Brüel & Kjær Vibro

Application Note

Monitoring Hydroelectric Units with COMPASS

COMPASS offers a comprehensive vibration, process and performance monitoring solution for all types of hydro generating units, and is being used in hydro applications, world-wide.

There are enormous economic benefits to be made by reducing maintenance and unnecessary downtime in the hydroelectric industry, and condition monitoring of the hydroelectric generating units and their auxiliaries is one of the crucial factors for achieving this. Effective maintenance and operation decisions depend on reliable, timely and relevant machine condition information.

Brüel & Kjær Vibro offers several systems that satisfy this requirement, with **COMPASS™** being the most comprehensive solution.

This Application Note describes some of the basic features of the system that set it apart from other monitoring systems, and focuses on some of the advanced monitoring capabilities of COMPASS for the hydroelectric generating unit components.

What is COMPASS and why is it so special?

COMPASS is an integrated plant-wide safety and predictive monitoring system that is not only used extensively in the hydro industry, world-wide, but also in other power plants and petrochemical and heavy process industries. This success is partly because of its unique design and service concept.

Integrated system concept - COMPASS is renowned as a complete, stand-alone vibration monitoring system. But it also has process and performance monitoring capability, and has been designed from the out-start to have an open architecture so it can take in data monitored by other systems, and send it on to other systems via 4-20 mA hardwires, Modbus or local area network. This system integration capability allows dedicated monitoring systems to be readily interfaced to COMPASS for specialized monitoring tasks such as cavitation, temperature, flow and partial discharge measurements. COMPASS functions in this case as a core monitoring system, where imported information from various monitoring and control systems is:

- Stored in the COMPASS database and automatically compared to alarm limits and used for activating relays
- Further processed in COMPASS and correlated to other data in multiple-display plots
- Exported further on to a distributed control system (DCS), computerized maintenance management system or other system for operator information

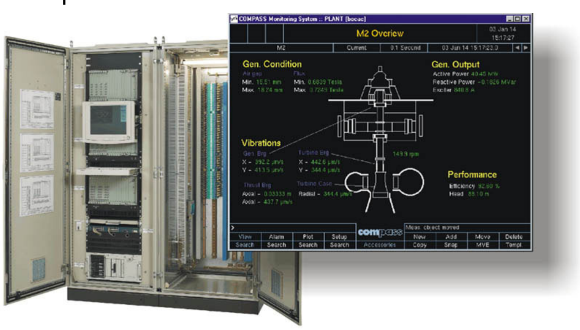

Fig. 1 COMPASS - Hardware cabinet with monitoring modules and an "at-a-glance" view screen showing vibration, process and performance values and alarm status of a hydro unit

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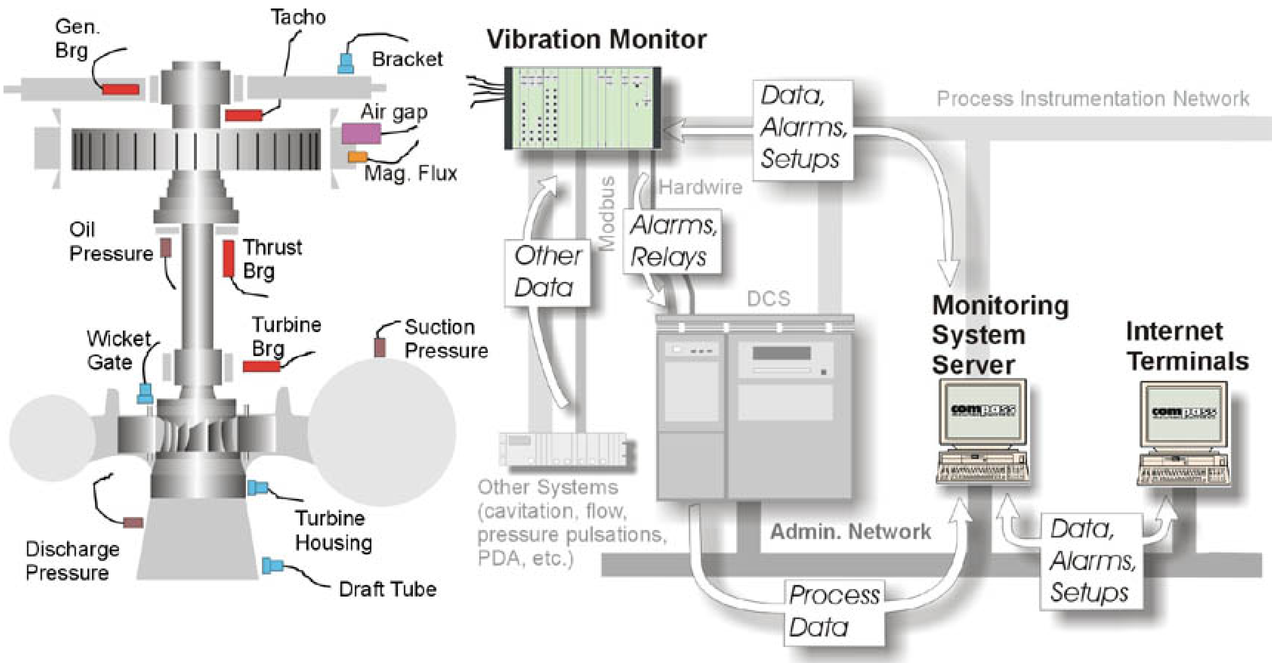

