Remote Diagnostic Services – always on board

JAROSLAW NOWAK AND ALF KÅRE ÅDNANES – ABB has built up a remote diagnostics service (RDS) that supports the crew remotely, reduces downtime and improves the availability and safety of operations.

Energy efficient and highly optimized diesel-electric propulsion, thruster and drilling systems are delivered by ABB. Compared to the systems in the past, modern installations have more sophisticated control systems, and new technologies are being adopted faster than ever before. But, as in the past, the systems are equally critical for the safe and reliable operation of the ship.

Even though the crew is offered training on such systems, there will be situations where expert assistance is required. RDS reduces the need for such experts to travel to the vessel by providing remote access to the installed diagnostics and control systems.

RDS aims to offer a service to ship owners and operators that will reduce the repair time of installations, hence improving the availability and safety of operations.
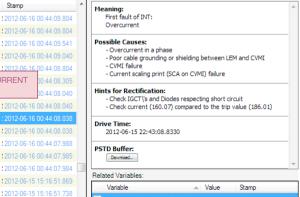
Availiability is improved by:
• Fast troubleshooting, which reduces the time required to identify and correct the source of a problem
• Providing immediate assistance in critical situations from a 24/7 global technical center

Safety is improved by:
• Enabling preventive maintenance, which detects potential issues before they escalate, degrade performance or cause system failure
• Rectifying single component failures as quick as possible

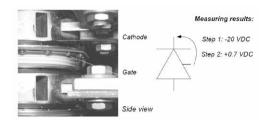1 Fault and event log from the time system tripped

Besides the safety benefits of an RDS, the availability of the system and reduced downtime has a direct economic benefit. But, an RDS is more than just an internet connection to the ship; certain essentials, such as a proper and safe IT infrastructure and organizational support also have to be in place.

RDS agreements
The onboard diagnostic system can be offered as an integrated part of the delivery to newbuildings. By integrating the infrastructure from the beginning, the additional work of installation and equipment costs are minimized and will have a positive impact on the commissioning work. For sailing ships, the remote diagnostics can be installed as a retrofit.

Once the onboard infrastructure in place, three levels of support can be agreed with the ship owner; depending on the owner's preferences and policies for operation of the fleet's vessels.

Troubleshooting gives access to on-demand assistance in diagnosing specific events and failures and provides assistance and guidance in taking corrective action.

Preventive adds periodical system audits and health checks, including recommendations for further action.

Rectifying a propulsion system trip

An over 100,000 DWT gross tonnage LNG tanker is sailing full speed across the Indian Ocean from Singapore to Cape Town. An unexpected trip in the starboard MV frequency converter causes an immediate loss of 50% of the propulsion. The giant vessel does not lose any of its safety-critical maneuvering capability but needs to reduce speed significantly. Slower sailing means longer time to destination that directly turns into higher operational costs and, as a part of the redundancy is lost, the safety margin of the vessel is reduced.

In a typical case, this would lead to sailing with reduced speed at least for several days, until a qualified service engineer arrives on board in Cape Town.

However, this scenario was avoided and the problem rectified faster because the crew was fortunate enough to have an RDS system on board and an agreement with ABB for delivering remote assistance. When they could not find the cause of the fault, the crew immediately telephoned the global 24/7 support center. The technical support engineer on duty then initiated the remote connection to the RDS system onboard and was online within 20 minutes. The specialists could then see all the logs, data transients and events that were recorded at the exact time the failure occurred. (see Figure 1).
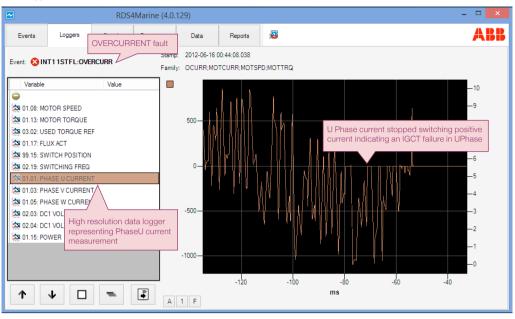
The specialist and chief engineer on board, both of whom had simultaneous access to the information, could together browse through the event list from the frequency converter and discuss this case via the chat function. The result of their shared investigation was to indicate the possible cause to be a broken semiconductor in one of the phase outputs.

