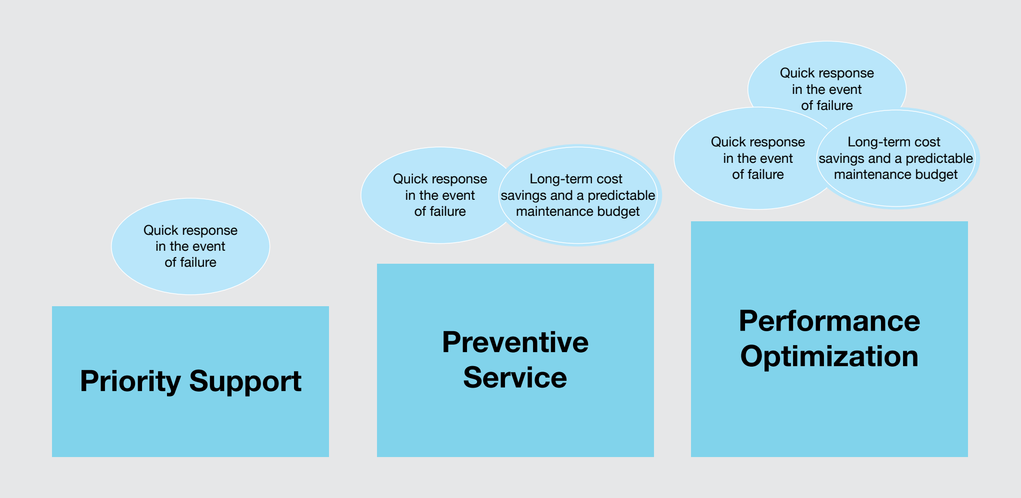
Service agreements improve overall availability

TEEMU PAJALA – The Marine Service Agreement is a customized, modular approach that aims to optimize service performance and availability for the vessel operator and owner at minimum total cost of ownership. The term "optimize" means that while availability of the installed equipment is the aim, it should be balanced against overall cost of maintenance and unavailability. This article presents some of the elements in ABB's service offerings that support the owner and crew to optimize maintenance; in particular related to rotating electrical machines.

The optimized service approach supports an overall view of a vessel's installed equipment base, crew compe-tence and operational profile. The Service Agreement should combine and optimize preventive mainte-nance, condition monitoring, technical support, spare parts, audits and competence development services. Sophisticated advisory and energy efficiency services can also be included into one package with a long-term per-spective. By concentrating on performing the right tasks in a planned sequence, the result be an improvement in equipment reliability. Systematic planning increases the efficiency and effectiveness of site visits by per-forming the appropriate tasks, at the appropriate time, based on equipment usage, type of the equipment and its criticality. Further productivity improvements and cost savings can be gained by right timing and effective condition monitoring as well as reducing unnecessary administrative costs.

1 Typical operators' needs in asset operations and respective ABB Marine Service Agreement-level



Customized service

The ABB Marine Service Agreement is a systematic way of packaging, promoting and delivering a customized service offering. It is a collaborative vessel operator centric approach that uses all opportunities to improve overall cost of ownership.

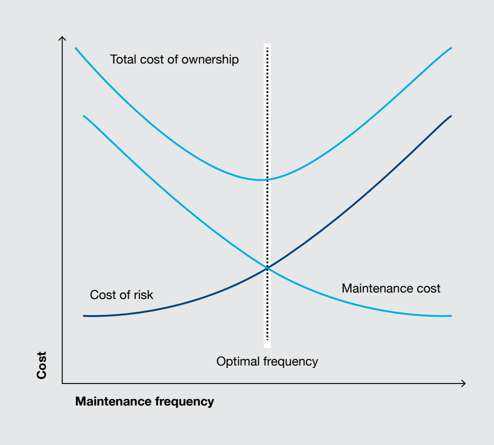
The Service Agreement concept supports an overall view of the customer's installed equipment base and long-term asset management. It enables the vessel operator to optimize asset management and operations, while offering effective communication and transparency between the owner/operator and ABB.
Maintenance optimization