Fig. 2 Example of a COMPASS monitoring system configuration for a hydroelectric application

Advanced monitoring technology – Not only does COMPASS offer highly flexible sensor input to the system, but also a wide range of early fault detection and diagnosis measurement techniques that can be used to process these signals. This includes a user-defined calculated measurement, which is the basis for our performance monitoring package. All of these measurements are stored in a versatile Oracle® database so slowly developing faults can be trended and detected - automatically. This advanced monitoring technology gives you early, reliable fault detection and diagnosis with minimal risk for false alarms.

Adaptive monitoring strategies – COMPASS offers a variety of tools that significantly increase the reliability of monitoring by distinguishing signal changes from process conditions from those due to developing faults. This means you can accurately monitor a unit to individual alarm limits at different speeds and loads without false alarms.

Automatic machine diagnosis system – In large installations where there are many measurements, the user may not have time to look at each individual measurement. Our neural network based machine diagnosis system, **ADVISOR™,** can be programmed to automatically look at all measurements in the database for potential fault symptoms. This greatly reduces the diagnostic work-load so the user can focus on other tasks.

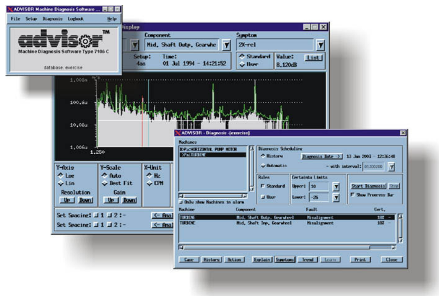

Fig. 3 ADVISOR makes a probabilistic diagnosis, where there is a calculated certainty for different faults that may have the same symptoms

Tailor fit monitoring application with minimal engineering – COMPASS is cost-effectively “customized” to specific applications using a wide range of standardized products and services. This gives you an effective, quality controlled condition monitoring solution that specifically meets your requirements and the design and construction demands of your unit. Our experienced project implementation group ensure the system is up and running on schedule, and our world-wide sales and support network ensure you get the maximum condition monitoring benefits out of the system, long after it is installed. Services include everything from installation, training, upgrades and long-term service agreement contracts.

Time proven system – Although COMPASS is continuously upgraded with the newest monitoring, communication and information technology available today, the basic, robust platform is not “tampered” with, and has been successfully used for over 10 years now.

Specialized monitoring capability for hydroelectric generating units

The basic COMPASS system platform offers a number of measurement techniques for the hydro generating unit and auxiliaries.

Generator monitoring

Fault diagnosis for these machines can be difficult since the root cause can be an internal electrical or mechanical fault, an outside grid fault, a fault with the external hydraulic/auxiliary supply, or any combination of these faults. COMPASS offers a number of different measurement techniques that accurately pinpoint the problem at an early stage of development.

Air gap Monitoring – Monitoring the air gap distance between the rotor and stator can give early warning detection of many kinds of generator faults and is therefore one of the most important measurements done on a generator. One or more stator-mounted capacitive sensors are used to monitor the air gap of each individual passing pole.

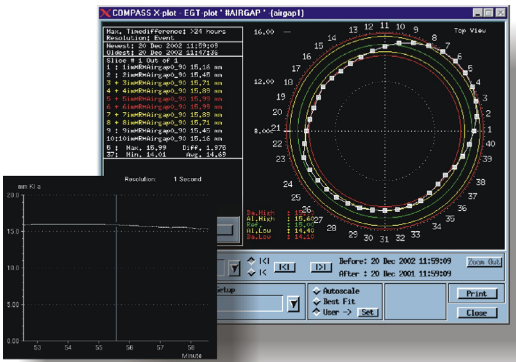

Fig. 4 Polar plot (right) showing rotor shape as determined by maximum and minimum air gap measurements for each sensor (upper and lower alert and danger alarm limits are indicated by respective yellow and red concentric circles). Air gap trend plot for pole 6 is shown on the left

Stator core vibration – Much information on both the mechanical and electrical condition of the generator (including magnetic unbalance) can be cost-effectively monitored and trended by stator-mounted accelerometers.

Partial Discharge Analysis (PDA) – Studies have shown that about 40% of all hydroelectric generator outages are caused by the failure of stator winding insulation. Insulation deterioration is monitored by capacitive couplers permanently mounted in the stator. Dedicated PDA monitoring systems are easily interfaced to COMPASS.

Magnetic flux - By monitoring the magnetic field unbalances of a generator, it is possible to detect shorted winding turns and hot spots. Poles are monitored individually and monitored for deviations during each turn. These can also be trended.