A basic feature of the RDS system is that in the event of a tripping fault, the diagnostic system automatically uploads high resolution data-logs from the frequency converter. In this case, it was particularly important to study individual phase current transients.

As shown in Figure 3, the fact that positive switching of the U-phase current had stopped indicated the failure of an IGCT board. In order to verify this diagnosis, ABB system specialists instructed the crew to measure the voltage between the gate and cathode on the suspected semiconductor (see Figure 2).

The measurement results confirmed the initial judgment of a faulty IGCT. The component was replaced from spares stored on board and the frequency converter put back into operation.

The entire troubleshooting process took about two hours from the first call until the entire propulsion system was back in operation. Two hours of downtime would have equated to a minimum of one day's off hire if an expert had had to meet the vessel in port.

3 Data loggers from the frequency converter

Continuous extends the latter two with continuous proactive condition monitoring to the services, based on hourly system status updates and the automatic transfer of events and alarms.

Technical details
The Remote Diagnostics for Marine (RDS4Marine) system is built with so-called diagnostic objects (solutions) that are engineered to monitor certain physical assets in the marine power and propulsion chain.

These diagnostic objects are uniquely designed to record all necessary information related to the performance of assets being monitored and thus to provide the best fault-tracing, troubleshooting and condition-related information to the operator onboard and in the RDS service center. In principle, the design of each diagnostic object (or diagnostic solution) is based on two engineering approaches:

• Static definition of all signals that are to be recorded by RDS4Marine and the relation between them to derive key condition indicators about assets

• Dynamic, monitoring actions , i.e. scenarios for uploading measurements from field devices into RDS4Marine system. A number of factors are considered, e.g. sampling frequency, validity times

of measurements, storage policy, firing condition for measurements, complex monitoring actions that are executed in the system according to time- or event-based conditions

The result is a portfolio of predefined, diagnostic solutions that can be deployed in various combinations depending on the particular implementation of RDS4Marine. These diagnostic solutions are tailored for each asset with a focus on compatibility – for example, each version of frequency converter application software or each library version for thruster controller application has its own, corresponding RDS4Marine diagnostic solution.

Next, the combination of diagnostic objects can be designed for particular application to form diagnostic packages or diagnostic subsystems; for example, D4Propulsion (Diagnostics for Propulsion), D4Switchboard (Diagnostics for Switchboard), D4Azipod® (Diagnostics for Azipod®).

Safety by security
Providing a customer with personal attention remotely solves problems quickly and effectively. But when a vendor or service provider that supports a mission-critical application requires remote access, it often encounters challenges. For example, Information

Security Officers are faced with the dilemma of keeping their networks secure while at the same time receiving remote support.

ABB has deployed new technology in order to provide the most innovative remote support in the industry. The Remote Access Platform (RAP) was implemented in 2009 as the standard method of providing remote support and has been successfully introduced and integrated into the RDS4Marine concept. RAP security features address the concerns of IT administrators on security issues around remote support technologies.

RAP is a web-based application in the client/server architecture. Its main components are a RAP Service Center (SC) and RAP Site Servers (Virtual Support Engineers or VSE). The Service Center (SC) is managed and operated globally, while VSEs (SC agent applications) are installed on ABB customers' locations, such as RDS4Marine computers onboard the ship. VSEs will connect to RAP SC and send reports on the diagnosis performed on installed ABB equipment.

These reports (such as alarms, warnings and notifications) can be accessed by designated operators in the service center at a common web-place. Figure 4 illustrates the connection and dependencies between the global RAP service center and the VSE installed within the RDS4Marine infrastructure on board the vessel.

Each layer shown in Figure 4 implements its own security rules and techniques. Below is a description for each layer from the bottom up.

- Layer 4, where the VSE application guards access rules to the underlying RDS infrastructure. All actions trigged from remote, such as the remote desktop connection and automatic data transfer can be easily enabled or disabled by the operator onboard. In addition, each activity is logged and can be tracked back at any time. On the RDS onboard system level, connectivity to the vital control systems, frequency converters and protection relays via the OPC (OLE for Process Control) interface is limited to read-only access.