Manufacturers' maintenance schedules provide a systematic and functional means of maintaining a specific asset. ABB schedules are based on extensive experience and know-how. Specifications of component suppli-ers are also carefully observed. Nevertheless, the responsibility to follow the manufacturer's recommendation falls solely on the owner of the asset. Service companies support asset owners in decision-making but this does not mean responsibility is transferred to them. The simplest way of describing optimization is to compare maintenance cost with different intervals to the cost of risk involved on a given maintenance frequency. The longer the maintenance interval, the higher the cost of risk. The point where the sum of maintenance and cost of risk has the lowest value is the optimal frequency at which to conduct maintenance. One can easily imagine the difficulties in setting the cost of risk for a certain maintenance interval. This cannot be practically ap-proached without proper failure statistics. However, as shown in Figure 2; it gives a good way of understand-ing the principles of optimization.

The most pragmatic way to optimize is to modify the manufacturer's maintenance plan together with the manufacturer and plan a package of planned maintenances and continuous condition measures. By having continuous measures in place, unpredictable risk level is reduced and maintenance plan can be reviewed.
Further productivity improvements and cost savings can be gained by right timing and effective technical sup-port as well as reducing unnecessary administrative costs.

Preventive maintenance and condition monitoring events are sets of standard and planned actions to be per-formed during a site visit. The harmonized global maintenance modules are developed and described in ad-vance and the tasks can be divided between crew and service provider depending on the available competen-cies.

2 The principle of optimizing cost of risk and maintenance costs



Maintenance optimization in rotating machines

A synchronous machine often forms an important part of a larger installation and, if it is supervised and maintained properly, it will be reliable throughout its lifetime. The purpose of maintenance is therefore to ensure that the machine functions reliably without any unforeseen actions or interventions. Condition monitoring is needed to estimate and plan service actions well in advance in order to minimize downtime.

Maintenance optimization for generators

The difference between supervision and maintenance is diffuse. Normal supervision of operation and maintenance includes logging of operating data such as load, temperatures and vibrations, as well as verification of the lubrication, and measurement of the insulation resistances.

By intensifying maintenance and supervision activities, the reliability of the machine and long-term availability will increase. This requires qualified personnel performing maintenance on electrical equipment and installa-tions. Personnel must be trained in, and familiar with, the specific maintenance procedures and tests required for rotating electrical machines.

A good method to avoid over-maintaining equipment while keeping operational risk under control is to is con-tinuous condition monitoring through frequent measurements or an on-line monitoring system.

Below is an example of a recommended maintenance program for ABB generators. This maintenance program is of a general nature, and should be considered as a minimum level of maintenance. Maintenance should be intensified when local conditions are demanding or very high reliability is required. It should also be noted that even when following this maintenance program, normal supervision and observation of the ma-chine's condition is required. Even though the maintenance programs below have been customized to match the generator, they contain references to accessories not installed on all machines.

The maintenance program is based on four levels of maintenance, that cyclically repeat according to equiva-lent operating hours. The amount of work and downtime vary, so that level L1 includes mainly quick visual inspections and level L4 more demanding measurements and replacements. The recommended maintenance interval can be seen in Table 1.
The operation hour recommendation in this chapter is given as equivalent operating hours (Eq. h) that can be counted by the following formula:

Equation 1 Calculation method for equivalent running hours

Equivalent operating hours (Eq. h)
= Actual operating hours (h)
+ Number of starts (pcs) * 20 (h)

Maintenance optimization

Failures of motors and generators are often caused by the ageing of components during normal operation. As any unplanned stop in operation is costly and as component failure may result in sequential damage to vital parts such as the stator and rotor, it is important to avoid failure.

Typically manufacturers and equipment suppliers give maintenance and inspection plans and recommendations to the asset owner, based on design knowledge and experience. The asset owners copy the plans to their maintenance management systems, which are also inspected and verified by classification societies.

