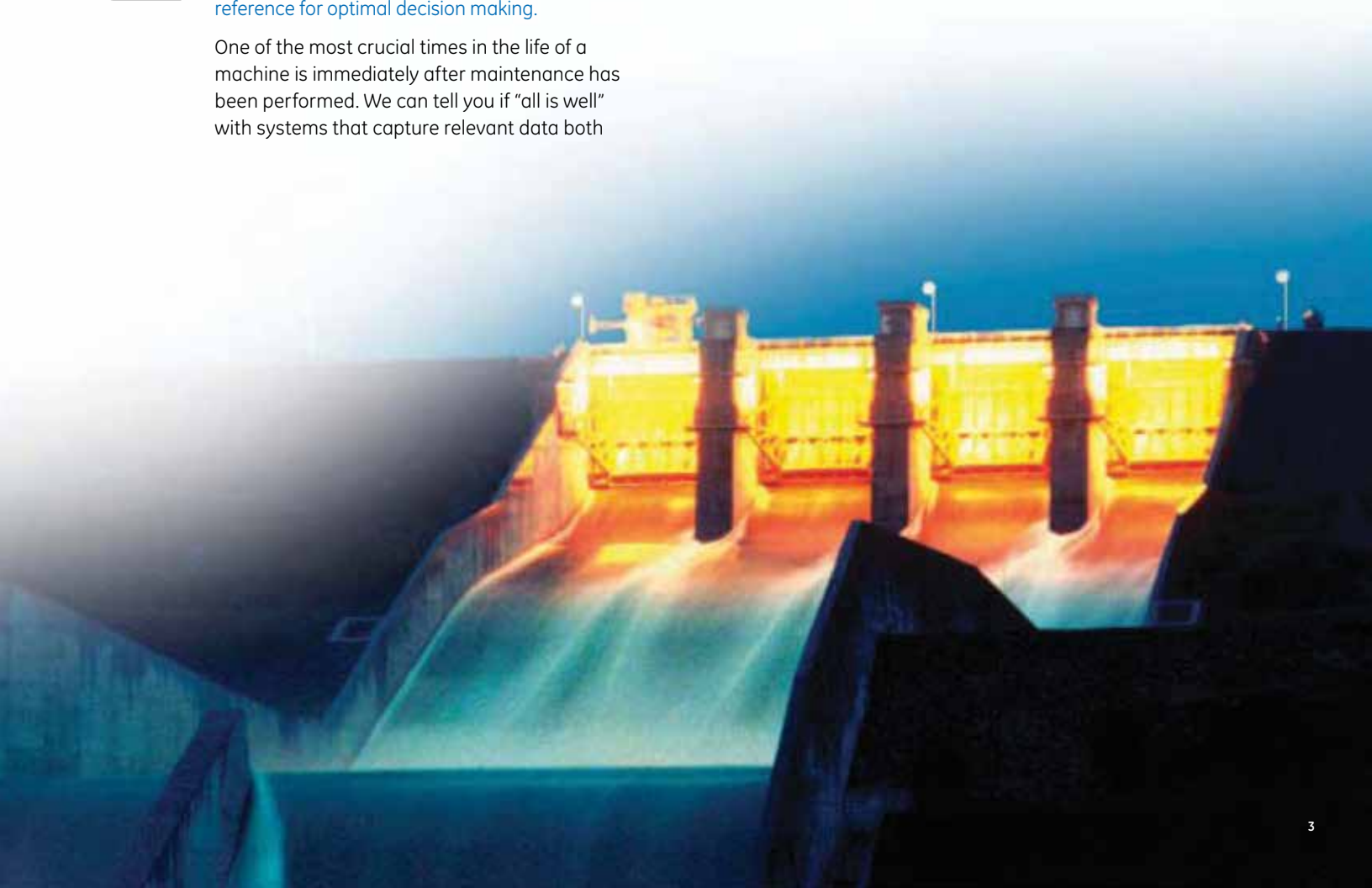
before and after maintenance. You can instantly see if problems are present and make decisions accordingly. For many customers, the ability to knowledgeably continue with or abort the startup of a hydro turbine-generator unit can more than pay for their entire system in a single event.



Payback through Predictive/Proactive Management

Our solutions deliver information that allows you to manage your assets proactively and develop maintenance regimes when conditions—not calendars—dictate.

Hydro power generation units can be operated in varying operating conditions and cycles, and are required to be reliable, operational, and available based on the varying electricity demands in the industry. The ability to manage the asset performance and condition through predictive maintenance can yield immediate savings in maintenance costs, the ability to respond, as well as asset health.



Hydro Unit in Detail

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.

