Cruise control

A propulsion condition management system that allows onshore monitoring of offshore installations

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Keeping tight schedules is a fact of life for most cruiseship operators. Because speed and maneuverability are two important factors that help a ship's punctuality, ABB's Azipod® electric propulsion system is fast becoming the system of choice for many operators.

System reliability throughout the life of the vessel is also an important factor that could make or break operators. Knowing the condition of their assets at all times not only prevents the unexpected from happening but it also can help to improve long- and short-term efficiency and performance.

With the availability of new and improved service solutions, ABB is helping operators get the absolute most from their investment. Its new Propulsion Condition Management System (PCMS) is a fully scalable and flexible monitoring tool that is now used on one of the most state-of-the-art cruise liners ever built, Celebrity Solstice.

Innovation on the move

As the expression goes, "time is money," and in an environment as cut-throat as today's, tolerance of delays and downtime is quickly diminishing. Preparing for the unexpected is and should be an integral part of any organization's effort to reduce risk. Instead of responding to particular events, companies need to focus on maintaining operations no matter what happens. This means implementing a strategy that not only manages risk but also brings other long-term benefits with strategic payoffs.

For cruiseship operators, staying on schedule is absolutely fundamental to their business. Even with the continuous improvements in ship design techniques and propulsion technology, operators can never give a cast-iron guarantee that nothing will go wrong. The best strategy, however, is to be prepared for most, if not all eventualities.

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Ship designers today not only look at ways of increasing reliability but they also have to focus on energy efficiency, performance and the need to cut emissions. Even though the term energy efficiency is usually associated with the reduction of energy needed to provide the same level of energy service, it also encompasses other attributes, such as proper maintenance, planned repairs and the maximum availability of technical equipment.

Recent studies made by Wärtsilä[1)] on boosting energy efficiency in ship applications have identified four areas with the potential for improvement: ship design, propulsion, machinery, and operation and maintenance [1].

ABB's Azipod® is an example of an electric propulsion system that is well-known for its energy efficiency. Such is its reputation that 50 percent of all cruise liners built during the last two decades have the Azipod electric propulsion system installed, and today an ever-increasing number of vessel types are being designed and built with it. It can reduce fuel consumption by up to 30 percent – when Dynamic Positioning (DP[2)]) a computer controlled system to automatically maintain a vessel's position and heading by using its own propellers and thrusters – is included as part of a ship's operation.

For a cruiseship operator, the availability of Azipod is extremely important. That is why ABB works hard to support the end customer with tools and services that not only ensure he is constantly aware of the condition of his asset but also that he is informed of the most optimal way of using it.

The latest addition to this portfolio of solutions is called the Propulsion Condition Management System (PCMS). It is a result of a two-part strategy that sets out to give the customer the best possible service both during the warranty period and after it has expired. PCMS was developed during the first part of this strategy, which involved developing a condition-monitoring system in a pluggable and scalable architecture that would collect and analyze process data from as many installed devices as possible. This data constructs a continuous image of the system performance, which can be remotely accessed by an ABB service engineer, thereby allowing him to plan and recommend improvements in the responsiveness and quality of the system with the customer.

The second step in the strategy involves the evaluation of service offerings for the customer after the warranty period has expired. It consists of a model that is comprised of different service-contract scenarios and options ranging from simple troubleshooting through periodic maintenance right up to continuous monitoring.

A pilot version of the PCMS was installed onboard the Celebrity Solstice cruise liner in October 2008. Constructed in the Meyer-Werft shipyard in Papenburg (Niedersachsen), Solstice was, at that time, the biggest ship ever built in Germany.

Efficiency in motion

Celebrity Solstice (title picture) is designed to be the most energy-efficient cruise ship on the market; when compared with other ships, energy savings of approximately 30 percent have been achieved using high energy-efficient components, such as a photovoltaic system, optimized hydrodynamics, an extremely efficient underwater coating and an energy-saving lighting system using LEDs.