Up to now, the operational environment or operating profile of the asset owner has not been considered. The present pressure to reduce the overall operational

Table 1 Recommended maintenance interval for ABB generator AMG 1600

Maintenance level	Level 1 (L1)	Level 2 (L2)	Level 3 (L3)	Level 4 (L4)
Interval	•Max 10,000 equivalent hours of operation	•Max 20,000 equivalent hours of operation, or max 3 years	•Max 40,000 equivalent hours of operation, or max 6 years	•Max 80,000 equivalent hours of operation, or max 12 years
main customer preparations prior to maintenance	•Disconnect the machine electricaly •Connect outgoing lines to the earth	• L1 • Give access to terminal connections	•L2 • Block cooling and oil system • Disconnect piping from machine • Drain water coolers and bearing house	• L3 • Split shat couplings • Prepare for rotor removal
Measurements, tools and special instruments		• IR/PF of stator. Stator diagnostic measurement • IR of rotor	• IR/PI of stator. Stator diagnostic measurement • IR of rotor. Impedance measurement or rotor coils • Bearing and exciter removal tools •Fiber optic or video borexcope • Rectifier test equipment	•IR/PI of stator. Stator diagnostic measurement • IR of rotor. Impedance measurement of rotor coils • Rotor, bearing, exciter removal tools • Rectifier test equipment
Maintenance parts	• L1 preventive maintenance kit	• L2 preventive maintenance kit • Parts recommended in previous preventive maintenance	• L3 Preventive maintenance kit • Parts recommended in previous preventive maintenance	• L4 preventive maintenance kit • Parts recommended in previous preventive maintenance
Expected duration	• Approx. 1 working day	• Approx. 2 working days	• Approx. 5 working days	• Approx. 10 working days

expenditure of assets forces asset owners to reconsider the level of maintenance. In order to modify a maintenance plan, understanding and quantification of the cost of the risk is needed. The cost of the risk has to be compared to the risk associated with the aging asset. On the other hand, the deteriorating condition of the asset should be monitored to control the risk and estimate main-tenance needs.

Optimal maintenance requires asset information, that is, data about a physical asset. Good asset data is a requirement for proper decision-making. Decisions such as optimal maintenance or replacement of the asset require data to justify cost and risks. The asset data can be identity and technical specifications, operational profiles, overall condition and environment as well as measured and identified condition.

The minimum data required on rotating machines are actual running hours and number of starts. Knowledge of the history and operational plans for the future make it possible to estimate when maintenance is due.

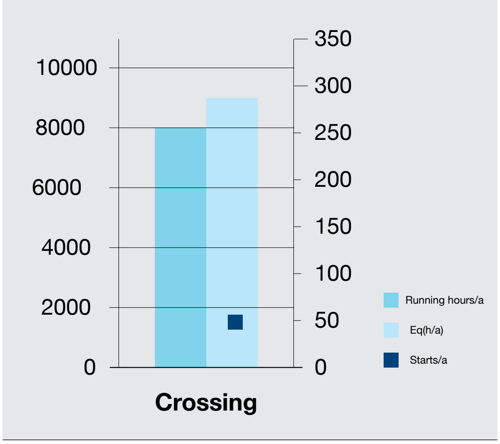
The starting and running time of machines in relation to operational needs can also affect the maintenance schedule. A reduction in the number of starts effects equivalent operating hours more than actual operating hours.

Comparing equivalent running hours in different operational profiles

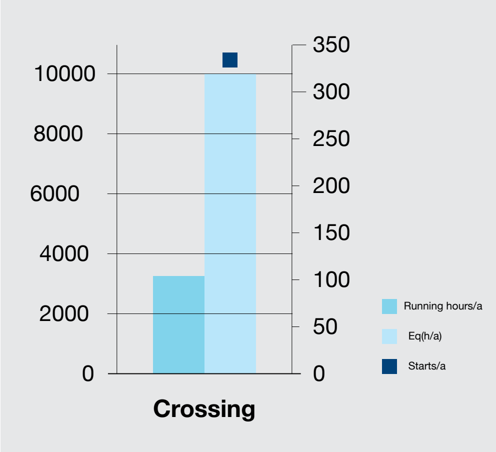
In the following example, an ocean-going vessel sailing non-stop long trips is compared to a vessel in costal service requiring short sailing and several starts and stops. Surprisingly, Figures 3 and 4 show how different operational profiles result in the same maintenance needs. In both cases, the equivalent running hours result in about 10,000 hours per year. In the ocean-going example, the hours are mainly accumulated from actual running hours. In the coastal service example, the hours are accumulated mainly from the number of starts of the machine.