- 3500/46 Hydro Monitor
- 330505 Low-Frequency Seismic Sensor, Velomitor or Velomitor CT
- ADAPT 3701/46 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 babbitt 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.

- 3500/40M or 42M Vibration/ Position Monitor
- 3300 XL Series Proximity Transducer
- ADAPT 3701/46 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 3701/46 monitors.

- 3500/50 Tachometer or 3500/25 Keyphasor Module
- 3300 XL Series Proximity Transducer
- ADAPT 3701/46 Hydro Monitor

Rotor Vibration and Position

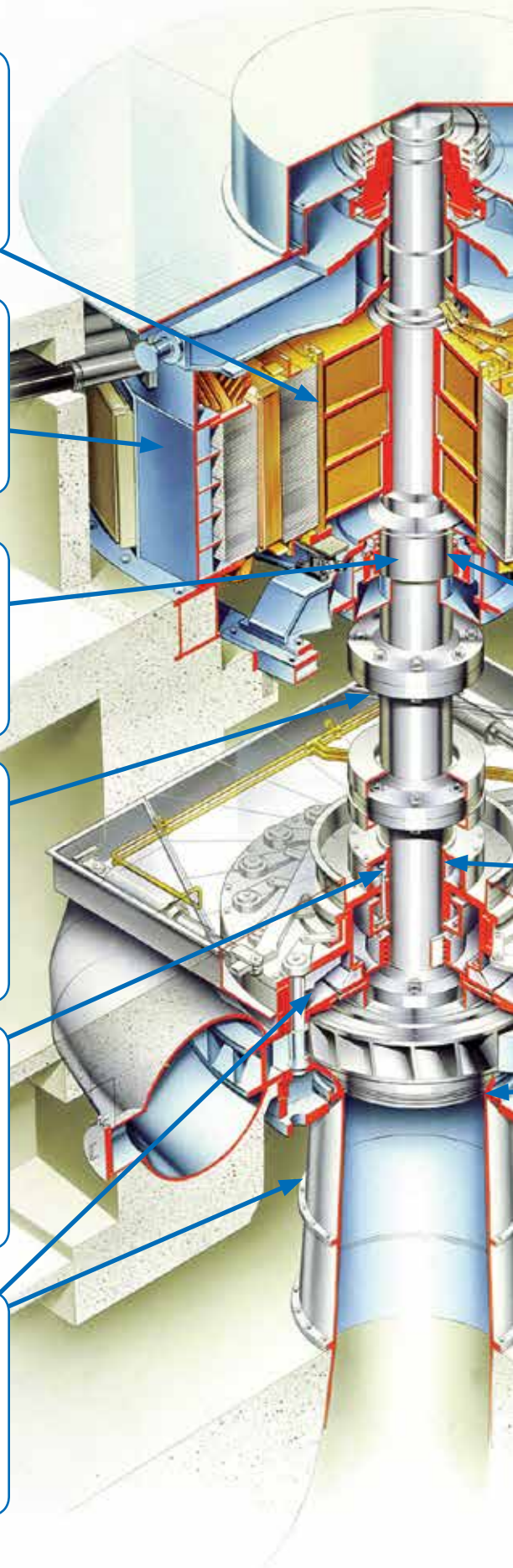
Detects a variety of important malfunctions such as rough load zone, various sources of unbalance, shear pin failure, bearing problems, and wicket gate problems. Each channel of the 3500/46M module can simultaneously monitor direct, 1X vector, NX vector, NOT 1X, shaft radial position (gap voltage), and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