ABB's new Propulsion Condition Management System (PCMS) is a fully scalable and flexible monitoring tool that collects and analyzes process data from many installed devices.

Power generation for all propulsion and electrical power needs onboard is satisfied using only four main diesel generators rather than the five or six required by other recent big cruise ships. The four Wärtsilä 16V46CR diesel engines, each rated at 16,800 kW at 514 rpm, are arranged in a power-plant configuration and give a total power output of 67,200 kW. Celebrity Solstice is the first cruise ship in the Royal Caribbean International, Celebrity Cruises fleet with common rail fuel injection Factbox 1.

Propulsion is provided by a pair of ABB V23-type Azipod units, each with a rated power output of 20.5 MW running at 137 rpm. Each five-bladed propeller has a diameter of 5.8 m and is interconnected with a synchronous and brushless 6-phase electric motor,

Footnotes

1) Wärtsilä is a Finnish manufacturer of large diesel and gas engines for use in powering ships and electricity generation.

2) Position reference sensors, combined with wind sensors, motion sensors and gyro compasses provide information to the computer pertaining to the vessel's position and the magnitude and direction of environmental forces affecting its position. DP is used extensively in the offshore oil industry.

which is driven by two medium-voltage propulsion drives ACS 6000SD voltage source inverter (VSI) frequency converter) each rated at 10.5 MVA Factbox 2.

As well as focusing on efficiency, the ship's designers put a lot of effort into implementing sophisticated navigation systems. The latest version of NAPA Power, a system that finds the optimal way to operate the vessel by optimizing the route, speed profile and propulsion mode for each part of the voyage, is installed on the Celebrity Solstice. The system is based on a 3-D model of the ship and includes the latest research on the hydrodynamics affecting a ship's resistance. To properly estimate the ship's performance, the model requires an accurate representation of the power plant and propulsion system, and other parameters, such as sea currents, varying winds, waves and water depth also need to be taken into account [2].

The ever-watchful PCMS

Since so much effort has gone into creating a ship that is new in almost all aspects of design and operation, it seems only right to have some sort of supervisory system in place that is capable of listening to, recording and monitoring selected and critical components in the propulsion chain, and then correctly making a diagnosis in the unlikely event that problems were to arise. As the supplier of choice for the propulsion system, ABB was also commissioned to supply a pilot version of its newest monitoring tool, the PCMS.

PCMS is based on DriveMonitor™, ABB's well-known diagnostic tool developed for medium- and low-voltage drives. PCMS takes the best aspects of DriveMonitor and expands their functionality to create diagnostic packages, such as pod and medium-voltage distribution network monitoring, that are specific to marine applications. The aspects that distinguish PCMS from other condition monitoring systems include:

- Scale
- Weight
- Data source versatility
- Sense of timing
- Intelligence
- Access and feedback

Scale

The Azipod is a sophisticated and complicated system. Apart from the pod itself with all its internal components, sensors and the multiphase synchronous motor, there is also: a lubrication system for the main, rolling-element shaft and slew bearings; the steering system; an air-cooling system for the motor; a frequency converter; supply and excitation transformers; a

Factbox 1 A common rail injection system

The way in which fuel is injected into the cylinders of diesel vehicles determines their torque, fuel consumption, emissions and noise level. Two factors are important for an efficient system: the fuel pressure as it enters the cylinder, and the shape and number of the injections.

A common rail injection system separates these two functions (generating pressure and injecting) by first storing fuel under high pressure in a central accumulator rail and then delivering it to the individual electronically controlled injection valves (injectors). This ensures that incredibly high injection pressures (in some cases over 25,000 psi or 1724 bar) are available at all times.

Source: http://www.dieselforum.org, retrieved September, 2009.

Factbox 2 VSI-type propulsion in a cruise ship

Celebrity Solstice is the first cruise ship that utilizes voltage source inverter (VSI)-type propulsion frequency converters. VSI is known to provide improved efficiency – the power factor (cosphi), which is around 0.75 for cyclo-converters (this varies with loading), is practically constant at 0.95 over the entire operational speed range. At full load, it exceeds 0.95, resulting in an efficiency greater than 98.5 percent! The ACS 6000SD converter uses integrated gate-commutated thyristors (IGCTs) as the switching devices and the ABB patented Direct Torque Control (DTC) principle for synchronous motor drives.