As the maintenance table indicates, the L1 maintenance is due in the both examples every year, when 10,000 equivalent hours are reached. Equally, the L2 maintenance is due every second year, when 20,000 equivalent hours are reached. If only actual running hours were followed, without considering number of starts, the maintenance interval for the coastal service vessel would have been extended to three times longer than the manufacturer's recommendation, running the risk of operational failures.

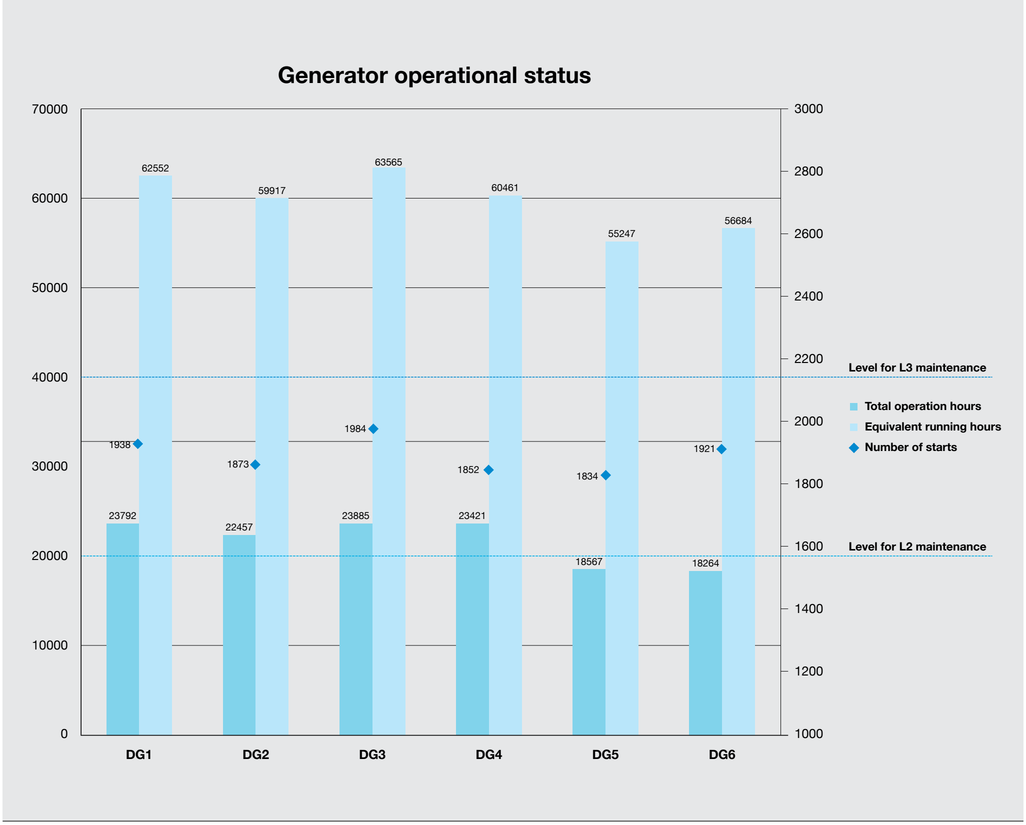
3 Equivalent running hours for ocean-going vessel



4 Equivalent running hours for coastal vessel



5 Absolute and equivalent running hours of synchronous generators in a cruise ship



It is also possible to extend the maintenance interval by proper planning of power management and engine configuration. Also, when the vessel changes operational profile, it should be a common approach to reevalu-ate maintenance needs and not just follow a calendar-based maintenance plan.

Operational planning for reduced maintenance

Figure 5 is a real case from a cruise ship operating in Caribbean Sea. The engine management has been done well and they have been running for an equal amount of time. In the case of the coastal vessel, the en-gines are required to start often, resulting in a big difference between absolute running hours and equivalent running hours.

In this case, the equivalent running hours are monitored, instead of actual running hours. In the maintenance planning, the vessel operator should start to plan for L4 level maintenance, which is due in 80,000 equivalent hours.

