Marintronics™ optimizing marine power and automation systems through industrial IT

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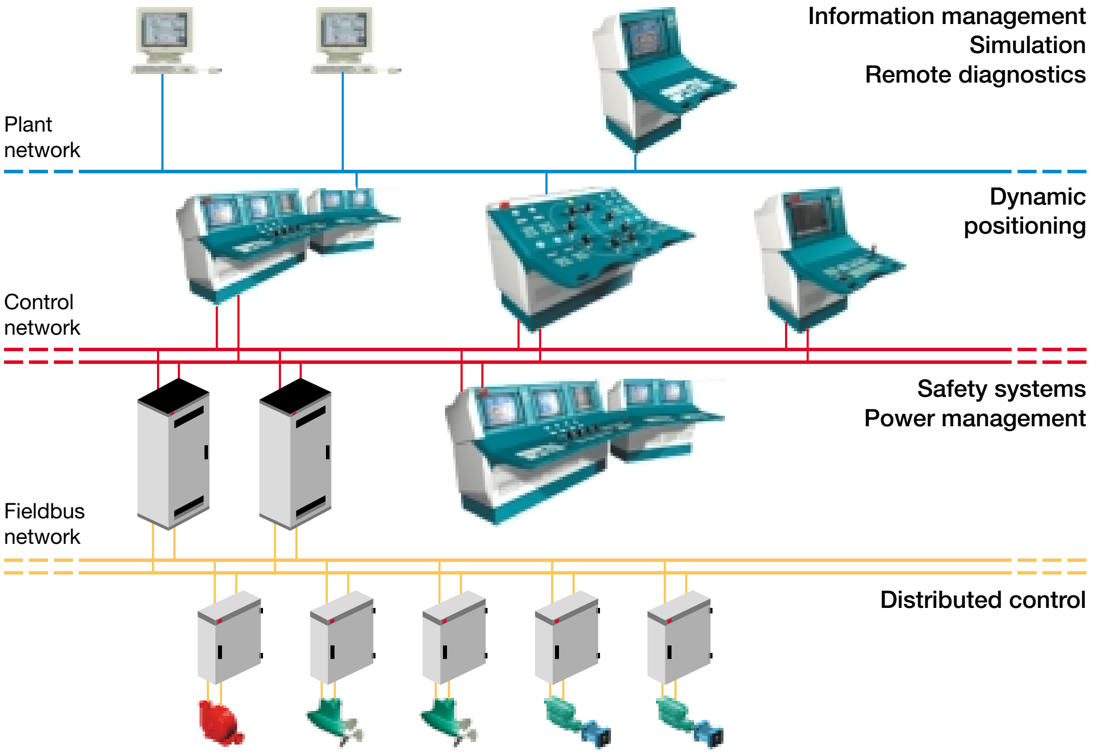
As a leading supplier of power and automation equipment to the marine sector, ABB has developed for this market integrated solutions comprising electrical power, automation and positioning systems. Now Marintronics™ introduces new industrial IT solutions with software tools and features that offer extra benefits to customers choosing an integrated solution from ABB. The new software functionality is implemented as design and dynamics analysis tools, an Energy Management System, operator support and new positioning control features. With Marintronics™, ABB's capability in automation and power technology is fully utilized and combined with process knowledge to the benefit of both customers and the environment.

Marine offshore operations require a wide array of vessels and rigs for oil exploration, drilling, production, loading, pipeline laying and power supply. These tasks typically demand large amounts of energy, expensive installations for its production, safe and reliable operating equipment, and a dependable operations management system. Taking everything into consideration – production, drilling, utilities, positioning and hotel loads, etc – the installed power can be of the order of 25–50 MW. ABB integrated solutions, featuring power, automation and positioning systems, are designed to meet these needs.

Since all the loads requiring power (eg, positioning/propulsion, drilling and automation processes) are connected via the common power system, a huge potential exists here for reducing energy and gas emissions, and for increasing operational safety. This potential can be freed up by exploiting the advantages of integration even further.