The 6-phase motors have two 3-phase windings and each motor is normally driven by two VSI-type frequency converters. However, in the event that one of the converters is not available, the other is more than capable of driving the Azipod motor. A high level of redundancy and fault integrity has been built into the design to ensure that even with a single failure in any of the four frequency converters, 75 percent of the propulsion capacity remains.

medium-voltage distribution network with all its feeders and switchgears; electric generators; and finally the entire control network in which the main propulsion controllers ensure proper balancing between the speed set points sent from the ship's bridge and the total electrical power available in the system.

PCMS is unique in that it provides fundamental and valuable condition monitoring functions for offshore vessels on a scale that had been previously very difficult to achieve.

The main data links between the PCMS system and Azipod components are shown in 1. The system is either plugged into the operator's network or has independent, dedicated data links to particular devices. This allows the PCMS to access data – via the operator's network (green link in 1) – supplied by the Azipod's interface unit controller and the protection relays in the medium-voltage distribution network as well as the signals handled by the main propulsion control. A fiber-optic Distributed Drive Communication System (DDCS) link between the PCMS and the frequency converter (in blue) is used to transmit parameter changes, as well as fault, event and alarm information generated inside the converter.

Connectivity to non-ABB condition monitoring devices or nautical systems is achieved using a specially developed software and hardware layer (black link).

Weight

Data collection, processing and storage are performed using a simple but flexible and "hidden" distributed setup. Each Azipod pod contains an embedded robust and compact DriveMonitor PC, which is installed inside the propulsion control unit (PCU) cabinet. All incoming data from this pod is processed in a single DriveMonitor box. A third PC, known as the PCMS server, is used to store and display all pod measurements, and is located in the main electrical control room. From the system's performance perspective, this setup can be easily configured to handle and balance different loads in case the system needs to be restructured.

Data source versatility

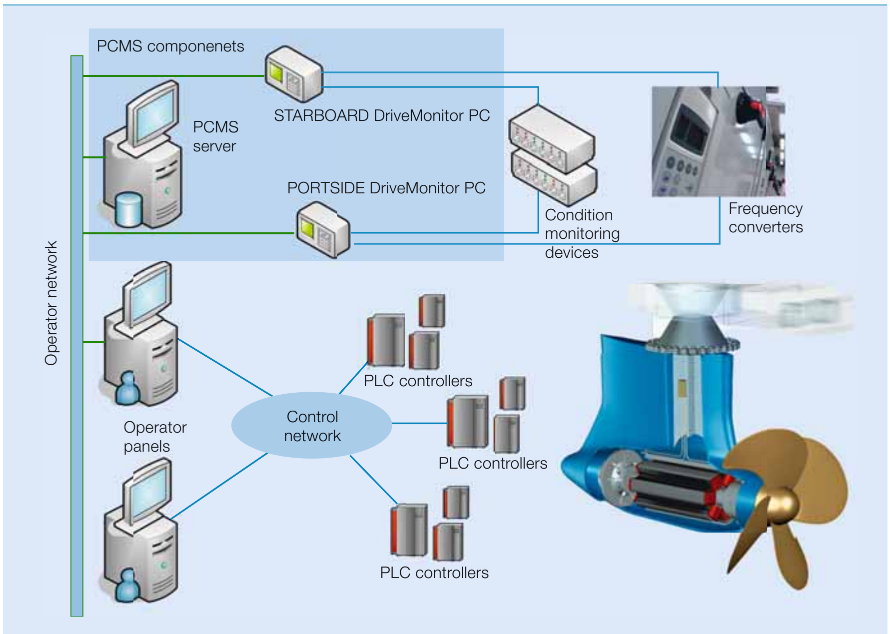
Azipod incorporates a large number of devices. Some communicate with each other using industry-standard communication protocols while others are simply hardwired together, with measurement and set-point values indicated by current and voltage levels. Even though the Azipod is an important part of a ship's construction, data from it alone is not enough to properly monitor a ship's overall performance. For this reason, PCMS also collects information from several other onboard non-ABB systems. To overcome the differences that exist in the various data formats, PCMS uses OPC[3] connectivity.

