Customer driven

Fine-tuning an integrated drive monitoring system

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When factory equipment unexpectedly breaks down, production grinds to a halt, resulting in costly downtime while the equipment is repaired. But with ABB's renowned Condition Monitoring Systems (CMSs) for continuous tracking of asset history (ie, operation, wear, damage and maintenance), these production hiccups can be prevented, thereby relieving a company of serious economic implications.

One such CMS is ABB's drive monitoring system. As large drives are often used to power critical equipment, their continued maintenance is also critical. Drive units, such as ABB's medium voltage (MV) drives, also serve as huge data banks, recording information related not only to the drive converter performance, but also to the driven equipment and the whole downstream production process. Because of their important role, a reliable and intelligent CMS is highly desirable. This requires detailed asset knowledge and analysis of the operational context, application requirements and reference data. But this information can only be gained through practical application – here, cooperation with ABB customers is vital. To develop its drive monitoring system, ABB collaborated with several customers to test the system in real industrial environments. This article highlights two of these successes.

One of the world's longest communication tunnels is being constructed through the Swiss Alps. The new railway route under the St. Gotthard Pass will be over 57 km long and comprise a total of 153.5 km of tunnels, shafts and passages. The project is expected to be completed in 2016.

To help excavate the tunnel, a 821 m deep shaft was dug near the mountain village of Sedrun. A large hoist machine lifts rubble out of the mine through this shaft. ABB's multi-megawatt ACS 6000 drive powering the hoist machine's motor is one of the first pilots for the drive monitoring system. While thoroughly tested in the laboratory, this CMS required verification under true industrial conditions – dust, vibration and temperature variation – and, perhaps most importantly, it required real data from a real application. The tunnel construction site provided these very conditions.

The pilot installation helped to optimize the hardware design, enabling evaluation of performance and data storage capacity to thermal and cooling issues of the monitoring unit. Only a real-world installation with its cyclic process could enable analysis of average data intake and processing speed, thereby minimizing CMS installation costs for future customers.

This pilot also provided a field test for the remote connection under realistic, albeit somehow unusual (underground) conditions. To ensure a stable remote connection and a secure VPN data access between the client site and ABB offices, the two groups had to work together closely.

The industrial environment also verified that the diagnostic procedures had been well defined: Is the system responding to the changes as anticipated? How could one improve the original design to add even more value, robustness and effectiveness? These basic questions could not be answered by the development team alone.

A customer pilot provides benefits for both ABB and the client. To test the drive monitoring system, ABB observed the state of the huge drive with great scrutiny while this was at the same time automatically monitored by the CMS. This provided ABB had the opportunity to test, debug, and fine-tune a new product that is being deployed in many applications.

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A year of test experience in the tunnel excavation site confirmed the robustness and efficacy of the drive monitoring system. With no faults in the CMS, ABB could confidently move forward with a mature product.

Ventilation tunnel at Sedrun. © AlpTransit Gotthard Ltd

Smooth sailing

Imagine a double-acting tanker more than 250 m long, carrying 120,000 m^3 of crude oil and crashing through the ice with its propeller while sailing astern across the frozen waters of the Botnic Sea, or a luxurious cruise liner with more than 1,300 crew members, taking 2,500 passengers onboard for a dream vacation to exotic, tropical islands.

These starkly different vessels have at least one thing in common – they are operating examples of state-of-the-art technology where innovation combines with care in terms of product reliability and vulnerability. The functioning of these ships involves not only economical cost, but also human and environmental safety.

Both types of vessels use the Azipod® propulsion system, distinctive for its great maneuverability, functionality and efficiency, which was developed by ABB Marine, a global leader in the marine propulsion market. With its engineering and manufacturing facilities in Helsinki, Finland, ABB Marine developed an entire propulsion monitoring system (Propulsion Condition Management System, or PCMS) that incorporates not only the Azipod® unit but also frequency converters, transformers, switchboards, generators, automation, controls and more. Collaboration with Royal Caribbean Cruises Ltd. to test a part of this system was instrumental in further developing the PCMS.

