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# generations



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This issue of *Generations* is dedicated to safety and availability. In the *Business Insight* section, we present customer cases and articles introducing key concepts, market trends and business strategy. This is followed by *Technology Insight*, where ABB engineers, as well as external stakeholders, share research findings, details of new solutions and the thinking behind them.

Our goal has not been to make the complex simple, but to make it comprehensible.



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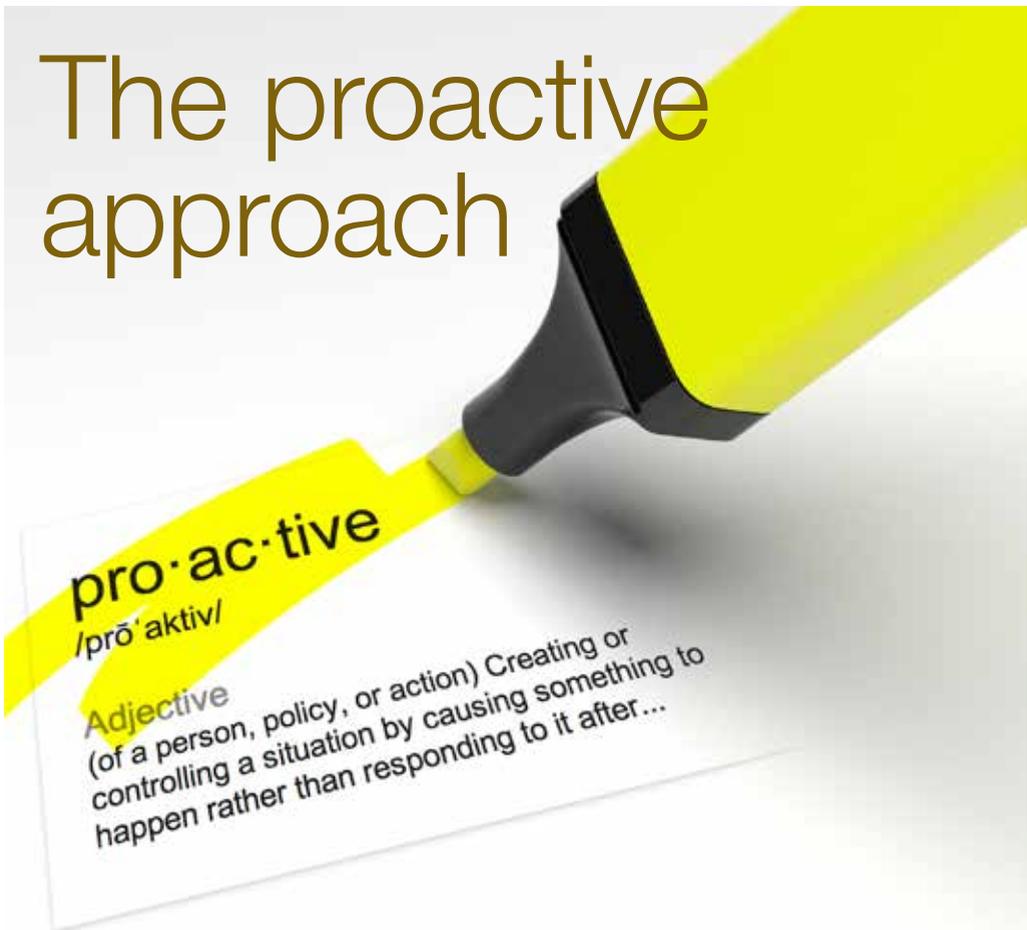
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# The proactive approach



The development of new standards for safety has traditionally been a history of learning from mistakes. Every major accident at sea has led to new awareness and understanding of risks with new technology and stricter regulations to follow. This happens slowly and at a high price for those involved.

**S**afety and availability is about avoiding undesirable interruptions in what we see as successful, normal operation. We want things to work as intended and over time value is created most effectively in the mode we name "business as usual".

For this issue of *Generations*, we focused our writing on three key issues related to safety and availability:

systems integration, industry partnerships and customer value. What we discovered was that in all of these areas, there is a shift from the traditional reactive approach to a proactive pursuit of higher performance at lower cost.

Instead of waiting passively for the next accident or undesirable event, developers and trainers create critical situations in a safe test environment. It is the

case with simulator training at Aboa Mare<sup>1</sup> and at the ice lab at Aker Arctic<sup>2</sup>. Not only is experience gained on how to manage rare events, but the boundaries for safe operations of vessels and equipment are explored for more economical use.

At the Remote Diagnostic Service<sup>3</sup> (RDS) facility at ABB, wear and tear can be monitored to schedule timely shipment of spare parts and reduction of stockpile. A change from schedule-based to condition-based maintenance can be achieved and form more effective cooperation between operator, equipment supplier and the class society.

Feedback from operations to product development becomes a continuous process. Best practice can be identified and instead of dealing with problems reactively, service centers will support the management of assets over their entire life cycle.

### Systems integration and simplicity

IT and automation offer a whole new level of productivity to fleet and port operation. But new technology also adds complexity and increased vulnerability if not intelligently integrated. Furthermore, the challenges of systems integration always include people. Good human-machine interfaces<sup>4</sup> combine pre-processed, real-time data with the unique decision-making capabilities of trained professionals.

Safety and availability by design can be achieved as long as engineers keep searching for the simplest solution to problems. Standardized multi-purpose system components and common technical frameworks like the extended automation System 800xA<sup>5</sup> support this philosophy in power systems, automation as well as in control and advisory systems.

The multi-functionality of an Azipod® unit has led to the development of “double-acting” ice-breaking vessels<sup>2</sup> and unmatched maneuverability in general.

### Partnerships and risk sharing

Unbound by geography, the maritime industry demonstrates the dynamics of the global market like no other sector. Industry partnerships are essential for sustainable success in this competitive environment. A bright idea or brilliant new technology can make headlines and win prizes and still have zero impact on the industry unless supported globally.

Together, academic institutions, research and training centers<sup>1</sup>, class societies<sup>6</sup>, design houses<sup>7</sup> and

manufacturers bring new solutions to the market. Solo players achieve nothing in this industry. For new technology to be recognized as “proven”, it is essential that it is supported by world-wide service and training. Design houses work as hubs in the networking of professionals who share and integrate the best ideas into working concepts that meet the requirements of financially motivated investors and operators.

ABB has always strived to be a community player and proudly presents some of its partners in this issue of *Generations*.

### Customer value

Cruise ships, with a priceless “cargo”, constantly push safety and availability to new levels. Working with the main cruise operators in a market scrutinized by American consumers has taught us to never rest on our laurels. In a similar way, day rates above half a million USD for drilling rigs highlight the value of availability.

To never cause delays to a newbuild project or off-hire time in operations for Seadrill<sup>8</sup>, to apply automation to help APM Terminals build its gigantic Maasvlakte II terminal<sup>9</sup> with 25 to 30 percent more productivity than at existing European terminals, and to enable an oil tanker to operate in the Arctic without waiting for the assistance of a specialized ice-breaker are all examples of value creation in which ABB is a major contributor.

Where the safety and well-being of the crew is the top priority, customer value follows. A sound practice in risk management draws the line between unacceptable and acceptable risk and creates a culture of predictable performance, value for money and return on investments.

**Text:** Johs Ensby

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1. Aboa Mare, see page 49
  2. Aker Arctic, see page 44
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  6. ABS, see pages 32-39
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  8. Seadrill, see page 6
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Alex Mosen, Vice President Asset Management at Seadrill

# Oiled Machinery

We buy turnkey solutions from the yards, says Alex Monsen, Vice President Asset Management in Seadrill, with a staggering 26 new build projects in progress.

**G**enerations caught up with Monsen in his office in Singapore the week after he took delivery of a new jack-up rig from Keppel and the day before he headed off to christen three new drill ships at Samsung Heavy Industries in South Korea. The triple-launch is illustrative of the “assembly line” approach to newbuildings at Seadrill.

Since Monsen started working for the company in 2006, Seadrill has acquired Smedvig, Mosvold Drilling, Scorpion Offshore and built an organization that now operates 75 drillships, jack-up rigs, semi-submersible rigs and tender rigs.

The company is listed on the New York Stock Exchange and is – like its chairman John Fredriksen – famous for its focus on financial performance. Being responsible for building and delivering drilling units to operations all over the world, Monsen has no room for experimentation. Proven designs from yards that meet deadlines without cost overruns is an absolute must.

“The way we can get a good price from the yards”, Monsen explains, “is by giving them room to negotiate with suppliers. Our approach has been to establish a makers list that we can live with and then get involved in the technical evaluations together with the yard to make sure specifications are met.

“Of course we listen to suppliers, and when we see solutions that we believe have advantages, we write them into the specifications.

“But it’s not like when I worked in Stena Drilling where we were much more enthusiastic about new technology. At Seadrill we go for things that we know work.”

## **Cost-benefit and risk management**

Seadrill’s focus on financial performance allows no single piece of equipment or unproven technology to jeopardize timely delivery of new units and uninterrupted operations once they are in service. This is the reason why new developments must provide a real step forward in performance to be considered.



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Experience and feedback from 75 units has built a unique knowledge on what works and what doesn't at Seadrill.

It is all based on cost-benefit analysis. In some cases we have gone back to more basic solutions, says Monsen and mentions VFD (Variable Frequency Drive) on jack-up motors as one example of a feature that did not add value as expected.

Experience and feedback from 75 units has built a unique knowledge on what works and what doesn't in Seadrill. "We have seen solutions that we don't want to use again, admits Monsen, and we keep suppliers that provide equipment with consistent performance".

Asked about which category ABB belongs to,



Monsen says: “I can’t remember a single incident related to their equipment that has caused us major problems, and ABB has never caused a delay for us in the yards.” However, he quickly adds, “the reason their equipment is found in so many of our units is that they are also competitive on price”.

### **Global support**

Monsen would like to see new suppliers enter the market – for increased competition and development. However, without global support he cannot afford to take the risk.

He recalls a decision to change a supplier because

they charged a very high fee for their engineers. The new supplier offered lower cost on both systems and service, but the problem was that they did not turn up fast enough when something went wrong. The savings were lost after only six months in operation and the equipment was torn out and replaced. All equipment needs service, according to Monsen, and the cost of down-time makes speed and reliability of service extremely important.

With operations in Brazil, the Gulf of Mexico, UK and Norway, Africa, South East Asia and China, Seadrill must rely on suppliers with a network of service engineers worldwide. Rigs operate on 3-5 year contracts

West Tellus is a 6th generation drillship with planned delivery Q3 2013. The design is based on Seadrill's existing Samsung drillships.



The ideal situation for us is to have as few suppliers as possible, but still enough players in the market to create real competition.

and he mentions the semi-submersible *West Aquarius* as an example of their mobility. It has been operated in Singapore, Malaysia, Indonesia, the Philippines, Vietnam, China and Myanmar and is now in Canada.

#### Improvements on the horizon

Seadrill is clearly conservative when it comes to the implementation of new technology, still they need to identify their competitive advantage five years down the road. The last five years very little new has happened, according to Monsen.

“Everyone builds drillships now, I have looked at 15 different designs, but none are significantly better than the Samsung design that became so popular.

“We are trying out a completely new drilling system on one of our projects and we have a discussion on DP systems (see page 93) right now”, Monsen says.

“DP with ‘closed bus’ could reduce fuel costs. Traditionally, a 3-split DP system has been used; now technology seems to be available for higher performance in normal operation while maintaining the same safety in the case of systems failure. This will be considered in our next series of vessels and even for upgrade of our existing units.

“The oil companies pay the diesel bill themselves, but we need to make sure that our units are competitive in terms of overall costs to win new contracts. As long as we can maintain the same safety as with traditional DP class 3, fuel savings are very important.