- Layer 3 is the communication link between the VSE onboard and the communication server on shore based on TLS/SSL encryption. In addition, a public X.509 certificate must be signed and trusted by VSE application during its configuration.
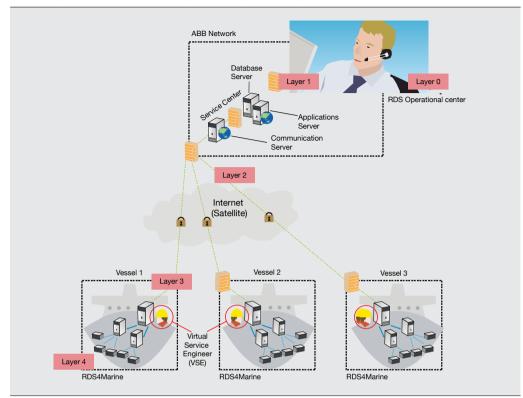
Sensor fusion approach to deliver preventive techniques

Quick and effective troubleshooting and reliable condition monitoring depends mainly on the knowledge of the person analyzing the case and the quality of information that diagnostic systems may provide.

The main requirement of a diagnostic system is to have robust fault detection and identification algorithms in place. This can be achieved by combining information from different components of the same process chain. A technique known nowadays as multi-sensor data fusion finds its practical implementation in a diagnostic system where it is used for a better fault identification.

An example could be a thruster motor equipped with a vibration-monitoring device that may detect a resonance effect. Left to vibration measurements alone, we would not know what the primary cause of the resonance is. It could be the result of wrong structural design, where the resonant frequencies are moved to the motor operational area, or it could be caused by the disturbance derived from the driving system, eg, the control system and frequency converter.

Additional analysis of the electrical measurements available at the frequency converter, together with a high frequency sampled reference signal from the control system, filters out incorrect diagnoses and sends a reliable final message to the operator.

- Layer 2 and Layer 1 is a communication between the VSE, communication server and application server, also TLS/SSL encrypted with server-side certificate and client-side fingerprint.

- Layer 0, where the user gains access to the service center over a secure https protocol.
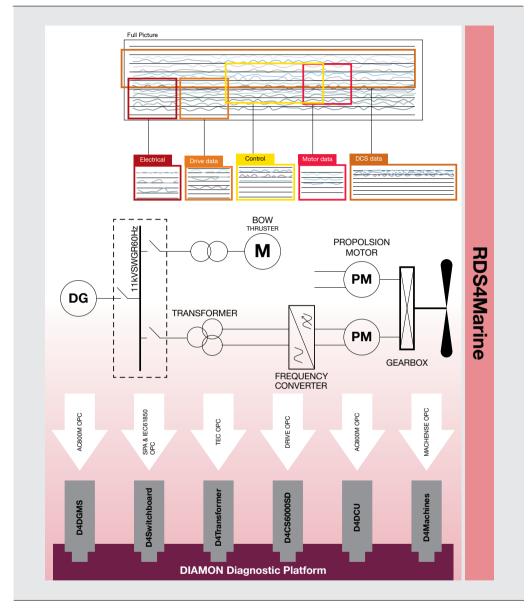
Onboard logging and analysis infrastructure

A well-defined business concept and processes, a support organization in place, secure infrastructure for remote access – these are the building blocks of effective remote diagnostic services. The leading performers, however, are tools, a software platform and techniques used on board and that can bring high-quality, meaningful diagnostic information to both the crew and remote experts.

The example shown in Figure 5 explains how the RDS4Marine system was used for monitoring an entire shaft – starting at the generator and ending up at the propulsion motor. Space does not allow for the full scope of a typical application with multiple deployments of the same components to be discussed here. The scenario has thus been broken down into separate solutions.

The connectivity backbone between the RDS4Marine and individual components in the propulsion chain is the OPC interface. In the majority of cases, there is no need for any extra hardware sensoring and cabling Access to the measurements is achieved either by connecting to existing OPC servers or by deploying them on RDS computers. The exception to this rule is related to the monitoring of mechanical equipment, where additional DAU (data acquisition units) and sensors are required. Typical functions of the diagnostic system are explained with examples for individual diagnostic solutions.