Marintronics™ introduces new industrial IT solutions in the form of software tools and features that offer extra benefits to customers choosing a functionally integrated total solution from ABB.

The cost of designing power, automation and positioning systems is reduced by analytical capabilities in a new software tool that takes account of the mutual interaction of the sub-systems during the design phase as well as later during operation of the plant. By increasing the overall stability in terms of more predictable performance of the different installed equipment, the design can be made less conservative and thereby less costly. Oper-



1 *Marintronics™ exploits the physical network integration of the various ABB systems and products.*

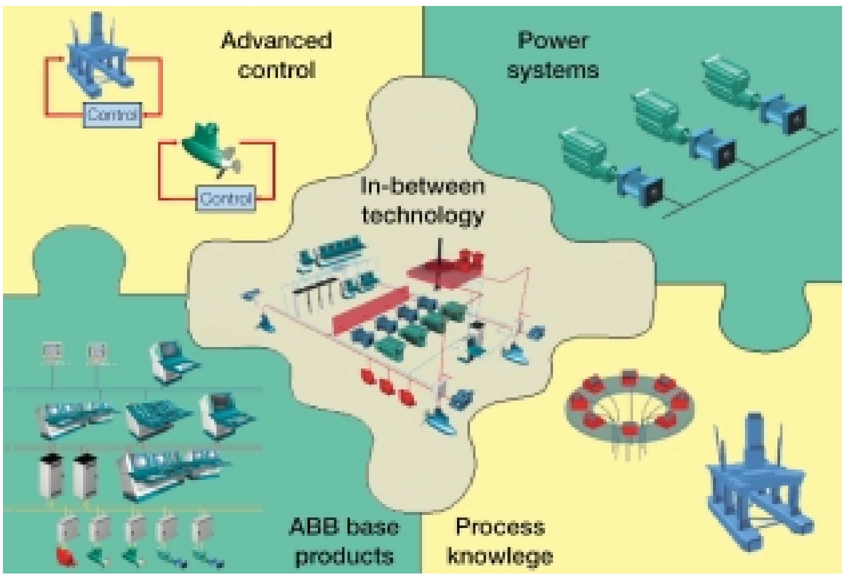
ational costs are lower due to the improved power system design for each vessel/rig and the introduction of a new Energy Management System (EMS), plus new features in the positioning systems, where process knowledge is also fully exploited. By using knowledge about the power system in the positioning system, and about the positioning and automation systems in the EMS, energy consumption and fuel gas emissions are reduced. The duration and cost of commissioning are reduced by extensive pre-engineering with a total system simulator. Likewise, re-use of the total system knowledge in software tools for on-line and off-line analysis and operator support increases both operational availability and safety.

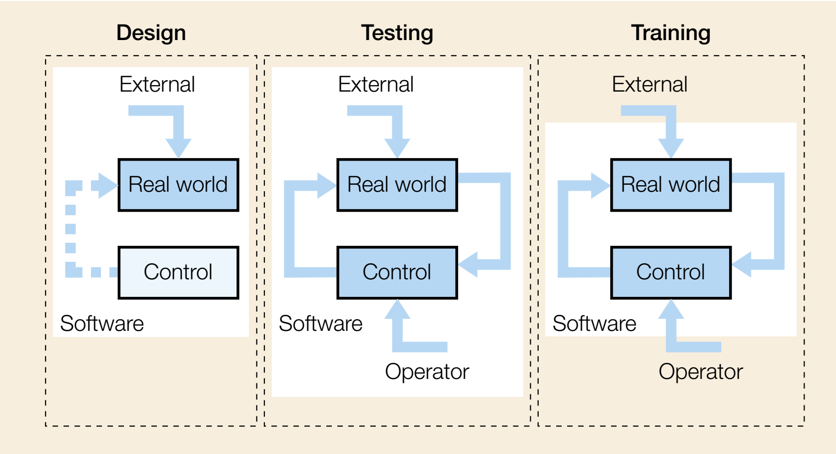
For an overview of ABB positioning systems, the reader is referred to the list of references.