“What are the drivers for new solutions in offshore drilling? The oil companies are always driving for more capacity, space for more deck loads, bigger fluid tanks, and operability in all kinds of weather. They also push for separate systems for oil-based and water-based mud to allow switching from one mode to another without flushing the system.”

#### Space savings increase capacity

All the new demands compete for a limited amount of space on board. This is why Monsen has his eye on space-saving solutions. When we ask what could make Azipod® an attractive option in future designs, he points to its space saving features as a possible argument.

Due to the requirements for redundancy, propulsion systems, switchboards, transformers and other parts of the electric installations take up a lot of space that

could have been used to increase the capacity for things like mud handling – on semi-submersibles as much as a thousand cubic meters.

### Keeping the number of suppliers to a minimum

“Ten years ago we bought the top drive from one supplier, the pipe handler from another and the control system from a third one,” Monsen recalls. The market was much more open to small, innovative companies.

“Today there are typically three suppliers that compete for each package. MH (Aker Solutions Maritime Hydraulics), NOV (National Oilwell Varco) and Camron compete for the drilling package while ABB, Siemens and GE (General Electric) compete for the electro package. For us DP is a field where Rolls-Royce and Kongsberg Maritime are important, whereas the boundaries can be more blurred when it comes to vessel control systems and automation.

“The ideal situation for us is to have as few suppliers as possible, but still enough players in the market to create real competition”, Monsen explains.

### Increased availability

With nine units approaching five-year classification, Seadrill is focused on reducing the time this takes to a minimum. Thrusters are in need of dismantling and service, other vital parts and systems are up for inspection and approval for a new five-year period.

With each vessel earning day-rates of 550-600,000 US dollars, shortening classification procedures would be worth millions to Seadrill. “To achieve this we work with the class societies for continuous, condition-based class inspections rather than the traditional interval-based inspection and maintenance.”

Equipment that needs reclassification after ten instead of five years could be what Monsen looks for in his next series of projects. He mentions the designers at Samsung, GVA Consultants, Moss Maritim, Bassoe Technology and Friede & Goldman as design houses that he shares his expectations with.

## Seadrill – setting the standard in drilling

Seadrill has grown significantly since it was established as a Bermuda-based company in 2005 with an offshore drilling fleet of 11 units. The company now has a fleet of 75 units for operations in shallow to ultra-deepwater areas in both harsh and benign environments – the second-largest ultra-deepwater fleet in the industry and the largest fleet of modern high specification jack-up rigs.

This growth is set to continue. Seadrill currently has 26 rigs under construction, and long-term contracts have already been secured for 12 of these. The delivery schedule ranges from the first quarter of 2013 to the second quarter of 2015, with the majority to be delivered in 2013 and 2014.

A booming offshore drilling market is conducive to further growth. In the ultra-deepwater market, oil and gas companies are increasing their spending on exploration to offset declining maturing fields, and demand is strong in the Gulf of Mexico, West Africa, East Africa and the North Sea. Very limited rig availability in 2014 and 2015 is boosting demand for harsh environment units as newbuilds replace an ageing rig fleet. Increased demand for premium jack-up rigs is being driven by the Middle East, Asia and West Africa as older units are replaced to increase efficiency. The market for tender rigs is also showing further room for growth.

Seadrill, which is listed on the New York Stock Exchange and the Oslo Stock Exchange, is also poised to increase the scope of its listings. The company is part of Norwegian-born shipping tycoon John Fredriksen’s sprawling business empire. Fredriksen has served as Chairman of the Board, President and a director of Seadrill since its inception in 2005. He is also Chairman, President and CEO of Frontline, a director of Golar LNG and a director of Golden Ocean Group.



**Text:** Johs Ensby and Vibeke Larøi  
**Photos:** Fredrik Refvem and Seadrill





# Joint effort

Plans by Brazilian state-run oil giant Petrobras to invest \$237 billion through 2016 is attracting every major equipment supplier in the offshore oil and gas industry.

**T**his year's breakthrough for ABB Marine and Cranes' Brazilian venture came when they won an order worth \$160 million to supply the main electrical systems for seven next generation drillships that will operate in the deep-water oil and gas fields off the coast of Brazil.

On delivery, the drillships with ABB equipment on board will be chartered to Petrobras for 15 years. They will be built by the Estaleiro Jurong Aracruz shipyard in Brazil, a wholly-owned unit of the Jurong Shipyard in Singapore, with expected delivery in the second quarter of 2015.

Sembcorp Marine – the group with a network of five yards in Singapore and operations in Indonesia, China, India and the United States – established Estaleiro Jurong Aracruz on the central eastern coast of Espirito Santo.

## Sharing risks

Competition was fierce. André Silva, Local Business Unit Manager for ABB Marine and Cranes, attributes excellent project execution of ongoing projects in Singapore, on the other side of the globe, as key to securing the contract in Brazil.

Silva, who moved back to Brazil at end of 2008 to start a new Marine Service Center and provide local service support for vessels operating offshore Brazil, says long, successful cooperation with the Jurong Shipyard built up a relationship that carries a lot of weight in a new market.



## Sorocaba factory

ABB's factory in Sorocaba, São Paulo is set to generate 1,000 jobs by next year.

The facility, which was acquired in 2012, manufactures low-voltage and automation products for the infrastructure, energy and industrial segments. It will also meet the needs of national development projects, such as the 2014 World Cup and 2016 Olympics Games, as well as large investments in the oil, gas and mining sectors.

Using the know-how and technology employed at ABB Italy, the Sorocaba factory produces circuit breakers, motors, drives and instruments. Comprising 125,000 square meters, the industrial complex is close to major highways and an airport. It is the fourth ABB location in Brazil.

The investment includes an after-sales structure to provide predictive, preventive and corrective maintenance to help circuit breaker users. According to Miguel Manas, Local Division Manager for Process Automation, the production in Brazil will improve services in the local market, as well as reducing delivery time, compared with that of imported products. With this factory, ABB is expanding its production in Brazil and meeting the demands of the local market faster.

In 2009, Petrobras announced they were looking to build 28 drilling rigs locally. The following year, the private company Sete Brasil was established to administer the order of 28 drillships and semi-submersible rigs and to reduce costs and potential debt for Petrobras. Petrobras holds 10% of the equity interest in Sete Brasil while seven pension funds and banks became investors in the company: Petros, Previ, FUNCEF, Valia, Santander, Bradesco and BTG Pactual.

The Sete Brasil contracts will enable the establishment of two new shipyards in Brazil, Estaleiro Jurong Aracruz and Estaleiro Enseada Paraguaçu, and the expansion of the shipyards Estaleiro Atlantico Sul (EAS), OSX, Brasfels (the Brazilian subsidiary of Keppel Singapore) and Estaleiro Rio Grande (ERG2).

The Estaleiro Atlantico Sul (EAS) shipyard won the tender for the first seven Petrobras orders in 2011. Brasfels won the second tender for six semi-submersible rigs in April 2012. The third tender, for three drillships, was awarded to Estaleiro Rio Grande, seven to Estaleiro Jurong Aracruz and six to Estaleiro Enseada do Paraguaçu.

### Industry partnerships

Of drillships to be built by Estaleiro Jurong Aracruz, three will be partially owned and operated for Petrobras by Odfjell and three by Seadrill, which has a 30% stake in the ships.

Alex Monsen, Vice President Asset Management for Seadrill, says the company normally builds its vessels in South Korea and Singapore, and selected vessel types in China. To build elsewhere is too costly and the risk too high, he explains.

When Seadrill goes against this principle and invests in vessels being built in Brazil, existing partnerships play a crucial role. "We know Jurong and the main suppliers, including ABB – and the design concept for the vessels is very familiar to us. The remaining unknown elements become the ticket for entering a very interesting market," Monsen says. The 15-year Petrobras charter further reduces risk for Seadrill, a company that has almost always taken the chance of building before securing contracts.

### Local content

Authorities in Brazil are demanding that a certain portion of the fleet and installations be built locally with local content. According to Sete Brasil its drillship

orders will generate more than 100,000 direct and indirect jobs in the rig construction industry in the country.

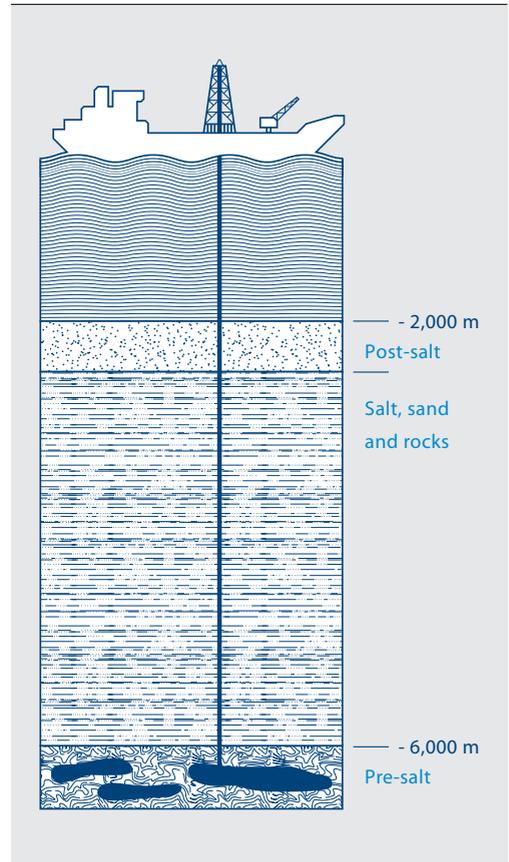
But according to *The Wall Street Journal*, Brazil's services industry is having trouble meeting demand. Abitam, a local trade group representing Brazilian manufacturers of tubing and other metal products, asked the National Petroleum Agency (ANP) to reduce the amount of local content in onshore drill casings to 95 percent from 100 percent. "None of Abitam's suppliers can meet demand for 100 percent minimum local content for this subitem," the trade group said.

Petrobras also asked Brazil's ANP to reduce the amount of local goods and services for 34 separate items related to offshore and onshore exploration and development. "The minimum percentages of local content for the cited items and subitems cannot be met by the national supply chain," Petrobras said in a recent request to ANP.

However, during a public hearing at Brazil's 11th auction of oil and natural gas concessions ANP officials ignored these requests, saying local content rules will be kept at the same levels as the country's last auction in December 2008. Contracts will demand between 37 percent and 80 percent local content for the exploration phase and between 55 percent and 85 percent for the development phase, with lower requirements for deepwater offshore blocks and higher requirements for onshore blocks.

ABB's Silva recognizes that local content was a big challenge, but securing the involvement of ABB factories to support ABB Marine and Cranes helped meet these requirements. In the end, ABB's ability to provide locally produced content and the expertise of its local organization were important factors in winning the order.

Extracting oil at 6,000 meters below sea level



**Text:** Johs Ensby and Vibeke Larøi

**Photos:** Shutterstock (Anton Balazh), ABB



# Dealing with risk

We all do it, every day: the pedestrian crossing the street, the ship master entering a port, the investor putting his capital into a new venture. All of us, in some way, deal with risk in our daily lives.

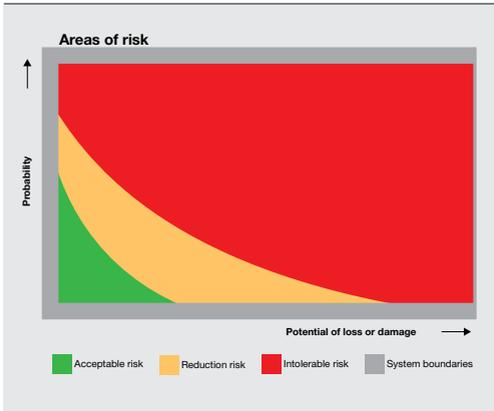
Dealing with risk could entail making a decision that impacts an entire industry in which many lives are at stake and that involves an elaborate process over years – or it could be one person making a decision in a split second. Risk management has become an integral part of every industry. For the maritime industry, this means ensuring safe and uninterrupted operations of increasingly complex vessels and systems.