In principle PCMS is a client application for OPC data access and alarm and event (AE) servers, meaning it can read measurements as numerical data and import alarm and event type signals. There are cases where non-ABB devices are used that are not OPC compliant and tailor-made OPC servers, developed by ABB, are needed to read their data. One such example is a vibration condition monitoring device located inside the pod, which collects and processes vibration data from the main shaft bearing frame. Information about the status of the bearing is given to the Azipod control system as a relay output. In parallel, raw vibration measurements, together with spectra and some calculated indicators are sent from the pod to the PCMS system via a wireless link running on one of the DriveMonitor boxes.

In principle PCMS is a client application for OPC data access and alarm and event servers.

Another example concerns bridge nautical systems. In order to collect information about the ship's speed, course, trim, heel and the sea conditions, an OPC server has been implemented to interface with the National Marine Electronics Association (NMEA) protocol.[4] This server resides

1 PCMS connection diagram

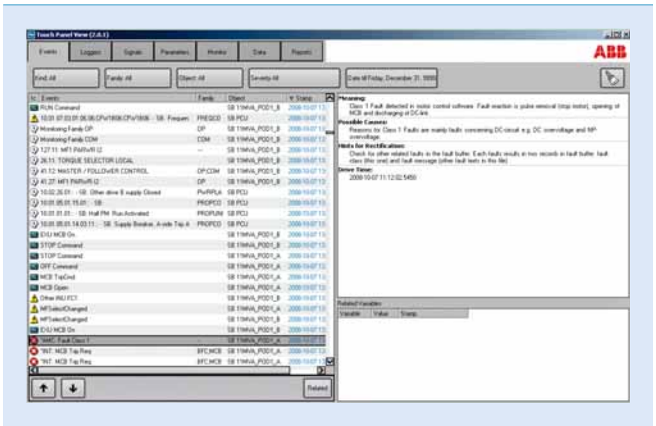


Footnotes

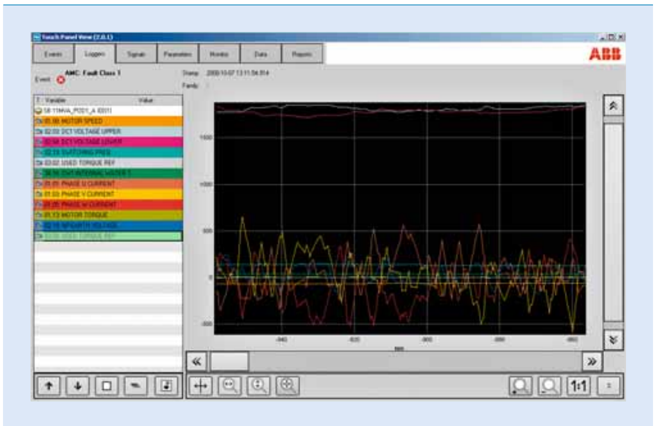
3) OPC stands for Object Linking and Embedding (OLE) for Process Control and represents an industry standard that specifies the communication of real-time data between devices from different manufacturers.

4) NMEA is a combined electrical and data specification for communication between marine electronic devices.

2 An alarm and event list with an example of a fault from a frequency converter generated during the commissioning tests



3 Loggers associated with a drive fault



in one of the DriveMonitor boxes and is connected to the nautical systems by a direct serial link. It converts NMEA sentences into OPC tags with recent values.

Currently, efforts are underway to develop a customized OPC server for protection relays that is capable of transferring transient recorders. These recorders are like snapshots of electrical transients (ie, phase voltages and currents) and are an indispensable source of information for a PCMS system in its attempt to find the real cause of a problem.