Shaft bearing diagnostics

One of the components with the most critical impact on the entire Azipod® system performance is a shaft bearing – more precisely, a set of bearings mounted on a short motor shaft that drives the propeller. Because of extreme, dynamic loads coming straight from the propeller, these bearings can deteriorate. For early detection of such rolling element bearing defects, ABB developed a bearing asset monitor (ie, novel diagnostic algorithms) as part of its overall DriveMonitor™.

To minimize the risk of bearing malfunction, ABB introduced the following predictive maintenance strategy: If bearing faults can be detected early on and the residual lifetime can be predicted accurately enough, dockings can be well planned, the costs will be relatively low and the customer can coordinate the vessel usage to fit its docking schedule. The key goal then was to develop and use specific diagnostic techniques that would signal bearing problems early on, sparing the customer a potential economic disaster. Moreover, diagnostic components were to be integrated with the Azipod® propulsion control system, allowing ABB Marine to provide the end customers with a wide scope of control, monitoring and diagnostic functionality.

After several short-term piloting installations on different types of vessels operating on different sea conditions, a vast amount of vibration data was collected and used to fine-tune the diagnostic algorithms, making them reliable and immune to false alarms.

This real-world implementation was essential to obtaining genuine data that can be used to improve the bearing monitor component of the PCMS.

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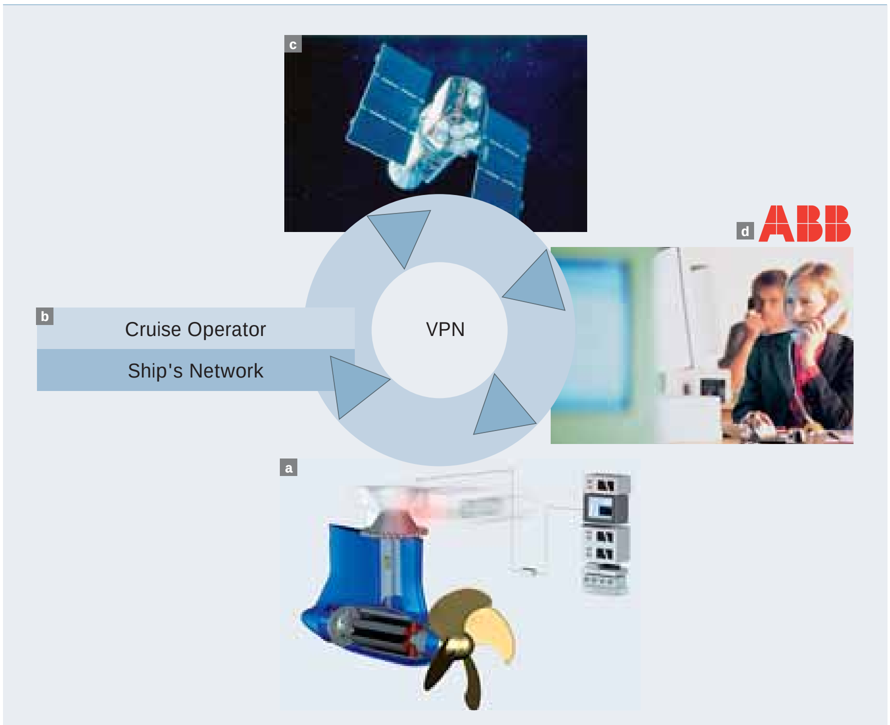
With Royal Caribbean's full trust in ABB's expertise and support of ABB's goal of improving its PCMS, the final system was deployed on one of Royal Caribbean's large cruise liners. Raw vibration data, together with the main shaft rotation speed and azimuth angle, were periodically measured and processed for almost a year.

The system concept was straightforward, yet used some advanced techniques. Vibrations at the bearing housing were collected with an industrial-rugged PC data acquisition unit mounted inside the Azipod®, where they were exposed in binary format as data vectors and transferred via wireless Ethernet to the diagnostic server installed in the ship's main electrical control room. Well-known high frequency enveloping techniques, as well as newly developed algorithms designed for early shock pulse detection, were used to process the vibration data. The entire cycle of data flow – from measurements to calculations – was automatically triggered at regular intervals.