## **What is risk?**

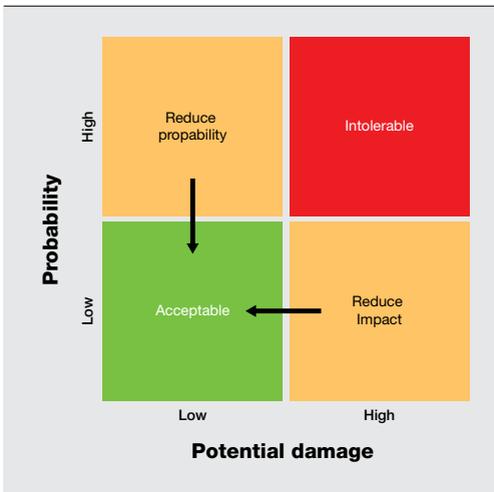
Risk refers to the uncertainty and severity of an event and its consequences for something with human value, explain Terje Aven and Ortwin Renn, co-authors of *Risk Management and Governance*. This two-dimensional approach – looking at uncertainty and severity – is central to risk management.

Managing risk starts with drawing the line between acceptable and unacceptable risks. As risk is all about uncertainty, this divide quickly becomes a grey zone that creates both challenges and business

1 Assessing risk: acceptable, tolerable and intolerable risks



2 When categorizing risks by probability and potential damage, measures can be targeted towards either reducing the likelihood of an occurrence or the extent of the consequences.



opportunities for anyone offering solutions to reduce the probability of an undesirable event and/or the severity of the damage it causes.

**The traffic light model**

When driving a car through a traffic light, we take red as a sign of unacceptable risk and yellow as a sign to stop, thereby reducing the risk of an accident. When massive amounts of data on probability and potential damage are available, the mapping of events might call for a diagram, still named “the traffic light model” by its division into red, yellow and green, shown in figure 1.

For generations, professionals have formed their views on what is acceptable, tolerable and intolerable based on experience and ethics. Today technology helps them measure the condition of equipment and process huge amounts of data. Vessel data can flood into an onshore support center 24/7 – if a sensor indicates a change in a vital piece of equipment, an early warning goes off. Automation, remote diagnostics and onshore expertise all support the onboard crew in managing operational risk. This also gives product developers information that can be used to improve technology and systems to prevent an accident or series of breakdowns from occurring.

The two-by-two matrix that is widely used by management consultants can represent a less fine-tuned version of the traffic light model. See Figure 2.

**Prioritization**

Efforts in reducing risk quickly face the challenge of prioritizing financial resources. Decision-making focuses on the utility of various options. The ALARP principle, which stands for “as low as reasonably practicable”, indicates that a risk-reducing measure should be implemented as long as costs to reduce the risk are not grossly disproportional to the benefits gained.

Even when it comes to saving lives, safety measures have a price. In this case, the so-called value of a statistical life (VSL) is often used. This is the value placed on changes in the likelihood of death. Economists often estimate the VSL by looking at the risks people are voluntarily willing to take and how much they must be paid for taking them. In cost-benefit analysis, typical numbers for the VSL are between 1 million euros and 10 million euros. According to Aven, oil companies use the guidelines in figure 3 to calculate the value of a statistical life.



## The value of a statistical life in euros

<b>0</b>	Highly effective, always implement
<b>10 000</b>	Effective, always implement
<b>100 000</b>	Effective, implement unless individual risk is negligible
<b>1 000 000</b>	Consider effective if individual risk levels are high
<b>10 000 000</b>	Consider effective if individual risk levels are very high and/or there are other significant benefits
<b>100 000 000</b>	Not socially effective, look at other options

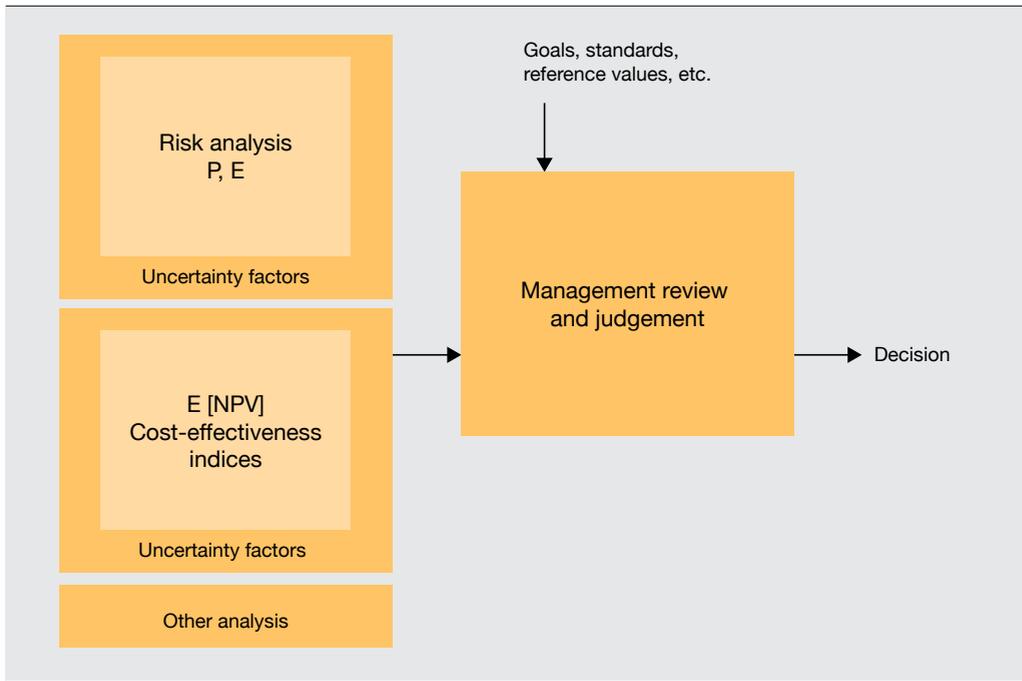
The economic risk perspective sharpens our attention to safety by incorporating expected utility and expected net present value. By calculating the net present value (NPV) of reducing the likelihood and/or severity of damage caused by an event, decision makers, who must prioritize how they use financial resources, can decide which risk reduction measures to invest in. Eventually, the business case for investing in safety also creates a market for technology developers to mitigate unwanted outcomes.

Eventually, the business case for investing in safety also creates a market for technology developers to mitigate unwanted outcomes.

### Beyond data and money

Cost-benefit analysis and cost-effectiveness analysis are both useful tools for decision makers, but assessments that go beyond this are also needed, Aven writes in his book *Misconceptions of Risk*. All relevant factors, including the limitations and constraints of analysis, should be taken into account before a decision is made. This is referred to as the “management review and judgment”.

Ethical principles also need to be factored into risk management – through a company’s core values or through the so-called “precautionary principle”. This principle states that if the consequences of an activity could prove to be serious and are subject to scientific



uncertainty, precautionary measures should be taken or the activity should not be carried out at all.

A globally accepted definition of the precautionary principle resulted from the 1992 Rio Conference, or “Earth Summit”. The Rio Declaration states: “Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”

The precautionary principle, known as *Vorsorgeprinzip* in German, can also be found in the 1970 German draft of a clean air bill. Another example dates back to 1854, when Dr. John Snow recommended removing the handle of a London water pump to stop a cholera epidemic. Without having any scientific evidence, he proposed a measure that was very effective in preventing the spread of the epidemic.

### Simplicity by design

To model complex structures of “risk agents” (such as a specific technology or component) and “risk absorbing systems” (such as an entire vessel) is

needed to assess risk and develop risk reduction strategies.

ABB engineers employ what they call “simplicity by design” – solving a problem in the simplest possible way. To design for the minimum number of parts, the use of standard components and processes as well as a modular design approach make sense from a risk management perspective.

Fewer components in a system, fewer steps in a process and fewer suppliers in a project translates not only into reduced costs, but it also results in fewer things that can go wrong.

**Text:** Johs Ensby and Vibeke Larøi

**Photo:** Shutterstock



# Pushing automation to the limit

If you're an operator with a dream of running the most advanced marine container terminal in the world, there's only one way to go: design and build it yourself. That's exactly what APM Terminals (APMT) did. Managing Director Frank Tazelaar tells us why.

Once complete in 2014, APMT's new terminal at Maasvlakte II on the port of Rotterdam will boast the world's highest ship-to-shore (STS) cranes. It will also be one of the two first terminals in the world whose STS cranes operate without a driver on board. The other terminal, Rotterdam World Gateway, is also due to open at Maasvlakte II next year. The cranes at both terminals will use ABB Crane Systems' technology.

"These type of terminals are so new that outsourcing the design and building was never an option for us," says Tazelaar.

Remote control was first used on stacking cranes. Since then, ABB has developed the technology

further for use with STS cranes and they can be operated from a control center. Automated and remote controlled cranes will not only improve productivity, they will also provide operators with a more comfortable, ergonomic working environment.

### **A leading technology**

"We've really taken automation as far as we could, given that we also have to open on time. I think we've taken some courageous steps in implementing new technology," says Tazelaar.

"ABB piloted the remote control of STS cranes in Panama and we are the first client to use this on a large scale at a working terminal. It's leading technology and the first of its kind.

## APM Terminals

- 23,000 employees in 68 countries
- Interests in 70 port and terminal facilities
- Provides port management and terminal operations to over 60 liner shipping and port customers
- Named “Port Operator of the Year” in September 2009 at the annual Lloyd’s List Global Awards Gala
- Headquarters in The Hague, the Netherlands
- Part of the A.P. Moller-Maersk Group

## How remote controlled STS cranes improve productivity

- Less stress on back and neck of operator working remotely in an ergonomic environment
- Onboard cameras give better views than those from a cabin
- Cranes are faster and ramp times shorter
- More aggressive corrections possible without driver on board

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We are targeting 25 to 30 percent more productivity than at existing European terminals.

“You can outsource the design and building of a terminal like this if you’ve done it two or three times successfully. Then you have the right people and the right track record to challenge whoever takes it on. At the moment we’re not an organization that has built many automated terminals on the go and this type of facility is still scarce.”

Worldwide there are only three terminals that use full automation: Euromax and ECT in Rotterdam and CTA in Hamburg. APMT also runs a semi-automated terminal in Virginia in the United States.

### Pace accelerating

The state of port automation today has been 20 years in the making. ECT paved the way, opening in the 1990s, CTA in 2002, then Euromax in 2008. Now, five years later, the two at Maasvlakte are in progress.

“So the pace is accelerating and I’m sure there’ll be more, also moving to other parts of the world. But there isn’t a vast track record compared to the hundreds of conventional terminals around the world,” says Tazelaar.

“Full automation is still very new and small. It may be getting a lot of attention now because it looks big. But that doesn’t mean it’s all easy going and we’re done. The resources are scarce and the experience is limited.”

### A unique project

Tazelaar notes that the APMT terminal project is unique “because we already have a working organization in Rotterdam. We know the place, we are adding something new, including new people, and we’re doing that for a client [Maersk Line] that is introducing the next generation of vessels.”

These ships will be bigger and with a capacity of more than 18,000 TEU. APMT’s new terminal will expand its capacity by 4.5 million TEU per year.

“Besides being the highest, the STS cranes are also able to cater for coming generations of vessels. So, they are future proof in terms of height and width,” Tazelaar says.

The initial phase of the project started with a team of five in 2008, which has grown to the current 40. By the end of the year, he expects the organization to have doubled.



APMT has a 50-year concession for the terminal. It is currently building the first 86 hectares but will be able to expand by a factor of two in the future, adding more quay wall and stack.