Marintronics™

Marintronics™ is an international R&D project with participants from both Finland and Norway. The international project consortium consists of companies from vessel equipment vendors (ABB), designers (Ulstein Ship Technology, a member of Rolls Royce Marine Systems), operators (Smedvig Offshore) and oil companies (Norsk Hydro). ABB Corporate Research, the research institute Marintek and the Norwegian University of Science and Technology (NTNU) are main R&D partners in

2 *Using 'in-between' technology, ABB develops an integrated solution that optimizes the vessel's mission whilst lowering lifecycle costs.*





3 ***Simulator set-up for the different project stages***

designed and used by the electrical power community to simulate the electrical power system. On the other, the vendors of positioning systems, vessel designers, etc, have their own vessel models which they use to test control algorithms and/or design verification. This has meant that, until now, the simulation of vessel motion and power system has been separated both by discipline *and* by simulation tool. This is so in spite of these two disciplines being closely coupled through the thrusters' role as one of the main consumers in the power system.

One example of the functional integration developed in the Marintronics™ concept is the interaction between the Power Management System (PMS) and the positioning system for the purpose of avoiding undesired load shedding and, in the worst case, a blackout being caused by high thruster load. To the best of the authors' knowledge, besides the ABB simulators described here no other software packages exist for simulating total vessel automa-

the project, whilst ABB Industri has overall responsibility for the project. The project is supported by the Norwegian Research Council (NFR) and has been awarded Eureka status for its considerable potential in the areas of energy optimization and reduced CO_X/NO_X emissions.

The focus of the project has been to exploit the physical network integration of the various ABB systems and products **1**, in addition to the knowledge of the dynamic behavior of the underlying physical processes and their mutual interactions.

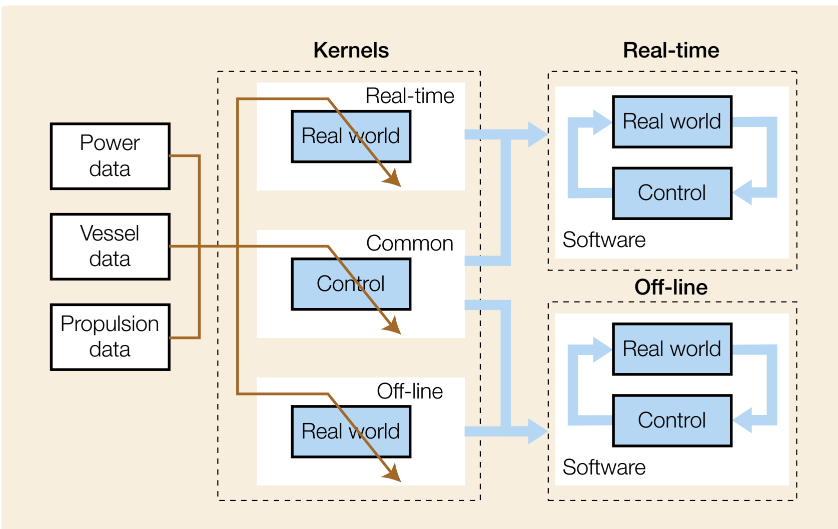
This functional integration of power generation and distribution, automation, positioning and propulsion systems for marine, oil and gas vessels is the core of the Marintronics project **2**. Hence, ABB's capability in automation and power technology is fully utilized and combined with process knowledge to the benefit of the customer and the environment.

Total plant simulation

All floating and fixed offshore installations, whether they are used for drilling, production or supply, have a number of processes that make useful models for simulations. Numerical simulations have proved to be the most effective analytical tool in the design and verification of plant performance and robustness, while simulators are also used at a later stage as operator advisory systems to ensure safe operation. Cases in point are drilling, propulsion, chemical processes, etc.