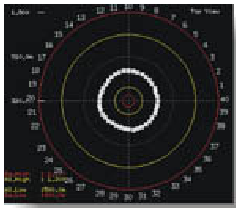

Fig. 5 Typical magnetic flux measurements

Current analysis – This technique allows various types of stator and rotor faults to be detected and diagnosed, such as bearing faults and load problems. COMPASS also provides transient monitoring capability to indicate voltage/current phase shifts and current time duration.

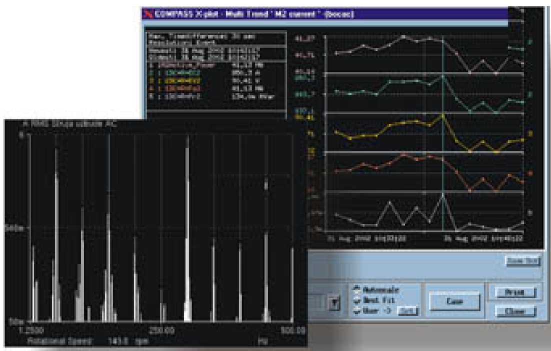

Fig. 6 Left: Exciter current spectrum of a 55 MW generator, (showing harmonics and sidebands). Right: Multi-trend plot showing real and reactive power, current and voltage

Turbine monitoring

As with the generator, a combination of vibration, process and performance monitoring techniques are used for monitoring the Francis, Pelton, Kaplan or Bulb type turbines. No one single parameter is sufficient for detecting and diagnosing a fault, so most of these parameters are correlated together to give a big picture of what is happening, and to increase the certainty of the diagnosis.

Efficiency and head monitoring – By monitoring the turbine efficiency and head, many performance-related problems such as flow turbulence, pulsations and recirculation can be identified at an early stage of development. The performance plots are also useful for trending the cumulative effects of runner blade erosion, cavitation and blade clearance. These parameters are calculated using process values that are typically imported from the DCS and other control systems.

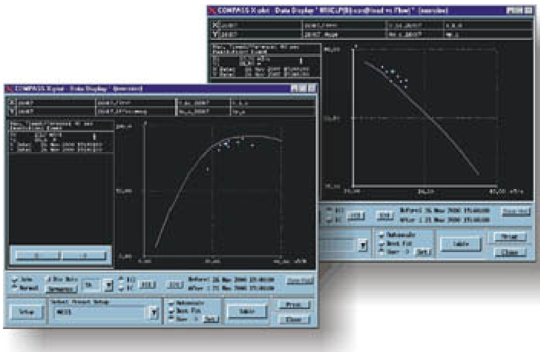

Fig. 7 Francis turbine efficiency (left) and head (right) curves

Flow measurements – These are used in the efficiency calculations, and are measured by the ultrasonic transit-time or other recognized methods. Dedicated systems for this are easily interfaced to COMPASS.

Pressure pulsation monitoring – The onset of vortices and turbulence can be detected together with its severity by taking pulsation pressure measurements at the entrance of the spiral case and on the draft tube using strain-gauge pressure sensors.

Cavitation – The onset of cavitation is detected together with its severity by taking high frequency accelerometer readings on one or more of the wicket gates near the runner. This value can be correlated to other parameters such as runner housing vibration. Dedicated cavitation monitoring systems are easily interfaced to COMPASS.

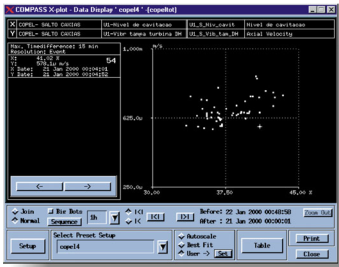

Fig. 8. Scalar vs. scalar plot from a 1240 MW hydro installation showing cavitation level vs. turbine cover vibration

Monitoring of other components

As shown in Fig. 2, a number of other components are monitored, such as the wicket gates, generator brackets, rotor and bearings. Relative vibrations and displacement and absolute vibrations are used to monitor for broken, loose parts, cracked wicket gate blades, turbulence, alignment, balance, damaged bearings, etc. Monitoring bearing temperature and oil pressure is extremely important, as for example for the thrust bearing. All these measurements can be correlated with other parameters to increase reliability of detecting and diagnosing machine faults.

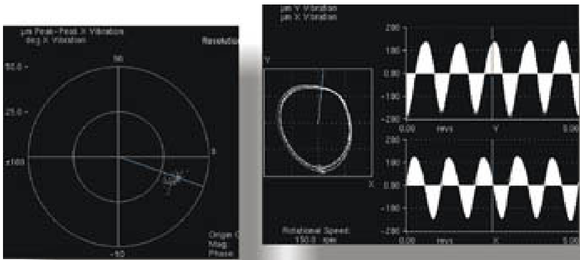

Fig. 9 Vector history (left) and an orbit plot (right) for Francis turbine bearings

Contact your local sales representative to find out more how COMPASS and other Brüel & Kjær Vibro products can help you maximize uptime and minimize maintenance costs at your hydroelectric power plant.

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