“Probably that will be more copy and pasting, not as exciting as what we’re doing now. These expansions will come on demand if the market and client need is there. And I’m sure that will come. Then we will be able to expand quickly,” says Tazelaar.

“It’s a combination of enormous pressure and freedom building a port like this from scratch. You have the responsibility of developing something for the next 50 years.”

### Reaching out

“What we realized from the beginning was the need to reach out to colleagues, other terminals, clients and various stakeholders to see how we could get the best out of this terminal. Selecting the right suppliers was also crucial,” says Tazelaar.

“The combination of automated technology, civil equipment, IT and operational organization all has to fit together in one system. It’s crucial for the teams to work towards a common goal.

“This industry isn’t mature enough yet to say to one supplier: ‘You take care of this and I’ll wait for you to knock on my door when you’re ready.’ This still has to involve a lot of our own thinking because we’re implementing new technology.”

With so many interfaces between different suppliers, Tazelaar says one of the most important criteria in selecting suppliers was “the willingness to do this together.”

“It sounds soft but it’s very hard. In the tender process we did the selection on all kinds of criteria but getting to know the supplier and its team, knowing who will take the effort, is important to us. We’ve had some tough negotiations with suppliers, not just based on price but especially on quality,” he adds.

## Where to, Rotterdam?

It may be the largest port in Europe, but Rotterdam's value has less to do with its size than its strategic position. With two new terminals about to take off, this shipping hub has its sights set on expansion.

Penetration into the hinterland will be a big part of this growth, predicts APM Terminals Managing Director Frank Tazelaar.

"If you look at Rotterdam with the existing and new terminals, each of the top 10 shipping lines all have a vested interest, either by way of a long-term contract or shareholding," he says.

By far the majority of exports outside the European Union travel via the port of Rotterdam; what these players are looking for is guaranteed access to capacity at this busy port.

"You can't miss Rotterdam in your network, even as a shipping line that has a terminal operator acting on its behalf," says Tazelaar, adding that the biggest challenge for Rotterdam is to "take one step further" by penetrating eastwards, either via the feeder to the Baltic or rail businesses towards Eastern Europe.

### Investing in Rotterdam

"I think with the additional investment in rail, both on the new terminals and on the rail network, we're well positioned for that. Rotterdam will become more important for a bigger part of Europe than it currently is," says Tazelaar.

The fact that Rotterdam is not just a container port but also serves chemicals and has a large bunker business adds to its attraction. Up until 2004 Rotterdam was the world's busiest port, a title that then went to Shanghai and now belongs to Singapore.

According to a recent press release from the Port of Rotterdam Authority, Chief Executive Officer Hans Smits says the business sector is investing almost 11 billion euros in the port area during the period 2011 up to and including 2015.

Construction on the RWG and APMT terminals marks the beginning of corporate investment on the land expansion. In the existing port area, there is ongoing investment with projects in refining, chemicals, tank storage and energy.

"This is evidence of confidence in the port of Rotterdam, and also positive expectations regarding the economic developments and integration of Europe," says Smit.

Tazelaar says the new terminal is "the ultimate in terms of productivity, reliability, safety and sustainability. We are targeting 25 to 30 percent more productivity than at existing European terminals. We'll need a few years to get there, but it's all in the specs."

### Zero emissions facility

Besides the unrivalled speed, height and productivity of its STS cranes, the terminal is also a zero emissions facility and its automated vehicles will run on batteries.

"The good thing with the full electrical choice is that we are now flexible to follow any developments on the energy front. If coal shifts to gas or gas to wind and solar, that's good for us. If our vehicles were running on diesel, we'd be stuck on the fossil side," explains Tazelaar.

The port of Rotterdam is one of the biggest land reclamation projects in Europe, and the two new terminals at Maasvlakte II herald a new chapter in its history, as

well as that of APMT, its clients, suppliers and indeed Europe. As Tazelaar puts it: "A lot of people on our team feel this is a once-in-a-lifetime opportunity." (See also page 26.)

**Text:** Helen Karlsen

**Photos:** APM Terminals

# Safety first

While automation gets people out of the way of dangerous machines, it can bring its own safety and environmental challenges. Maasvlakte II's Health, Safety, Security and Environment Manager Gabriël Kierkels outlines the safety pros and cons of building and running a fully automated container terminal.

**M**ost accidents at terminals are a result of people being hit or injured by heavy machinery – and the number one cause of fatalities is personnel being crushed under equipment carrying heavy loads.

At a fully automated terminal, keeping maintenance staff safe will also be the big priority. “A lot of people think that because you have an automated terminal, man and machine are separated so it's completely safe. That's true when everything works as it should,” says Kierkels.

Unfortunately, machines need maintenance and sometimes they break down. “Then people really get into harm's way because they go into automated areas with no drivers with eyes to see them and to brake. These are very heavy machines that won't stop if you get in the way,” says Kierkels.

For this reason, APMT put a lot of thought into safe maintenance of the automated cranes. One of the



Gabriël Kierkels



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We have a motto that safety doesn't know competition.

company's requirements during the tender phase was that areas on machinery that needed maintenance could be easily reached. This included the electrical installations.

#### **Block off for maintenance**

At the new terminal, staff inside the operations control room will be able to put automated areas out of operation with the help of the fence control system. "Then nothing operates and no automated vehicles (AGVs) can drive into the area. This has to be communicated to all the equipment and operators have to confirm that they know this," explains Kierkels.

This process takes only seconds. Once everybody has acknowledged the shutdown, the area concerned will be blocked off and the fence lock released. The maintenance engineer can then enter the area knowing it is safe to work there.

"That doesn't mean he or she can just wander off anywhere. But that's an aspect of behavioral safety that we have to manage – that people don't think they can quickly go to another area," says Kierkels.

Something APM Terminals did to mitigate the risk of people getting hurt by trucks is to leave the gates where the trucks drive through at the new terminal unmanned. At the existing terminals there are still gate inspectors who check things like seals and numbers. Cameras will now do this job. Instead of getting out of the truck, the driver will communicate through an intercom. And if anything, for example paper work, needs arranging, he or she must park the truck and go into a building via a safe pedestrian route.

### Vision for safety

Part of APM Terminal's vision for the new terminal was to "build it in the safest and most sustainable way. We communicated our safety vision at the tendering phase and chose our suppliers based, among other criteria, on safety and sustainability," says Kierkels.

For the next few months, the main concern for safety is the erection of large, heavy quay cranes and other material in a relatively small area, where other equipment is being built and tested as well.

"The safe remote control of the cranes is on the plate of ABB. Some recent accidents involved containers being hit by the trolley coming backwards on the ship and then toppling containers off the ship onto the quayside," he says. "So far we are lucky that no-one was underneath, but it could have happened."

ABB has developed a system to make a scan of the build-up of containers on the vessel deck. Then the crane adjusts for a safe height and the correct time to start moving back.

"We still have crane drivers, they are just sitting somewhere else, so we have to help them by making it virtually impossible to move back too soon and hit something," explains Kierkels. "That can be done with automation but you have to be 100 percent sure it is working, otherwise you will have the opposite effect – a false sense of security."

### Environmental benefits

An additional advantage of automated cranes is noise reduction. "Putting down containers on concrete or on top of each other can be pretty loud," says Kierkels. "If the operator does it manually, it depends on his feel, judgment and experience.

"Automated systems are much smoother. It's like landing an aircraft. If it's a very smooth landing, the computer probably did it, not the pilot." As an ex-Air

Force pilot, Kierkels knows what he is talking about. Increased traffic to the new terminal will bring more safety and environmental risks. The local authorities have already put plans in motion to heighten the capacity of the nearby A15 highway.

In a bid to reduce emissions from trucks, one of APMT's commitments to the port authorities from which it leases the ground is to make it more attractive for customers of customers to transport by boat or train, rather than truck.

"We have agreed to eventually bring down the modal split for trucks to a 35 percent maximum. That's low compared to some German ports, where the percentage is 89 percent," says Kierkels. The present level for trucks is 40 to 50 percent at the port of Rotterdam. "It's quite a challenge to bring that down, especially since we can't tell them because they are not our direct customers."

Whatever it takes to make a safe, sustainable terminal, a terminal operator cannot do it alone. Whether it is the central or local government, the immediate community, customers or the environmental authority for the port, all have a role to play in this mammoth task.

"We have a motto that safety doesn't know competition," says Kierkels. "We regularly meet with safety managers from other terminals to share accident information. That's what makes us stand out at Rotterdam – the joint effort."

**Text:** Helen Karlsen

**Photos:** APM Terminals

# Switch to mega-ships raises stakes at ports

Terminal operators have good reason for taking the leap to the next level of automation. Providing an efficient service for the new breed of mega-ships is vital if they are to stay ahead of the game.



*Tauro Rickmers* is trading as *Maersk Evora* and was delivered by Hyundai Heavy Industries to Rickmers Group, a German ship operator with eight 13,100 TEU container ships in its fleet.

**T**oday container shipping is about cost and efficiency. Shipping lines have been in a sprint for growth for years, ordering bigger ships to leverage economies of scale, and these mega-ships come with a hefty price tag.

Even in today's oversupplied market, the new 13–18,000 TEU capacity container ships are being ordered. At the present fuel price, it is not viable to continue operating smaller or older ships that consume over 50% more fuel than the newer boxships.

The large ports on the Asia-Europe trade routes are preparing for the arrival of the first 18,000 TEU Triple E-class container ships later this year. With an estimated quayside exchange of 7,000-10,000 TEU per visit, terminal operators are looking for solutions to a central dilemma: how to discharge more containers within the same handling time as that of ships half the size.

Uno Bryfors and Fred Hoonard, respectively Vice President and Senior Vice President of ABB's Crane and Harbor, stress that highly efficient container



handling is going to be crucial for terminal operators. “In an over-supplied market, terminal operators have to switch to innovative solutions to handle fast increasing volumes efficiently and safely,” says Hoonard.

With fewer but bigger ships going to fewer ports, the competition for these mammoth loads is heating up. “The number of ships arriving in Northern Europe from Asia has gone from 35 per week in 2007 to 23 today and may soon be below 20”, says Bryfors. Under the terms of their contracts with port authorities, many terminal operators are obligated to bring in volumes. “It comes down to how fast they can handle the boxes and for how many dollars per TEU,” he adds.

“Containers must be loaded and unloaded as efficiently and quickly as possible so that the ship can leave. Ships don’t make money at the quayside and shippers expect the shortest possible total transit time, says Hoonard. When the last boxes are being unloaded, the first ones must already be out of the gate. Otherwise, the operation becomes impossible due to the incredible volume,” he explains.

### Terminal operators’ response

Terminals are scaling up their facilities, ordering more and bigger cranes and introducing more automation to cope with the challenge.

A prime example is APM Terminals (APMT) in Rotterdam. It is leading the way at its new Maasvlakte II terminal by investing in the latest generation automatic stacking cranes (ASCs) as well as automated, remote controlled ship-to-shore (STS) cranes with ABB’s state-of-the-art automation solution.