For *floating* offshore vessels there are two processes being extensively simulated today: the *vessel motion subject to environmental loads* and the *electrical power system*. On the one hand, there are the diverse tools

4 ***Common simulator kernels for different simulations***



tion and power plant. This situation is the more remarkable as it is essential to verify and optimize control strategies to ensure fuel-optimized vessel performance, and hence maximum safety.

The novel total vessel simulator developed for Marintronics combines core-competence resources in the fields of power, hydrodynamics and control theory. As a result, it is possible to simultaneously simulate the electrical power system and the vessel motion in 6 degrees of freedom.

The total vessel simulator offers several advantages. First, it is a flexible test-bed for advanced integrated control strategies like the ABB Energy Management System. Second, the integrated vessel simulator can be used in a laboratory set-up to allow PMS engineering to be performed in-house rather than on-site.

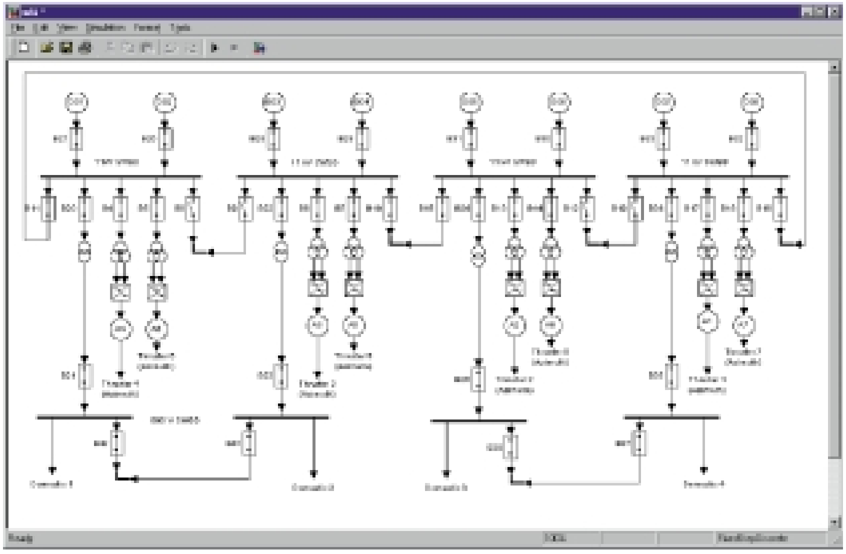
Common simulation tools

During construction of a new offshore vessel – from the conceptual design until the vessel is in operation – computer simulations are used for several purposes. The three main areas are:

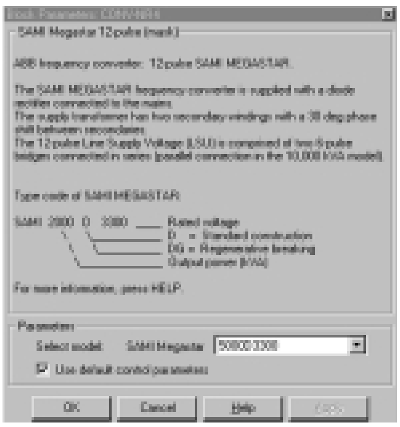
- Design verification
- Testing of software
- Operator training

Clearly, the requirements for computer simulations differ from project stage to project stage, and it is usual for different parties to be involved in developing and also using the various simulation packages 3 .

Recognizing that all of the mentioned simulation tools have common underlying requirements (ie, the need to predict vessel motion or performance of the power system to a desired accuracy), ABB has developed a common simulator for use at all stages of a project. The new set-up consists of three modules, two real-world models – one for real-time simulation and one for off-line simulation – and a common control module 4. The three modules use the same data file format, and can be put together to form two different closed-loop systems, one running in real-time and one off-line. All the modules offer auto-configurability based on process plant parameters. For example, the control system automatically adjusts to the given number of thrusters.