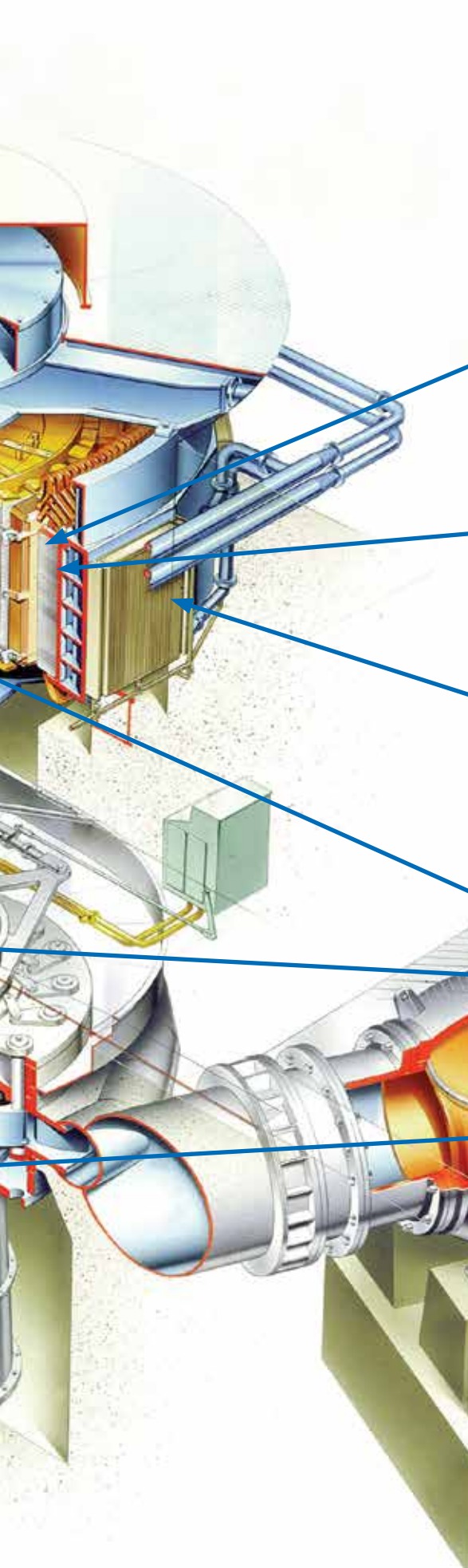
- 3500/46M Hydro Monitor
- 3300 XL Series Proximity Transducer
- ADAPT 3701/46 Hydro Monitor

Head Cover/Draft Tube Vibration

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 vibrations with accelerometers, these conditions can be detected and adjustments can be made to avoid operating in undesirable regions.

- 3500/42M Proximitor*/Seismic Monitor
- 330425/330400 Accelerometer
- ADAPT 3701/46 Hydro 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 interpolation between sensors, providing calculated stator shape plots.

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

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 3701/46 Hydro Monitor

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

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

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

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
- ADAPT 3701/46 Hydro Monitor

We Understand Hydro Machinery

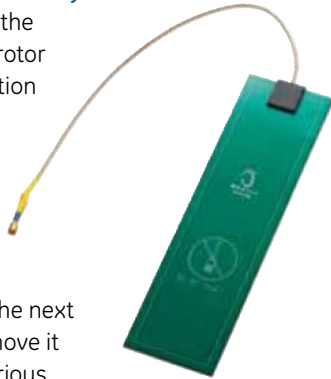
Whether Kaplan, Pelton, Francis, bulb, or propeller—vertical or horizontal—generation-only or pump/storage, our hydro monitoring solutions are effective because we understand the measurements you need to detect the unique malfunctions that can affect hydro units. While our current repertoire is impressive, we continue to expand and enhance our measurement capabilities, giving you keener insight into machine conditions, and making you better able to proactively manage your assets.

Transducers

In addition to the traditional proximity, velocity, LVDT, and acceleration measurements, our solution incorporates a wide array of sensors designed specifically for hydro power applications.

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 on-line 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.



330505 Low-Frequency Seismic Sensor

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



	Malfunctions and Corresponding Measurements					
	Guide Bearing Vibration (Runout)	Thrust Bearing Oil Film Thickness	Guide Bearing Temperature	Thrust Bearing Temperature	Keyphasor Pulse	Head Cover/Draft Tube Vibration
MALFUNCTION						
Mechanical/Electrical Hydraulic Unbalance	●				●	
Rough Load Zone	●				●	
Shear Pin Failure	●	●			●	
Misalignment	●				●	
Cavitation						●
Rotor Rim Movement					●	
Stator Winding Vibration						
Stator Core Shift					●	
Uneven Air Gap					●	
Unbalanced Air Gap Forces					●	
Insulation Fault						
Excitation Fault						
Seal Ring/Discharge Ring Distortion					●	
Excessive Turbine Vibration					●	
Bearing Overload	●	●	●	●		
Bearing Fatigue	●	●	●	●		
Insufficient Bearing Lubrication	●	●	●	●		
Stator Insulation Deterioration						
Stator/Rotor Out of Round					●	
Stator/Rotor Concentricity					●	
Stator Flexing					●	
Loose Stator Laminations						
Plugged Stator Coolers						
Blocked Stator Ventilation Ducts						
Overheated Stator Coils						

The Right Products

From robust sensors, to highly reliable monitoring hardware and diagnostic software, our Bently Nevada condition monitoring products are designed to work together, delivering the high quality information you need to manage your assets.

MEASUREMENT										
Generator Air Gap	Stator Frame Vibration	Generator Temperature	Process Variables	Generator Partial Discharge	Wicket Gate Position	Seal Ring/Blade Tip Clearance	Stator End Winding	Stator Bar Vibration	Rotor Mounted Air Gap	Brush Monitoring
					●					
			●		●					
			●							
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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.