TEU: twenty-foot equivalent units, length x width x depth below water in meters

#### Early container ship (1956-)

500 – 800 TEU, 137x17x9m



#### Fully Cellular (1970-)

1,000 – 2,500 TEU, 215x20x10m



#### Panamax (1980-)

3,000 – 3,400 TEU, 250x32x12.5m



#### Panamax Max (1985-)

3,400 – 4,500 TEU, 250x32x12.5m



#### Post Panamax (1988-)

4,000 – 5,000 TEU, 285x40x13m



#### Post Panamax Plus (2000-)

6,000 – 8,000 TEU, 300x43x14.5m



#### New Panamax (2014-)

12,500 TEU, 366x49x15.2m



#### Triple E (2013-)

18,000 TEU, 400x59x15.5m



Adapted with permission from Jean-Paul Rodrigue



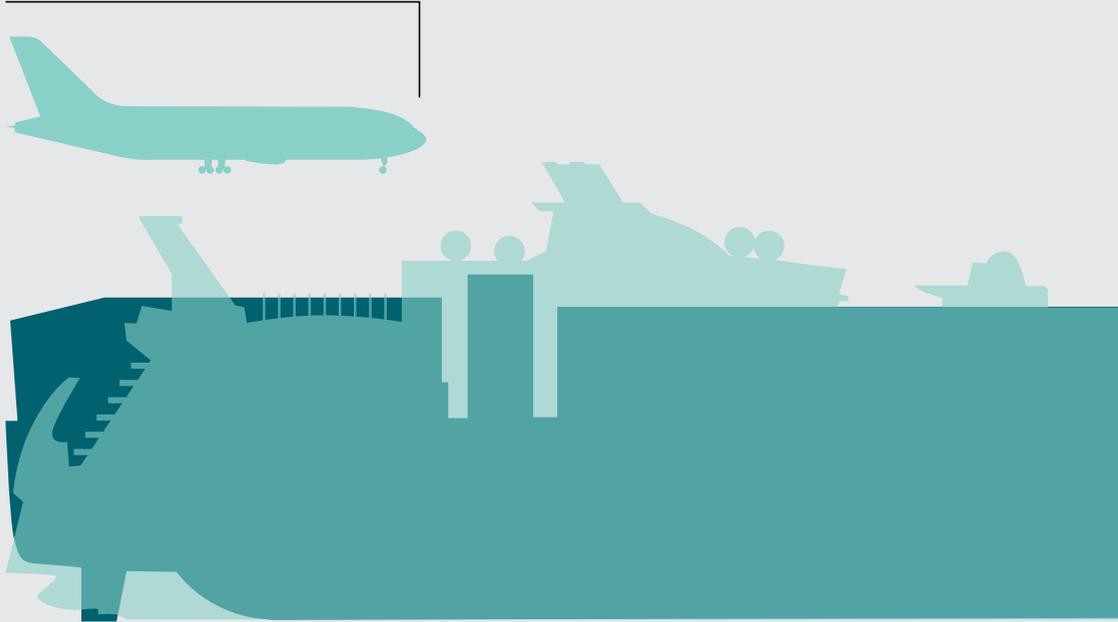
Marco Polo (396m)

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Oasis of The Seas (362m)

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Airbus 380 (73m)



Remotely controlled STS cranes will also be installed in the nearby Rotterdam World Gateway terminal. In the next few years 10000+ TEU ships will rapidly be introduced in all major trade lanes. This means that the need for efficient terminals is spreading far beyond Northern Europe. Long Beach Container Terminal in the USA and Jebel Ali Terminal 3 in Dubai are examples of terminal operators who have made large ongoing investments in new terminals with intelligent automation.

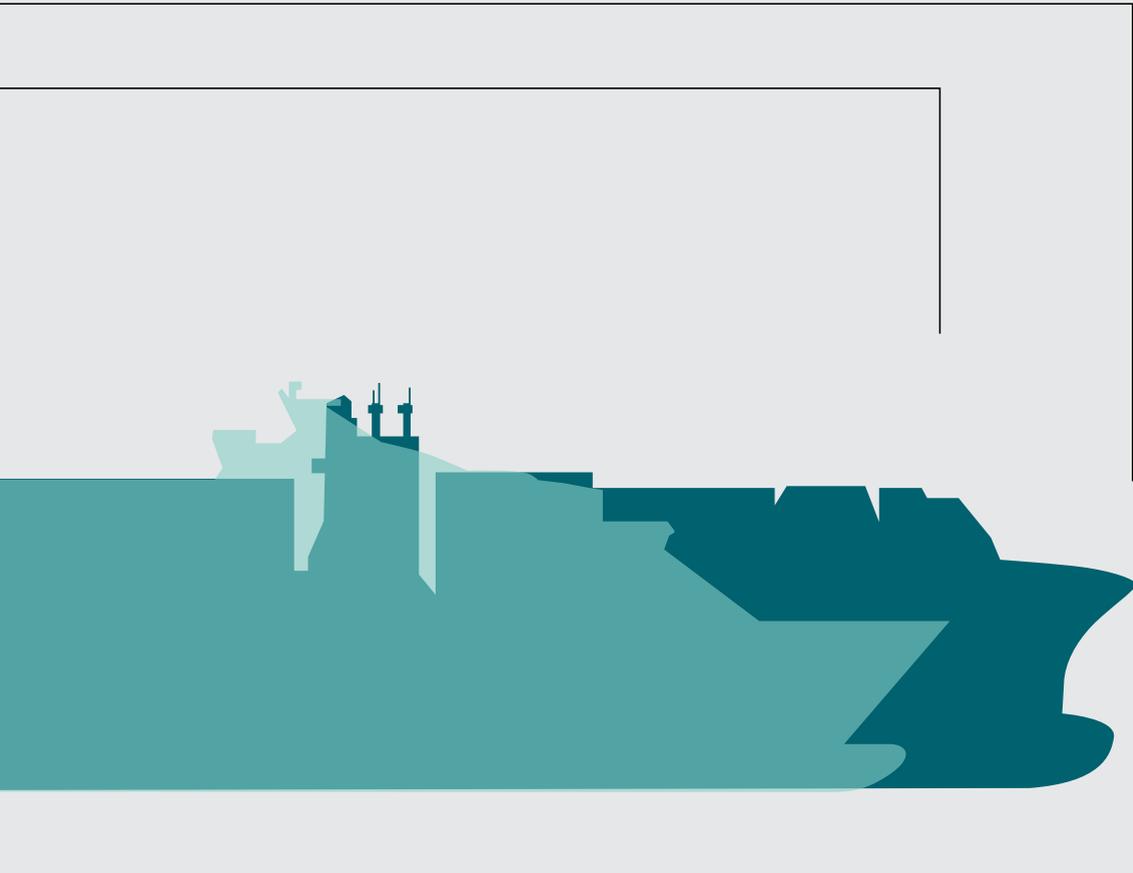
### Benefits of Intelligent Automation

New ship-to-shore cranes now have a lifting height of more than 50 meters, which would place crane drivers' cabins about 60 meters above the quay. Taking drivers off the moving machines, from which they have

limited vision, and putting them into a control room for remote operation is a far more efficient option.

"The crane can run faster and there is less ramp time. There are also no interruptions in shifts. One person just moves away from a chair and someone else takes over, instead of having to travel kilometers to the crane, go up and come down," says Hoonard.

Bryfors adds that ABB's remotely controlled STS cranes are only part of a total intelligent automation solution the company offers. Fleets of coordinated automatic stacking cranes (ASCs) handle the increasing volumes, optimizing productivity as well as the use of storage area and energy consumption. The ASCs stack containers five or six high, enabling



them to be stored in the smallest possible area and close to the quay saving the cost of paying for land.

With intelligent automation, the ASCs are able to respond to varying sea-side as well as land-side volumes and ensure timely delivery of containers for quay and rail terminal processes. The optimum scheduling of ASCs is crucial for overall terminal efficiency.

With more than 400 ASCs equipped with ABB automatic solutions to date and the remote control of STSs soon to go into large scale operation, Bryfors and Hoonard feel that terminal automation is really taking off.

They stress that this does not only mean automated remote controlled cranes. Intelligent automation

is about the whole organization and operation of container terminals. Crane operators go from the hands-on operation of cranes to supervising the process and handling exceptions. They move to a centralized control room that is a vastly improved working environment, allowing team work and collaboration for instance with operations and maintenance staff.

Intelligent automation means using real-time process data to optimize crane operation and the entire terminal operation and enabling collaboration between people in different teams and functions, say Hoonard and Bryfors.

**Text:** Helen Karlsen





# Time for class to shine

The narrow view of classification societies as mere rule-makers is a misunderstanding of their role. So says American Bureau of Shipping (ABS) vice president and chief engineer James Gaughan. We met him in New York City, where he told us about the glittering role class really plays.

“People need to take a step back and look at what we do,” says Gaughan, who took up the reins as chief engineer at ABS in April of last year. He adds that, like ex-mayor of New York City Ed Koch, who was buried the previous day, he’s not afraid to speak his mind.

“Because you have a number of organizations and IMO issuing requirements, a lot of people have been downplaying the role of the classification society. And if you look at the history of the maritime community, the role that class has provided in terms of maritime safety is not always fully recognized.



If there's a grounding, stranding, flooding or any distress situation at sea, it's the class society everyone will look to for a solution

"Class requirements have evolved over many years and many have been incorporated into SOLAS (Safety of Life at Sea). But long before there was a SOLAS, there was ABS, Lloyds, Bureau Veritas, DNV – major class societies doing their jobs.

"People are not necessarily aware of how often a surveyor is in a dry dock on a Sunday morning to tell someone a ship does not meet class or statutory requirements, that they must do a proper repair," says Gaughan.

"If there's a grounding, stranding, flooding or any distress situation at sea, it's the class society everyone will look to for a solution, be it a refloating or an evacuation."

"We have people working around the clock," says Gaughan, who recounts how ABS chairman Robert Somerville flew half way across the world to explain to a valued customer why his vessel could not proceed without necessary repairs being carried out.

"In some cases our decisions are contentious. You have a client who you hope will give you class on the next new order they build, who wants to get the ship on its way to making money and you have to tell them it's not in the best interests of the crew, the vessel or maritime safety."

But besides having to sometimes make unpopular decisions, Gaughan says another aspect of class that is often overlooked is its research and development role.

The organization has more than 600 engineers around the world, many dedicated to research. At any given time it will be running at least 100 to 150 research projects in conjunction with leading technology players or academic institutions.

An interesting relationship it has recently entered into is a "cooperative agreement" with ABB. Gaughan explains the background behind this association:

"As the industry changes, new developments come along and it's our job to keep abreast and be cognizant of evolving technologies.

"Because before too long somebody is going to tell us they want to do some activity that we don't have rules for and it's our responsibility to assess proposed approaches so that the activity can be done safely.

“In the past, a lot of the work at ABS had been directed on structure, but our focus started to expand some time ago to safety in terms of control systems, instrumentation, communications and understanding the operation of vessels.”

More recently, says Gaughan, operability performance and environmental concerns have come under the spotlight.

“We’ve formed a new group with in-house people and recruited industry experts in energy efficiency. Of course, a lot of this has to do with power generation, control systems and alternative forms of propulsion.”

Gaughan says that when ABB approached ABS about forming a cooperative partnership in this area, they jumped at the opportunity.

“We always develop new requirements working with industry and, typically, we will hear about something after being asked by a client if this is a structure or system we could class. We will do some internal research ourselves and then we’ll start contacting industry experts. Very often we’ll organize a committee of experts that we work with as we develop a new guide or rules.

“Our relationship with ABB is unusual in that it’s a strategic arrangement, not a commercial one. While this arrangement is progressive, it’s not new – we’ve done it before with shipyards and other organizations.

“Working with ABB, a world leader in this technology, not in one area, or just on one project or component but on a number of evolving technologies is a tremendous opportunity for ABS.

“Where this is going is towards developing what we call approval in principle on a number of designs or features. We are not meeting ABB after a contract has been placed with a shipyard, we’re meeting them a few years before the product gets to the shipyard.

“Once the Approval in Principle (AIP) is issued, ABB can work with shipyards or designers. So they can approach a shipbuilder and say ‘If you’re building a hybrid tug to ABS class, this power distribution system has already received AIP from ABS.’”

Another benefit of this relationship for ABB is what Gaughan calls “keeping them on their toes.”