5 *Single-line diagram for simulating a power system*



6 *Model of ABB SAMI Megastar used in power simulation*

ABB Integrated Vessel Simulator

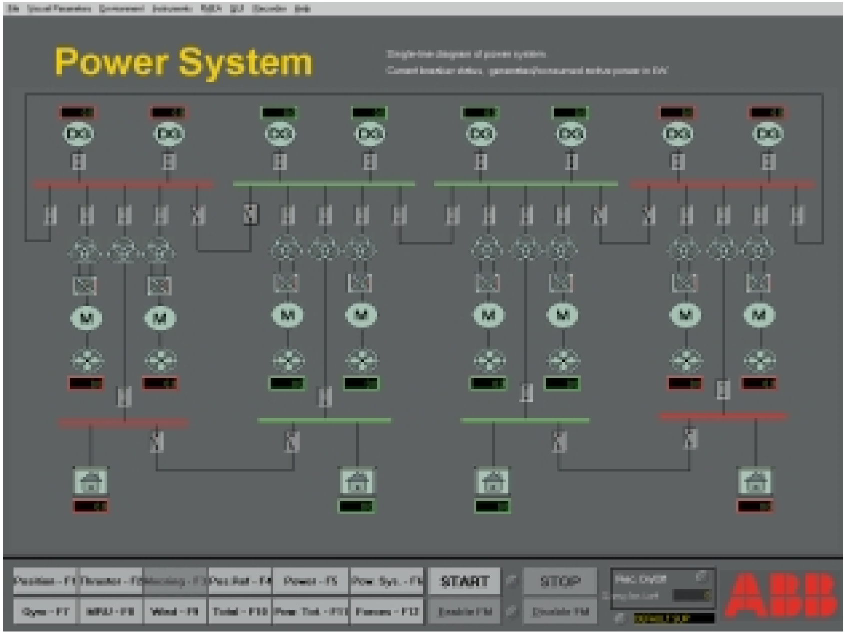
The ABB Integrated Vessel Simulator has been developed in Marintronics to enable total simulation and merging of the existing simulation tools.

Technical challenge

The main technical challenge when simultaneously simulating electrical and mechanical systems, is posed by the different physical properties. Whereas the dynamics of a mechanical system are slow, with time constants typically greater than 1/10 s, electrical dynamics tend to be fast (time constants are typically less than 1/10 s). Considerable in-house electrical power know-how was invested in the aggregation tasks in the power system models.

Features of the simulator

To create a user interface that is both familiar to customers and easy to use, it was decided to implement a drag-and-drop principle. Taking elements from a special library, the user can draw a complete single-line diagram and



7 ***Snapshot of the power page created with the ABB real-time simulator configured for the West Venture drilling rig***

use it for simulations **5**. The library includes all ABB power products relevant for marine applications, eg switchboards, generators, transformers, motors, converters. In addition, all blocks offer the possibility of parameter specification. For example, by double-clicking on the converter block, the window shown in **6** can be used to specify the converter model with the corresponding voltage and power ratings.

The simulator has the following features:

- Simultaneous integration of power system dynamics and the various heavy loads, eg drilling motors and thrusters. The thruster load calculations are based on complete time domain positioning simulations.
- Time series analyses of the various systems, eg for power, positioning and drilling.
- Thrust capability plots that take into consideration the power available for each thruster motor.
- First analysis of power system harmonic distortions and the short-circuit level.
- Easy generation of a real-time version for testing and demonstration of the target code.

An example of a display of a real-world power system (real-time version) is shown in **7**.