ABB's PCMS is flexible in that it implements various data collection scenarios to suit various aspects of a ship's design.

Sense of the time

The rate at which a component deteriorates or a fault propagates varies from device to device. Different scanning frequencies are sometimes required to measure various physical properties. However, it doesn't always follow that the higher the sampling frequency, the better the measurements that lead to fault detection. ABB's PCMS is flexible in that it implements various data collection scenarios to suit various aspects of a ship's design. Consider, for example, the bearings on the ship: Proper condition monitoring means supplying the operator with continuous information about both the main-shaft bearing vibrations and the number of metal particles in the bearing lubrication oil. Acquiring this information requires two separate measurement techniques, something the PCMS is capable of doing. It contains a Bearing Asset Monitor (BeAM) package that measures the vibrations using a sampling frequency of 41 kHz, while the number of particles in the oil is updated every 30 minutes.

Intelligence

PCMS is capable of collecting and processing raw measurements according to user-defined rules (ie, equations or formulas). For example, once an hour the system checks to see whether the azimuth angle and rotational speed of the shaft are within a certain range. If this is the case, the PMCS then checks when the last vibration measurement was taken and stored. If this occurred more than 24 hours previously, BeAM is triggered to sample vibration data over a period of 6 s at a high frequency. This sample is then processed by PCMS diagnostic algorithms to find the existence of shock-pulse transients, which are early indicators of a bearing fault. The entire procedure only happens once a day on condition that the angle and speed are within the specified range.

Another diagnostic package calculates operating profiles. For the sake of additional reliability calculations, the PCMS continuously calculates the total time the Azipod operates in different load zones, ie, for different azimuth angles, propulsion power and shaft rotational speeds.

The PCMS installation onboard Solstice also contains a monitoring solution for the medium-voltage distribution network. The main component in each switchgear pole is an intelligent protection relay connected via SPA to a PROFIBUS gateway to an AC800M PLC controller. This solution allows PCMS to define and monitor key efficiency indicators, such as the total power distribution between working generators, the load of individual generators and the balance between generated and consumed energy.

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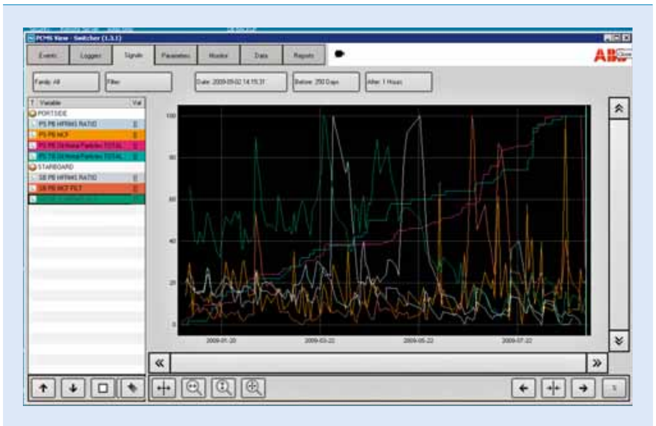
Access and feedback

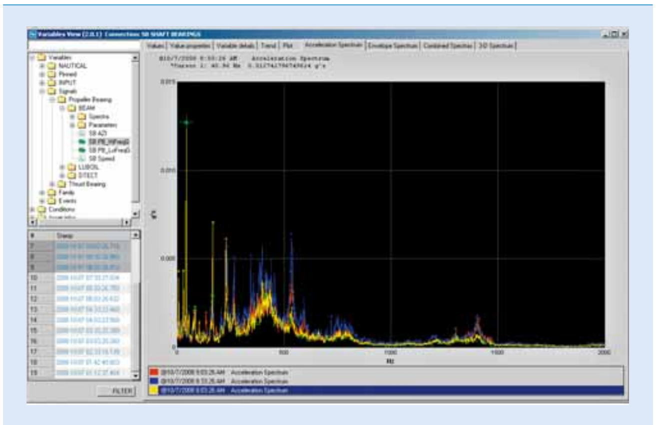
The main PCMS user-interface panel is located in the ship's engine control room. The amount of information given and the way it is displayed is customized according to the user type, which in most cases is either operator or service. Service engineers can remotely log into the system, something that is crucial if a quick and accurate diagnosis is needed.