## American Bureau of Shipping (ABS)

- International ship classification society, established in 1862
- Headquarters in Houston, Texas
- Offices in 70 countries
- Mission: to promote the protection of life, property and the natural environment
- Technology centers around the world that liaise with leading universities
- Currently running 200 research projects worldwide

### Technology focus areas for 2013

- Environmental issues
- Extreme environments
- Offshore energy
- Alternative fuels
- Propulsion
- Performance enhancement

“ABB has an excellent reputation so it’s important to them that they not put a product into service that hasn’t been properly documented, tested and justified, so they want to work with a classification society that will challenge them.

“We force them to answer questions because everyone has a good idea but it has to be tested, run through a certain level of scrutiny. That unbiased third party review is really what class provides.”

Whether it’s teaming up with major players on R&D projects or helping to get new technology onto the market, it seems that, far from being a bit-player in the shipping industry, class is one of its leading lights.

**Text:** Helen Karlsen

# What makes a good engineer?

Engineers cannot exist in a vacuum, says ABS vice president James Gaughan, who has been one for over 40 years. The best ones know about a lot more than engineering.

“Part of being an engineer is being able to work with and talk to people. It’s a problem when an engineer thinks they know everything, or that they can exist in their own world. To me that’s a very limited engineer.”

Gaughan says the best engineers he’s met are broad based. “They are really good engineers but they have other interests, such as law, politics, economics, finance.

“Another thing to realize is that a good idea does not make a project. Engineers have a tendency to come up with really good ideas but they have to understand whether there’s a commercial advantage to what is being proposed.”

The best way to learn about these other areas is to talk to legislators, financial people, anyone who can educate you, says Gaughan.

He adds that education is a two-way street. A good engineer is able to explain complex concepts in a simple way.

Gaughan gives the example of when he helped develop requirements for offshore drilling units, for which he went to the International Maritime Organization (IMO) with a US delegation.

“I could tell that some people in the room had limited knowledge of drilling rigs. Over lunch I would be drawing sketches on napkins, trying to explain how some of the important systems work.”

Asked whether he thinks rules discourage engineers from experimenting with new solutions, he says he was “always the guy thinking outside the box.”

## Fun stuff

“Back in the eighties I was the one they were throwing things at that nobody else wanted to do. I thought this was the fun stuff, the risk analysis sort of thing.

“Now when I meet ABS engineers around the world, I tell them if there’s a rule requirement, we’ve got to consistently apply it. But if there’s reason to deviate from the rule, you have to be able to document why and show the alternative solution will provide an equivalent level of safety.



“That’s the fun part of engineering. It’s not just checking items against the rules. It’s important that we do that, but every so often we get something that doesn’t fit into that box and it’s important to identify how we can and whether we should accept what is being proposed.”

Gaughan says it’s a tough approach “because it’s a lot of work. We deal with questions all the time in the Chief Engineer’s office and it’s interesting the way they are posed and how we go back to get the problem solved.

“Our engineering department is always growing. We have a young staff. It’s important to continuously engage these people. You have to let them know that we’re counting on them to come up with solutions. I’m looking for problem solvers.”

After more than 40 years in the business, Gaughan can spot one of these broad-based problem solvers, able to teach and learn, a mile away.

## James (Jim) Gaughan

Vice president and chief engineer, American Bureau of Shipping (ABS)

- Became chief engineer on April 30, 2012
- Was an international engineering consultant for 13 years
- Specialized in the design and operation of LNG carriers
- Worked closely with ABS during his consulting years
- Held a variety of engineering positions at ABS for over 28 years before becoming a consultant

# Old approach to new ideas

Every so often a new concept comes along that doesn't fit the box. American Bureau of Shipping (ABS) has a sure-fire way to deal with these bright ideas.

“ If someone comes to us with a novel idea, we don't tell a client 'well, we can't work with you because we don't have rules for this,'" says ABS vice president James Gaughan. What the organization will do is put a "novel concept" process into action that will culminate in an approval in principle (AIP).

"A very important guide that we have developed in the past 10 years is the guide on novel concepts. This is a systematic approach to reviewing and approving a novel concept," says Gaughan.

Based on risk analysis and safety studies, the process is well prescribed and means ABS does not have to wait until it has a guide or rules for a particular application in order to issue an AIP.

"AIP means we have satisfied ourselves that the level of safety is equivalent to what has been established in other published rules that we have.

## Approval in principle (AIP)

- Not a standard procedure for new construction projects
- Granted on novel concepts such as ABB's DC-Grid
- Means the concept is valid and is capable of culminating in a successful project built to ABS class, provided the correct path to final approval is followed
- ABS works with the designer to understand the concept and identify potential hazards
- The path towards final acceptance and construction may include safety studies, analyses and prototype testing
- AIP gives the designer confidence to carry on with the project

“We have rules for many vessels and marine structures, so we are going to compare it to a comparable system. We identify and learn what the new concept is, what the hazards are, then we look at similar processes.

“We also have the agility to publish new guides fairly quickly. A good example is gas fuel ships; everybody wants to burn LNG. We published a guide for gas fuel ships a few years ago and all the elements that were involved in that were a combination of requirements we already had in place.

“We are going to look at the containment system against our rules for liquefied gas carriers. Operators are burning methane in engine rooms, something they’ve been doing since 1964. The industry knows how to do this. Basically it’s a case of putting the right pieces of the puzzle together,” says Gaughan. “Then we had to identify new hazards introduced and deal with those.”

He describes the novel concept approach as “an alternative path” for the technology provider.

“A technology provider like ABB that is doing a lot of work in research and development, coming up with new ideas and technology, is somebody that we should be more than willing to work with, and we do this through our novel concept process,” says Gaughan.

The novel concept process starts with a company submitting drawings to ABS, which can be shared with its divisions throughout the world.

“Normally a young engineer will look at a concept, then check to see if it is covered by one of our published rules. If not, they would go to the ABS resource center to see if there is a process instruction that addresses the concept. If there isn’t, the engineer would review the situation with their supervisor. The issue would be elevated to the assistant chief engineer in the division, who would seek guidance from the Chief Engineer’s office, which is at the corporate level.”

Once an idea is identified as a potential novel concept, the chief engineer sends out a request form to the originator plus the other three ABS divisions requesting comment. So, as an example, if a proposal was submitted to the London office, it may eventually be considered by the engineering staffs in Houston, Singapore and Shanghai.



When we’re developing rules, it’s not just an engineer sitting in Houston writing things down.

With ABS engineers all over the world working with designers and shipyards, someone typically has the experience to assist in assessing whether the concept has been considered before or if it is a novel one.

“We have a requirement on urgent matters that people respond within 48 hours,” says Gaughan. “In my department we look at the answers coming back from the other three divisions and we have our own specialists in various disciplines. I have four chief engineers and an assistant chief engineer specializing in machinery, structures, offshore engineering and metallurgy, as well as an assistant chief in charge of statues, so I get them involved.”

As Gaughan says, “So, when we’re developing rules, it’s not just an engineer sitting in Houston writing things down.”

Indeed, with so much experience at its fingertips, ABS can draw on the knowledge and training needed to find alternative solutions to satisfy the intent of the rules.

**Text:** Helen Karlsen

# EU cracks down on equipment

Sub-standard maritime equipment manufacturers will find it much harder to operate when a new European Commission proposal becomes law. But for quality-minded companies, the move will be good news.

**T**he so-called wheelmark (or mark of conformity) – the European regulatory marking of all marine equipment – is recognized worldwide as a sign of quality. But it is not enough to prevent counterfeiting and inadequate certification.

A new proposal put forward by the European Commission (EC) to revise the Directive on Marine Equipment (MED) aims to remedy this.

“All going well, we might have an agreement at the end of this year or in the first half of 2014,” says Christine Berg, Head of Unit Maritime Safety at the EC’s Directorate-General for Mobility and Transport (DG MOVE).

She says the proposal takes into account the need to “adapt to the realities of shipping – not least that ship building and ship repair often happen very far away from EU territory.”

“The aim of our maritime safety policy,” she adds, “is to eliminate sub-standard shipping, increase the protection of passengers and crews, reduce

the risk of environmental pollution and ensure that operators who follow good practices are not put at a commercial disadvantage compared to those who are prepared to take short cuts with safety.”

## **Ineffective market surveillance**

A report on the market for maritime equipment that accompanied the proposal at the end of last year raised the issue of ineffective market surveillance, a problem common to many markets for goods circulating in a global economy and currently under general review.

Other aspects highlighted by the report were the unequal implementation of IMO regulations by EU member states and the misuse of “safeguard clauses”. Safeguard clauses are restrictive measures taken by a member state when non-compliant equipment is identified.

“This is always a very difficult situation and in the current directive the manufacturer must go through an entirely unregulated process before the Member State and then, if measures are taken, again before the Commission.

“This can last months, if not years,” says Berg. She adds that the new system “places emphasis on the quality of the dialogue between market surveillance authorities and the manufacturer, requires impartial and exhaustive technical assessment and privileges voluntary correction.”

These measures are an attempt to find solutions at the level of the Member State. However, for equipment that cannot be brought into compliance, the new measures should simplify and accelerate the process of taking protective measures, says Berg. Roadblocks to implementation

Another issue highlighted in the report is that the current MED legal framework “does not sufficiently ensure the complete application and implementation of IMO standards in the EU, possibly leading to safety risks and inefficient functioning of the internal market for marine equipment.”

Berg also points to the “long and cumbersome” process by which the current directive is updated to take account of new IMO requirements. It can easily take two and a half years for an international standard or instrument updated by the IMO to become law in a member state.

“By the time the requirements become applicable, the rest of the world has been applying them for some time. This hampers innovation and generates cost for the industry,” says Berg.

According to the report, in extreme cases, these costs can be up to one percent of a company’s annual turnover. “We intend to change that,” says Berg. “We have proposed a new procedure that will allow us to implement all new IMO requirements well on time and much more flexibly.”

“Conversely, we will avoid imposing new requirements that have little or no added value in terms of safety but cost a lot of money.”

Berg says that once the proposed legislation comes into force, quality-minded manufacturers will be rewarded with a system that works better and more efficiently and with better-equipped conformity assessment bodies, she adds.

Lack of confidence in notified bodies and in the whole notification process in general was another problem raised in the report accompanying the proposal.

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Christine Berg



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By the time the requirements become applicable, the rest of the world has been applying them for some time.

The proposed legislation “will now follow the general rules of the internal market legislation more closely. This will make everybody’s life simpler, especially those manufacturers who are present in other industrial sectors,” says Berg.

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## Electronic tagging has been used successfully in other sectors of the shipping industry.

### Proposed electronic tagging

Other measures put forward in the proposal are a new link with port state control and improved documentation on board for inspectors. The possibility of using electronic tagging to either supplement or replace the wheel mark is also proposed.

Currently the wheel mark is a printed label or plate. It must be legible, visible and indelible throughout the life of the equipment. The label indicates that a piece of equipment holds a Declaration of Conformity based on the certification issued by notified bodies acting on behalf of the maritime administrations.

Consequently, equipment bearing the wheel mark is entitled to free movement on the internal market and can be used on board ships flying a community flag.

“Electronic tags are cheap, very difficult to forge and can be read at a distance. They can also provide valuable information to inspectors. They are, however, quite new for this kind of usage, and we have to see if they can be used with all types of equipment and under what conditions.

“However, we are convinced that electronic tags will make a major contribution to safety and the fight against counterfeiting, which we must not forget doesn’t only cost money but lives,” says Berg.

Electronic tagging has been used successfully in other sectors of the shipping industry, such as at freight distribution centers, as well as in the railroad and aerospace industries and on luggage at airports.

### Leading the way

Berg says that DG MOVE wants its policy to take account of technological development but also be sensitive to the industry’s struggle to stay competitive.