Diagnostics for the DGMS (Diesel Generator Monitoring system) collect alarms, events and signals from the controller running the DGMS application. It may be crucial for the DGMS application engineer to look into the application performance. Therefore, alarms and internal variables are continuously monitored by RDS. In addition parameter snapshotting is
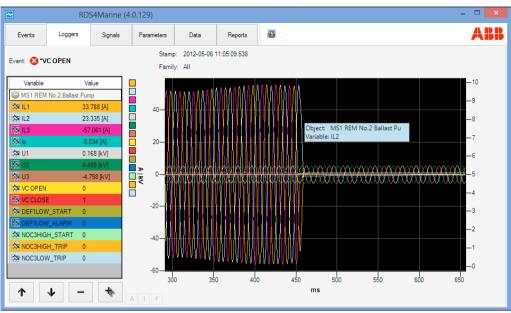
implemented. This allows for quick verification of what the current parameter settings inside the DGMS are, without needing to go into debug mode in the control application.

In addition to diagnostics functionality, the RDS connection to DGMS opens connectivity to all RELION protection relays and facilities continuous monitoring of the MV switchboard.

In the case of an MV Switchboard built on the REM/REF/RET family of relays, the RDS4Marine system monitors all alarms and events and transient recorders. Such recordings, exported to COMTRADE format, may be subjected to detailed phase analysis (see Figure 7). They can also be used to calculate power quality factors such as current and voltage THD content, imbalance and crest factor. The same transient recorders sampled with 2kHz sampling

frequency and acquired from REM relays that protect direct on-line induction motors (eg, bow thrusters, pumps, fans) are also used for current spectra analysis to detect mechanical defects of motors such as a broken rotor bar, rotor eccentricity, etc.

For a generator case, exact rotation speed derived from supply frequency and current measurements for stator phases are also easily acquired from REG protection relays and may be used for electrical condition monitoring of the generator.

In the case of a propulsion system containing oil type transformers (eg, for an Azipod® propulsor), the RDS4Marine obtains signals from TEC data acquisition unit to provide entire monitoring of the propulsion transformer (see figure 8). Here the focus is on recording the LV and HV side currents and hot spots and calculating oil ageing parameters and transformer load. The results of these calculations give a detailed picture of the way the transformer has been used (load) and the condition of the oil (water and gas content).

An example of a monitoring scenario for a medium-voltage frequency converter (e.g. ACS6000SD) has been already discussed. In addition to simple troubleshooting, exact shaft rotation speed (given

by encoders), estimated power factor and phase currents (measured by the drive and sampled in data loggers) can also be used for monitoring driven equipment such as the induction propulsion motor.

Signals available on the control layer, such as the drive control unit or propulsion control unit, are important in monitoring system. The example starts with monitoring the link between overriding control (eg, automation system) and the actuators (eg,frequency converters).

The remote diagnostics also include condition monitoring of rotating, mechanical equipment (eg, electric motors, gearboxes, bearings). In addition to electrical measurements that are already available in RDS4Marine system, there is a number of specialized, cost-effective sensors and measurement that can be easily integrated in the system.
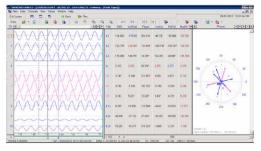
The combination of electrical and mechanical measurements offers almost unlimited possibilities for enhanced condition monitoring. For a long time introducing such advanced techniques was possible only with the use of an off-line system equipped with a number of portable data collectors that could be temporarily installed, configured and used only by experienced service personnel travelling to the vessel.

Now, the same is possible with on-line systems where the conditions for measurements are always normalized and triggered automatically according to the current operational conditions that are well known by the diagnostic system.

The highest level of asset management methodology that operators want is proactive maintenance. Besides the information that the component is in early fault stage, the system and service provider should also be able to advise to the customer on the remaining lifetime estimation. In other words, operator has to know if the component will survive until the scheduled, next maintenance visit in the dock.

Remote diagnostics also helps in this case as one of its functionalities is to transfer automatically key condition indicators and selected raw measurements from individual ships to an onshore service center and store it in a central database. The primary reason for this is to facilitate automatic generation of periodic reports, but it also offers the possibility of using historical data to perform fleet-wide statistical analyses about the condition of installations. Time to failure and time to suspension data can be derived from the database and, by clustering with individual components (eg, bearing types) it is able to build stochastic models for reliability (eg, Weibull distribution). Such models are still in the early phase of development and are expected to contribute significantly to the operational availability and cost of operations.

7 Transient recorders from protection relays subjected to phase analysis

8 Diagnostic signals for oil type propulsion transformer

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