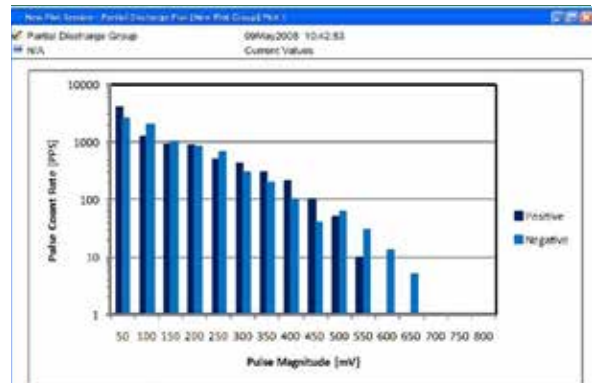


Designed to resist electrical tracking corona

damage, partial discharge, magnetic field interference and electric field interference, this system is well suited for the electrical environment in hydro generators.

HydroTrac™ Partial Discharge System

Insulation failure is one of the leading causes of major outages in hydro machinery. Partial discharge (PD) activity has proven reliable at indicating early onset of stator insulation problems. The HydroTrac Partial Discharge System provided by Iris Power Engineering, a leader in this technology, enables continuous on-line monitoring of partial discharge activity. Integrating this measurement with System 1 software's Partial Discharge plot enables viewing and correlation with vibration and other data on a common platform.



ADAPT* Hydro Monitor

The ADAPT Hydro monitor has been expertly designed for the condition monitoring and protection of a wide variety of hydro turbines that require no more than 12 sensor points. 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 source 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 3701 is configured and validated with Bentley 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 GE's Bentley Nevada field services team.

Operator Display for ADAPT 3701 is a simple, easy to use, entry package in the System 1* Evolution software family—termed System 1 Basic. This low cost, light footprint, display package is both an operator display and a troubleshooting tool with simple snapshot oscilloscope type features.

Key Features

- Ideal for hydro turbines where mechanical and hydraulic vibrations are of primary concern, and where generator air gap measurements are not required.
- Hydro turbine specific signal processing and measurements.
- 2 Keyphasor/Speed Inputs
- 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-T/100Base-TX Autosensing Ethernet RJ45 connections
- Hardware configuration lock prevents changes when in run mode
- One Protection Fault SPDT Relay Output
- Eight Programmable SPDT 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 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
- 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

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 Decision Support* software automatically audits data collected in System 1 software against user-embedded rules and knowledge. These rules detect mechanical, electrical, or hydrodynamic problems and generate informative Actionable Information* advisories. This software can tell you when there is a problem with your machinery—via e-mail, pager, cell phone, control system screen, desktop annunciator, or virtually any other notification method you prefer. In addition to rules you generate yourself, System 1 software can be augmented with pre-configured rule sets—RulePaks. **The HydroX™ RulePak** combines the expertise of IRIS Power, New York Power Authority (NYPA) and GE Measurement & Control, resulting in one of the most comprehensive solutions for monitoring and diagnosing hydro turbine generator faults. Using machine properties and models, it transforms complex data into anomaly identification including Partial Discharge Analysis, Air Gap fault problems, Mechanical Vibration problems and Process problems.

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.

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.
Air Gap Plots (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	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.
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.

¹Standard Plot Types: Orbit, Timebase, Polar, Bode, Shaft Centerline, Cascade, Waterfall, Spectrum, Trend, Bargraph, Tabular list

Comprehensive, Globally Available Services



Technical Support Agreements

A one-year renewable Technical Support Agreement (TSA) 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 and Diagnostics

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.



Design and Installation Services

We can provide comprehensive project management services to install and configure our solutions, document the installation, contract and manage site craft labor, and more. You determine the scope, from simple installation consulting to full turnkey services to everything in between.



Reliability Services

We provide our customers with the tools, processes, and methodologies to identify and implement the proper condition monitoring technologies, strategies, and predictive services for all maintainable assets required to meet their specific maintenance and operational goals.

- 
- Global Experience
 - Local
 - Deep Application Expertise
 - 24/7/365 Technical Support
 - Thermodynamic and Rotordynamic Expertise
 - Remote Service Capabilities – Move Data, Not People
 - Complete Turnkey Installation Capabilities
 - 50+ Years of Condition Monitoring Innovations

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Learn more about our Hydro Solutions online at
<http://www.ge-mcs.com/en/bently-nevada.html>
(Click on the “Application Solutions” link)



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