During its operation, the automatic fault detection module found no signs of defects in the bearings. However, regular analysis of the vibration spectra revealed additional information about the Azipod®'s performance. Although not alarming, the clear existence of particular harmonics originating from electrical as well as mechanical designs brought complementary knowledge about the system behavior. Such knowledge is of great value at early design stages of shaft bearings.

The ability to remotely connect from ABB on-shore offices to the diagnostic system onboard the vessel was imperative. With the help of Royal Caribbean's IT personnel, a VPN-secured satellite connection was utilized to access the diagnostic server 1.
It was then possible for the staff to see recent calculations and download the required data at their desks, checking the monitoring system's performance. The ship's crew technicians regularly sent mass amounts of raw vibration data on CDs to ABB for further analysis.

1 The concept of remote access to a PCMS onboard a ship a that utilizes connection to the ship operator's network b, secured with VPN tunneling and implemented over satellite link c to monitor AZIPOD performance from ABB service office d.



Developing the integrated PCMS

Diagnostics of the main shaft bearings, although crucial, cover only a small part of the entire propulsion system. It consists of many components, including ABB switchgears, protection relays, MV frequency converters, motors, transformers and control units, as well as third-party products such as hydraulic steering and cooling systems. For each of those components there are hundreds of different physical measurements already defined and used, partly for control purposes but mainly for visualization at the operators' panels. They bear direct information about the state of the device where the measurement is taken; moreover, they contain hidden knowledge about the other components linked in the process.

The real challenge is to provide a condition monitoring system that successfully integrates all the information at hand and provides an easy means for engineering diagnostic relations between signals. Such a system will eliminate time-consuming, error-prone software development of diagnostic solutions for specific applications. And the result: an Excel-like approach to defining the type, timing and frequency of data collection as well as the necessary calculations, providing clear, consistent information about the state of a particular system subcomponent.

The technical vision of such a system perfectly fits with ABB Marine's service strategy as well as with the end-customer's need to support its technical crew with an integrated condition monitoring tool. The customer must have either local or remote access to both consistent information about the assets' conditions, as well as to the history log of the propulsion system operation conditions. To maintain the PCMS, the customer may also arrange personalized service contracts with ABB.

Implementing an integrated PCMS

The condition monitoring system for the MV drives used in the St. Gotthard Tunnel and the bearing asset monitor module used in the cruise ship both employ an ABB platform known as DriveMonitor™. Because the frequency converters used in the tunnel and in the propulsion system are nearly identical, the natural choice was to take advantage of the experience gained underground and apply it overseas.

Factbox Royal Carribean Cruises Ltd.

Three Norwegian shipping companies founded Royal Caribbean Cruises Ltd. in 1969. Royal Caribbean's first cruise ship entered service in 1970. It now has a fleet of 20 ships with a capacity of over 47,000 people. Royal Caribbean's Song of Norway was the first passenger ship to be stretched; it was cut in two and an 85-foot section was added to its middle. The company has a net income of over $ 700 million (reported in 2005).[1]

Reference
[1] www.royalcaribbean.com, retrieved June 2007

Hoisting gear at Sedrun. © AlpTransit Gotthard Ltd

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With steady improvements as ABB learns more from such field tests, the PCMS will eventually be able to communicate and collect data from all propulsion system subcomponents. For most of the signals it will connect to the Industrial IT System 800xA control and automation platform. Faults, alarms and raw data – from the protection relays, through the generators and transformers, to the Azipod®'s steering, sealing and cooling – will be imported to the PCMS. The number of parameters, signals, events and alarms from the frequency converter will be continuously monitored. In addition, third-party condition monitoring devices can be used to obtain precise and complementary information about the state of a particular asset. Should the Azipod® malfunction, it will be important to determine the external conditions at the time (ie, speed of the ship, course, wind speed and sea condition). Finally, remote access from shore to the main PCMS server in the electrical control room must be assured.

Having the opportunity to test these condition monitoring systems in real-world situations is the only sure way to fully develop a PCMS. Real data from real environments enable ABB to create enduring products with a multitude of applications. But to do this, customer collaboration is essential.

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