The interface panel contains alarm and event information from the main Azipod components. Events are capa-

4 Selected signals – for example metal scan readings, high-frequency root mean square values, modified crest factor trend – related to the main shaft bearings (in percent)



5 An acceleration spectrum for vibration measurements



ble of giving additional information if required, such as "possible cause" or "hints for rectification," and they are linked with particular loggers and signals that belong to the same monitoring group and that were collected at the time the event occurred 2 and 3. Aggregating information from different sources and displaying it on one view brings added value to the fault tracking process. Various signal trends, both measured and calculated, from the main shaft propeller and thrust bearing are shown in 4. Specially developed views make it easy to analyze complex data types. The screenshots shown in 5 and 6 illustrate how a vibration spectrum can be managed using harmonic and side-band cursors or waterfall plots.

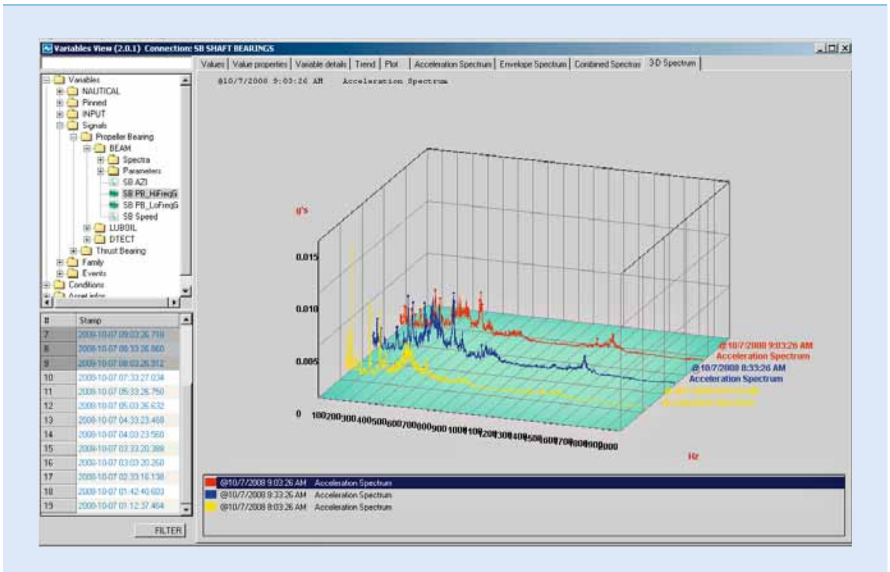
ABB's PCMS is able to generate automatic reports that contain a selected subset of recorded data over a specific period. Reports are designed to include general information about Azipod system performance, such as critical faults and the current condition of main components.

Looking to the future

PCMS is the first of its kind in that it is a scalable and flexible solution that provides fundamental and valuable condition monitoring functions for offshore vessels on a scale that had been previously very difficult to achieve. However, this is really only the starting point when one considers that more and more components and systems in the future will be covered by intelligent and automated diagnostics, thus raising productivity to a new level.

The development of PCMS focuses on improving technical performance and building new service scenarios. The ultimate goal is to have a system that has complete surveillance around the ship's critical systems and full control over the performance and life cycle of the complete fleet.

6 3-D waterfall plots with vibration spectrums



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References

[1] Wartsila, (2008). Boosting Energy Efficiency. Retrieved September 2009 from http://www.wartsila.com.

[2] Segercrantz, H. Celebrity Solstice boosts energy efficient technologies. Retrieved September 2009 from Cruise Business Review 3/2008, 40-51, http://www.cruisebusiness.com/images/cruise_old/20081217/cbr-3-2008-s-28-51.pdf.