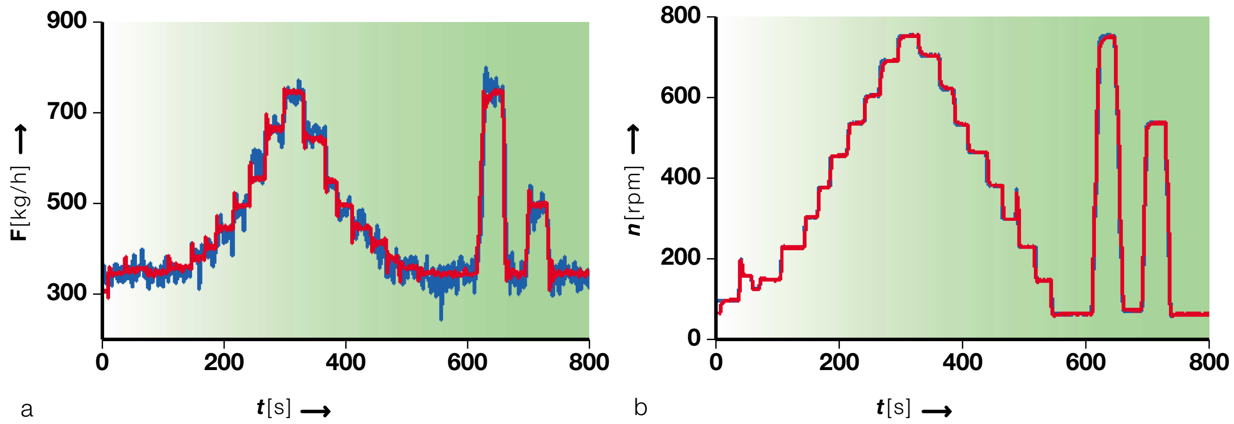
Verification

ABB Industri has recently completed delivery of a total solution, including the electrical power, automation and positioning systems, to the semi-submersible drilling rig *West Venture*, owned by *Smedvig Offshore*. The rig was built by Hitachi Zosen of Ariake, Japan, and completed early in 2000 **8**. During sea-trials in Japan (September 1999) and Norway (December 1999) measurements of the power system, thrusters and vessel motion were logged and compared with computer simulations. The simulator showed that there was excellent correlation between the simulated and measured values for all the plant parameters considered. **9** shows two examples: fuel consumption of generators 1 and 2, and the speed of thruster 1. In addition, the dynamics of each of the power system components were verified by simulations carried out with the high-accuracy power system simulator SimPow™.

Thruster torque control

An important feature of the ABB positioning controller is the thruster torque controller, which reduces the disturbances acting on the power system whilst improving thrust control. This feature

8 ***West Venture semi-submersible drilling rig***



9 ***Verification of the power simulator. Plot a shows the simulated and measured fuel rate (F) for generators 1 and 2, and plot b the simulated and measured speed (n) of thruster 1***
Red *Simulated* Blue *Measured* *t* *Time*

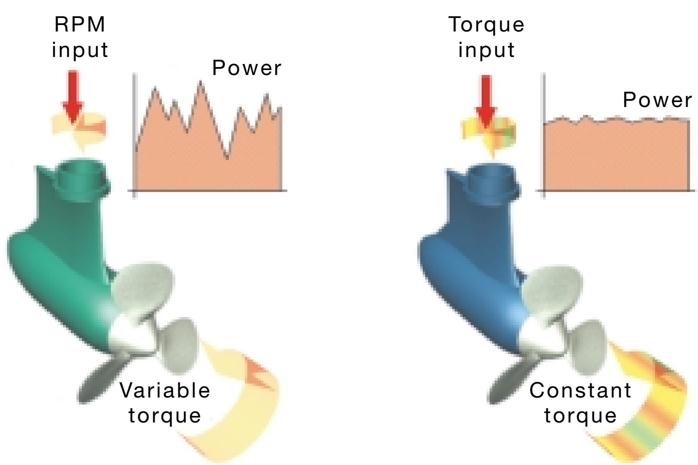
enhances the advantages provided by an integrated ABB power and positioning system.