Condition monitoring

For the condition monitoring of rotating machines, ABB has several options for different machine types and sizes. Studies have shown that the most common causes of failure in high voltage machines come from stator wind-ings and bearings.

Large motors and generators of 2 MW and 3 kV rating and up, exhibit a relatively higher proportion of winding failures than lower power designs. Based on figures from an IEEE survey, it can be concluded that the predic-tion of winding failures needs to be improved and that ABB LEAP can fill a critical gap in the maintenance toolbox of electric motors and generators.

ABB LEAP takes into account the aging of the stator winding insulation due to thermal, electric, mechanical and ambient factors to deliver a predicted life expectancy that has an 80 percent probability of being reached. As a result, maintenance plans can be optimized and actionstaken during planned downtime.

6 Statistics from an IEEE survey show that predictive methods are needed to avoid winding failures.

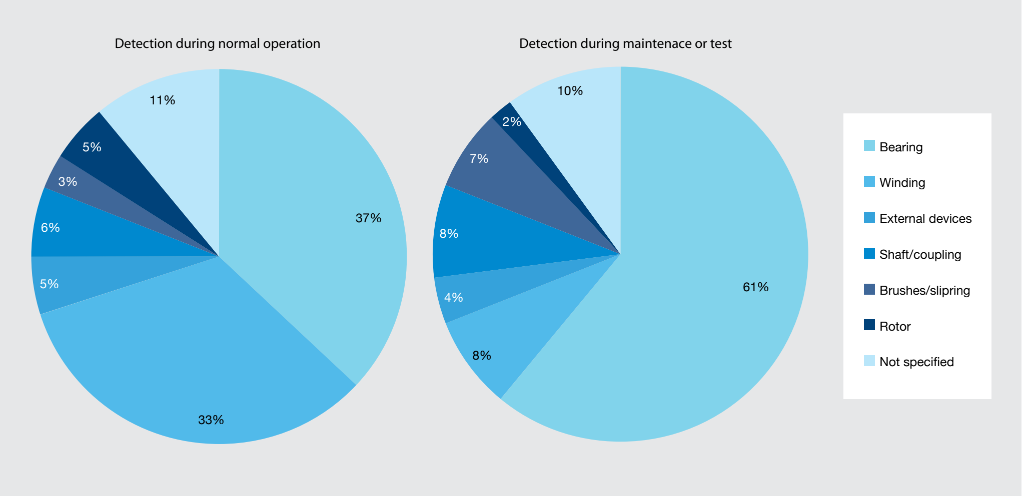


Table 2 ABB MACHsense-P measurements

Solution levels	Measurements When	Measurements What	Deliverables	Measurement Frequency
Standard	When the motor is operating at nominal load	• Vibration, voltage, current, temperature (winding, cooler and ambient) and speed • Operation history, maintenance and failure records	• Cage rotor package • Rotor winding defects, air gap eccentricity, imbalance, looseness, static and dynamic shaft bends, internal misalignment • Anti-friction bearing package • Bearing defects, bearing assembly defect, lubrication interval estimates • Installation • Soft foot, misalignment, foundation resonance • Power supply • Harmonics and distortion, imbalance, over/ under voltage, frequency • Maintenance and inspection recommendations	Every six months
Advanced	When the motor is operating at nominal load and with multiple loads and/or start-up	• Vibration, voltage, current, temperature (winding, cooler and ambient) and speed • Operation history and maintenance and failures records	• Same as above • Cooler • Fouling • Root cause analysis	When a defect is suspected either from standard measurement or from observed prob-lems and there is a need for further investigation

For smaller rotating machines with a power range less than 2 MW and 3kV ABB MACHsense-P was devel-oped to address reliability. In smaller machines, studies have shown that problems related to bearings, rotors and other mechanical components account for most total failures.

With ABB MACHsense-P, data is collected by a specialized service engineer, who produces a report on-site. The report gives an analysis and interpreta-tion of the test results and includes defect identifica-tion, severity, possible causes and effects on the rotor condition, the condition of the anti-friction bearings, the power supply and the assembly and installation of the motor.

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