The EU maritime equipment sector is a world leader, with an estimated 5,000 to 6,000 companies and close to 300,000 direct jobs, according to DG MOVE.

Berg says the industry “makes a considerable effort in terms of research and development. New ideas are coming all the time. I think we need to work together to make these ideas known and embraced internationally so the entire shipping industry can reap the benefits as soon as possible.”

Eero Lehtovaara, Senior Vice President of ABB’s Marine and Cranes business unit, says the company welcomes the new proposal: “Maritime equipment is critical for the safety of a vessel and its crew and it is therefore vital that our industry adopts a zero tolerance approach to sub-standard shipping.”

Lehtovaara adds that the new proposal should boost the growth of the maritime equipment industry as well as encourage innovation and productivity.

**Text:** Helen Karlsen

# Russian Connection

Nowhere is safety and availability more crucial than in Arctic areas. ABB was the first to use the Azipod® technology now used to drive icebreakers in these harsh environments. It all began with the first diesel-electric vessel on the Volga river.

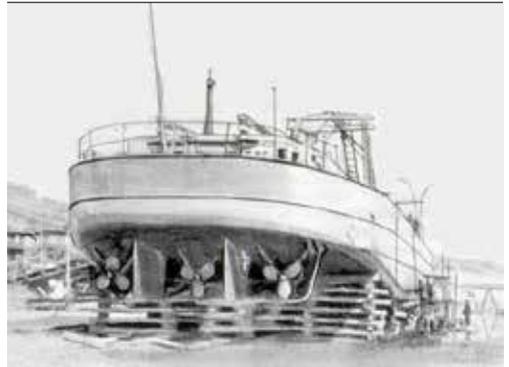
**E**ver since the maiden voyage of the river tanker on the Volga River, a bond between ABB and Russia was formed that has lasted up to the present time.

German engineer Rudolph Diesel invented the diesel engine following the oil industry's search for an economical oil-burning engine. He marketed his technology to oil barons around the world and in 1898 granted exclusive licenses to build his engines in Sweden and Russia.

In 1902 Karl Hagelin – a veteran of the Volga – suggested fitting diesel engines to river barges. He envisioned the direct shipment of oil through a 1,800-mile route from the lower Volga to Saint Petersburg and Finland. Since the canals of the Volga–Baltic waterway dictated the use of relatively small barges, steam engines were uneconomical and the diesel engine thus seemed a natural choice.

Up to this time, although diesel engines were reliable enough to be used for ship propulsion, they were still not reversible. Hagelin believed that reversing the engine and regulating its speed could be done with electrical transmission, and contracted Swedish ASEA (the A in ABB after a merger between Asea and Brown Boveri in 1988) to test the electrical drive system. Hagelin then recruited naval architect Johnny Johnson of Gothenburg to design the ship. *Vandal* was built at Sormovo shipyard in Nizhny Novgorod and then towed to Saint Petersburg for final assembly.

An old drawing showing *Vandal* on the Volga river.



The ship started operation in the spring of 1903 and served on the Volga route for 10 years. The rest is history: power electronics made it possible to fully utilize the “power station” concept. The Finnish coastal defence ships *Ilmarinen* and *Väinämöinen* built in 1928-29 were among the first surface ships to use diesel-electric transmission. Today cruise ships and icebreakers use Azipod® thrusters powered by electricity that is produced by an onboard diesel engine.

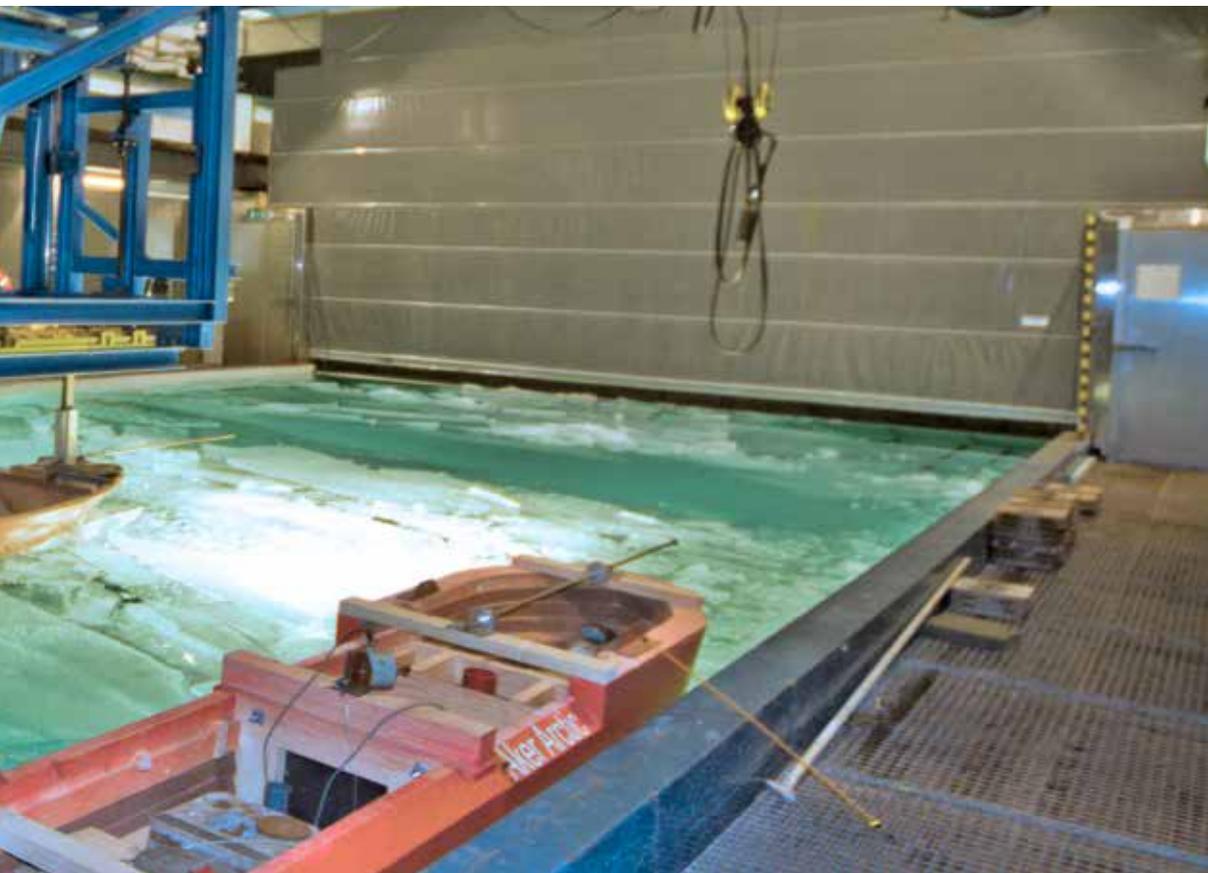
ABB was the first to use this technology, whose roots date back to the historic building of *Vandal* in 1903.

**Text:** Helen Karlsen



# Accelerated icebreaker development

Imagine a ship owner having the right to refuse to take delivery of a new container vessel if it does not sail at 2 knots in 1.5-meter thick ice. Would anyone guarantee the performance of a new, innovative vessel in advance?



This is not a theoretical example but a real-life situation. Aker Arctic Technology Inc. is probably one-of-a-kind in giving such a guarantee. The owner is Norilsk Nickel, the world's largest exporter of nickel and palladium and in need of an ice-breaking container ship.

As a so-called double acting ship, this type of vessel is designed to lead the way in open water and thin ice, then turn around and proceed astern (backwards) in heavy ice conditions, sucking the ice in under the ship with its Azipod® thrusters. Such ships can operate independently in severe ice conditions without icebreaker assistance, while performing better in open waters compared with traditional ice-breaking vessels.

#### **Confident predictions**

"We are quite confident about our predictions for new vessel designs," says Arto Uuskallio, Sales & Marketing Manager at Aker Arctic Technology. The

organization has a long history in researching and developing maritime ice technologies and a unique set of groundbreaking achievements to go with it.

"Computer simulations estimate how much power a vessel will need to meet specific ice conditions," says Uuskallio, adding that these need to be verified in model testing.

Model testing is done in our ice tank, which is 75 meters long and 8 meters wide, with a water depth of up to 2.1 meters. We can also do tests in Aalto University's ice tank, which is 40 by 40 meters and more suitable for testing maneuverability.

When water is sprayed into the air as a mist during model testing, small water particles freeze and form the model ice layer by layer when they land on the water surface, explains Uuskallio. Temperature control in the room and the salinity of the water give the ice layer its desired strength. When working with a

Oblique icebreaker. Illustration: Arctech helsinki Shipyard



1:25 scale model, everything needs to be kept in line with the scale laws of the test. Even time is scaled; the captain has to make decisions at five times the normal speed.

### Combining models and real-world data

Testing new hull forms and propulsion systems against various ice conditions in a computer model or a scale model is just part of the job for Aker Arctic, which analyzes the trade pattern of the vessel and the possible variations in ice conditions to arrive at the right design.

“We do our own ice research in the field and collect data from a large pool of vessels in operation to verify our models,” says Uuskallio.

He emphasizes the importance of understanding the correlation between model-scale predictions and real-life experience. Long-term measurements to determine how the fleet of a vessel is performing is also important because rubble, ridges and different kinds of ice formations at sea always differ from standard test conditions in the lab.

### Exporting through ice

Aker Arctic is located in Finland, bordering Russia and Norway – the world’s two largest exporters of natural gas, and the second and sixth biggest exporters of oil, respectively. Finnish shipyards have also built about 60 percent of the world’s icebreaker fleet.

Because of climate change and the development of Arctic oil and gas resources, the idea of a possible seaway opening up that connects the Atlantic and the Pacific does not seem as distant now as when it was first put forward by the Russian diplomat and philologist Dmitry Gerasimov in 1525.

The recent developments in Arctic shipping means that double-acting vessels, such as ice-breaking tankers and container ships, can operate year-round without waiting for assistance from specialized icebreakers.

Not only do the extremely harsh ice conditions of the Arctic create a need for new icebreakers, but environmental regulations and energy efficiency requirements also demand new solutions. In particular, increasing oil shipments through the Gulf of Finland are spurring new developments for uninterrupted and environmentally safe oil transport.

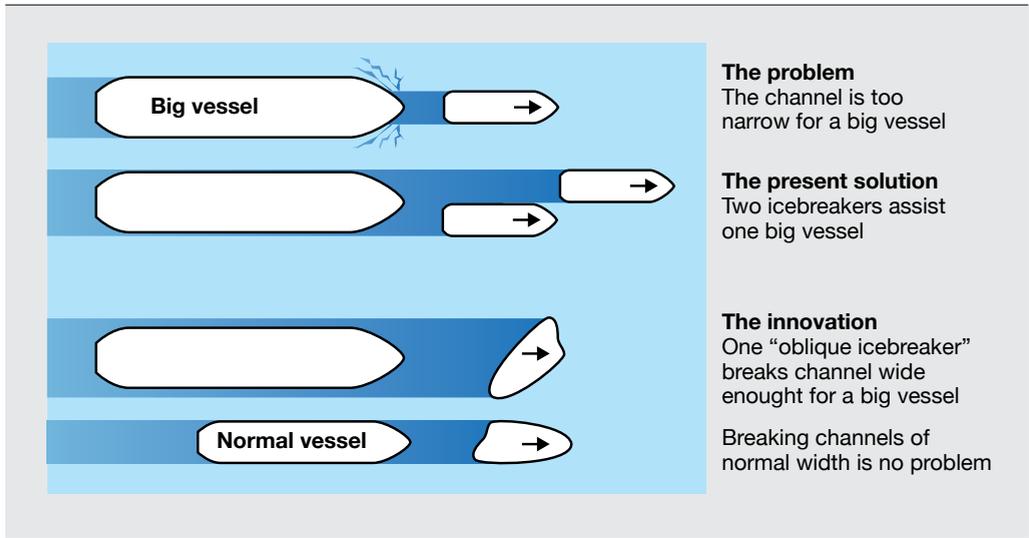
The Aker Arctic ice lab test models in scale 1:25



The ice tank is 75 meters long and 8 meters wide, with a water depth of up to 2.1 meters.