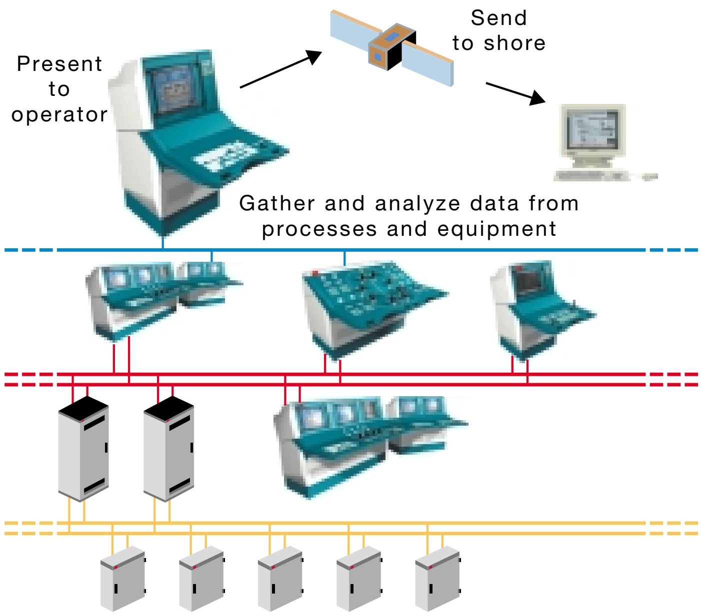
The positioning controller computes setpoint forces in surge and sway, as well as moment in yaw. The thruster allocation algorithm determines the force and direction each thruster and propeller device must produce in order to fulfill the positioning controller commands.

In conventional torque control, the final pitch or speed setpoint (rpm) signals are determined from stationary propeller force to speed/pitch relations based on information about the thruster characteristics and bollard pull tests provided by the thruster manufacturer. These relations may later be modified during sea trials. However, they are strongly influenced by the local water flow around the propeller blades, hull design, operational philosophy, vessel motion, waves and water current. With conventional positioning systems, variations in these relations are not taken into account in the control system, resulting in reduced positioning performance with respect to accuracy and response time. In addition, the variations may lead to a deterioration in performance and stability in the electrical power plant network due to unintentional peaks or power drops caused by fluctuations in the propeller shaft load. The unpredictability of the load variations forces operators to have more power on call than is necessary, and hence the diesel generators will, on average, run longer at lower loads. The result is more wear and tear, and thus increased maintenance.

With the ABB thrust torque control concept, propeller forces to torque and power mappings are used to control the propeller and thruster. The setpoint for the thruster is a torque, as opposed to rpm/pitch **10**. This approach reduces the above-mentioned problems. The performance and stability of the electrical power plant network will increase considerably, wear and tear of the

10 ***Different properties inherent in conventional rpm control and in torque control***





11 ***Principle of advisory system***

propulsion equipment is reduced, and the positioning accuracy is increased.

ABB advisory systems

The availability of process data and signals as well as a profound understanding of all the processes involved in the integrated physical and control system are exploited in the development of new advisory systems featuring both on-line and off-line functionality 11.

The main task of the on-line advisory system is to evaluate the ability of the current system configuration (including power production, power distribution and positioning) to solve the desired tasks with specific operator inputs or failure information. Important functionality in this context includes warnings/alarms displayed at an operator station when a failure or operator input would cause a serious error, eg loss of vessel position or overloading of the power system. In addition, the operator needs to have capability plots for the different systems displayed at his operator station. In the case of the positioning system, this will typically be a display showing the average environmental forces relative to the maximum holding of the thrusters for the different directions of the average environmental forces. The operator uses this information to produce sufficient power with a minimum of fuel.

The off-line advisory system gathers and analyzes all relevant data from processes and equipment on board the vessel. The results of the analysis are made available to the operator through functions for plotting, trending and statistical analysis. In addition, the data can be used to optimize performance, safety and diagnostic analysis, plus maintenance planning on shore, eg via satellite transmissions. ■

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