The "oblique icebreaker" goes sideways to do the job of two conventional icebreakers.



### Icebreakers on oil-spill recovery missions

The Finnish Transport Agency recently contracted Aker Arctic Technology to design a new icebreaker for the Finnish government. It will be equipped for oil-spill response operations at wave heights of up to 2 meters and will include tanks and heating capacities that can handle at least 1,500 cubic meters of recovered oil.

Aker Arctic is far from the only ice model test facility in the world, but its research and testing capabilities combined with its design and engineering expertise is hard to match. By combining all disciplines needed to develop new ice-breaking vessels time-to-market is shortened.

### The oblique icebreaker concept

A new design that stands out as a big leap forward is Aker Arctic's oblique icebreaker, a special type of icebreaker designed to operate not only ahead and astern, but also obliquely (sideways).

Ships are rarely asymmetric, but this one is – for good reason. Whereas, in the past, a second icebreaker was needed to break a channel for large ships, the oblique icebreaker now goes sideways to clear a channel wide enough for tankers and other large ships. This takes the already well-known double-acting ice-breaking method one step further by making the ship capable of breaking an ice channel 50 meters wide as it moves ahead with its side first.

Scan the code to watch a video interview with Arto Uuskallio



Not only can this small ship do the job of two conventional icebreakers, but it can also carry out emergency towing, oil-spill recovery missions, firefighting and ecological monitoring in between performing ice-breaking operations.

Text: Johs Ensby





# Simulation – the new norm?

In the not-too-distant future, those who buy a new vessel will be obliged to buy the simulator training to go with it. “It’s not standard yet, but it will be,” predicts Captain Magnus Winberg, senior lecturer at Aboa Mare Simulation Centre in Espoo, Finland.

Seeing the vital and growing role of simulator training first hand is one of the perks of his job. Another is trying out new vessels – like the world’s first large-scale cruise ferry to be powered by LNG, the *MS Viking Grace*.

The vessel was delivered to her owners in January this year shortly after Winberg had tried out a simulated version of her. He likes to joke that he was “the second man in history to drive her.” Unfortunately a fellow instructor beat him to being first.

When he is not facilitating simulator training for captains of large cruise ships, cargo vessels or small ferries – or even for leisure-time boaters – Winberg may be sharing his expertise with colleagues in other parts of the world.



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## The simulator is not a PlayStation.

“Last year I was at the Maritime Institute in Quebec training their instructors in ice navigation. They had just bought simulator software but were not trained to use the ice navigation module so they subcontracted us to deliver the training,” he says.

Ice navigation is a specialty at Aboa Mare, as is energy-efficient operations, as well as Azipod® training, conducted in partnership with ABB Marine. Testing out big guns like the *Viking Grace* might sound like every schoolboy’s dream, but “the simulator is not a PlayStation,” says Winberg, who believes the role of the instructor is more important.

### Testing out the simulator

*Generations* saw him play out this role during a recent mock training session at Aboa Mare. Led by Captain Dan Wikingsson (see page 53), ABB Technical Specialist in Finland Muhammad Yasir and Eero Lehtovaara, Senior Vice President of ABB’s Marine and Cranes, the crew was to dock at “Port ABB”.

Wikingsson was to be Navigator, with Yasir acting as Co-Navigator and Lehtovaara as Operations Manager. As Winberg explained, this type of simulator training is always done in such groups of three, with each trainee wearing a different colored vest to signify his job.



## Aboa Mare Simulation Center Espoo, Finland

- One of three Aboa Mare maritime training centers in Finland and the Philippines
- Specializes in ice navigation, energy efficient operations, Azipod® training, pilotage training and examination
- Partnerships with ABB Marine, Wärtsilä , Deltamarin, NAPA, Eniram, Germanischer Lloyd, Aker Arctic and more
- Training for maritime students, shipping companies, pilots, sea rescuers
- Caters for many vessel types, such as large cruise ships, cargo vessels, smaller domestic vessels and boats

But before the “crew” got down to business on the simulator, there was a briefing session in the classroom. Winberg told them they were to enter Port ABB, turn the ship around using maximum transversal thrust while controlling the pivot point, speed and rate of return. They were to maintain constant positive RPM (revolutions per minute) throughout.

Although Port ABB does not exist in reality, at Aboa Mare there are 90 digitized versions of ports that do. Trainees can navigate these on three generic bridge simulators at the centre in Espoo. At the main academy in Turku, there are eight bridges of specific vessels, such as the *Viking Grace*.

While the trio fiddled with the dials and eyed the surroundings through the “windows” of their generic bridge, Winberg turned on fog, rain and wind. He also dispatched a tug to help us after a simulated technical failure. Despite the fact that they weren’t moving, some of the crew felt seasick – apparently a trick of the mind.

In the debriefing room, Wikingsson had this to say: “It took me about five minutes to get familiar with the controls and movements, then it was business as usual. It’s that close to real life.”

“When you first go into a simulator, you focus on the views and the graphics. Is the crane in the right place, is the house painted the right color, does that seagull look realistic? When you have done a few simulator

runs, your focus moves to whether or not it feels right. A few minutes into this exercise, I felt it did.”

So did Winberg. He filed the details of Wikingsson’s maneuver to show students what a turn by an experienced captain looks like. If his prediction about simulation for all new vessel types comes true, who knows how many students may end up seeing Wikingsson’s expert maneuver.

**Text:** Helen Karlsen

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For technical insight into ABB’s Intelligent Maneuvering Interface, see page 124; see also page 144.



# Nordic know-how

Successful teamwork on the bridge is essential for safe shipping. According to two Finnish captains with a wealth of experience between them, a crew works well under the Nordic management model.

Earlier this year *The Economist* ran a 14-page report titled “Why the world should look at the Nordic countries”. Among the success factors it examined was the flat management model that companies use in these countries.

“In Scandinavia, companies manage with goals and values rather than control and strict chains of command,” the report said, adding that: “They pride themselves on their flat structures and democratic ways, which they feel promote trust and cooperation.”

“Swedish and Finnish crew have been using that model for years. It’s slowly spreading throughout the shipping world,” says Captain Magnus Winberg, senior lecturer at Aboa Mare Simulation Center in Espoo, Finland.

Captain Dan Wikingsson, currently MD of Salen Ship Management, agrees. “On most vessels the hierarchy is still strictly maintained, it’s certainly not a democratic environment. When things go wrong, it’s important to have one person ultimately in charge. But it’s a fine balance. A dictator-style management comes at a risk. A modern captain focuses on teamwork. You can’t have a one-man show anymore.”

Wikingsson is convinced that tragedies caused by human error, such as the *Costa Concordia* accident off Italy last year, are less likely if three factors are strictly implemented at all company levels: proper assessment, training and uniform procedures.

“I think it’s far too easy to make one individual, the captain, the scapegoat for what led to the *Costa Concordia* disaster. It’s the responsibility of the company’s management to maintain a healthy, safety-conscious culture and that senior staff are trained, audited and fit for their duties,” he says.

He says the best company culture he has experienced was that of Malaysian-based Star Cruises, established in 1993 after it bought two Finnish ferries *Kalypso* and *Athena*, which then became *Star Pisces* and *Star Aquarius* respectively.

“The crew of those two ferries brought a Nordic management culture with them. At the time, although well established in Scandinavia, the new company thought the consensus-based approach was novel. Star Cruises went on to become very successful,” says Wikingsson. So what makes for successful teamwork on the bridge?

The February edition of *The Economist* that urged readers to look at the Nordic model



“Every person in a bridge team must be fully trained and fit for their tasks and duties. Training and knowledge build confidence. It’s also important to have the tasks distributed according to a plan so that every member of a team knows exactly what is expected of them. This allows them to prepare before operations

“At the same time, team members must be cross-trained and familiar with the duties of the other team members. It’s like a football team, where everyone knows their position, what they are supposed to do and what everyone else is supposed to do,” says Wikingson.

Winberg agrees, adding that: “Human resource management is now considered so important that the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) has made courses in this subject mandatory.

“You can have the best equipment, but if your organization doesn’t work, it’s no good. Better to have slightly older equipment and good management. It’s not the machines that matter, it’s the people,” adds Winberg.

**Text:** Helen Karlson





# Taking risks to stay safe

Forget disasters and surprise events. The safety side of simulator training is all about testing the limits. So says veteran mariner Captain Dan Wikingsson. He spoke to *Generations* at Aboa Mare Simulation Center in Finland.

"It's a waste of time trying to get people to run aground on a simulator. That's just not educational," says former Norwegian Cruise Line (NCL) captain, and current Managing Director of Salen Ship Management, Dan Wikingsson.

"It's about assessing situations and building confidence. On a simulator you can try out things you wouldn't normally do. It's much safer to do that with an instructor than out there at a port."

He should know. With over 30 years' experience as a captain of both cargo and cruise vessels, Wikingsson has clocked up his fair share of hours on simulators around the world.

"Simulator training is so vital that you wonder how on earth people used to manage without it. With the



## Captain Dan Wikingsson

- Managing Director of Gothenberg-based Salen Ship Management
- Captain on cargo and cruise vessels for over 30 years
- Worked for Star Cruises and Norwegian Cruise Line (NCL)
- Helped build NCL's largest cruise ship Norwegian Epic at STX Europe's Chantiers de l'Atlantique shipyard in Saint-Nazaire, France
- Part of site team that built the Superstar Leo, Superstar Virgo and Norwegian Star for Star Cruises at Meyer Werft's Papenburg shipyard in Germany

simulator, the possibilities are so wide. For the sake of safety, you have to understand those possibilities and know what the borders are.

"In real life you can't push those borders because it's too risky, but on the simulator you might find a way to maneuver more safely or even more fuel efficiently," says Wikingsson.

When he worked for NCL, simulator training was standard practice if a ship changed itinerary. Navigators would be sent to a training center in Miami to practice moving in and out of new or challenging ports.

"When you're approaching a port with 2,700 passengers on board and about 1,700 people at the port, it's vital to know the limits. If, for some reason – be it wind, weather, the environment or current – you judge that you can't enter a port without huge risk to lives, then you might have to wait six or seven hours for a tugboat.

"Those are the tricky decisions for a captain. If you have been on a simulator, you will have realized you



can do it at this wind speed but not beyond. That gives you the confidence to say: 'Sorry, we can't do this'."

### **Azipod® simulator training**

Wikingsson's career included three years at Meyer Werft's Papenburg shipyard in Germany. As staff captain for Star Cruises, he was part of the newbuilding site team that delivered vessels in the late-1990s and early-2000s. During this time, he helped build the cruise ships Superstar Virgo, Superstar Leo and Norwegian Star.

"A week's Azipod® simulator training at the Danish Maritime Institute (DMI) in Copenhagen was included with each delivery from ABB. The training had two aims: familiarization with Azipod® maneuvering and with ports," says Wikingsson.

"The DMI took our itinerary, went to all the ports we would go to with the new ship and digitized them. Those are the most relevant courses I've done on a simulator," says Wikingsson.

"The reason why simulator training was started for Azipods was because when people started running these ships, they didn't do it properly. It's like jumping from a bicycle to a unicycle. You have to unlearn and relearn a lot of stuff. Like any advanced tool, it takes time to learn and practice," he says.

As for the quality of simulator training, he says: "It depends on who is running it, its technical capabilities and how accurate the computer model of the ship is. "If the simulator leader tells you to enter a port with, say, 12 meters of wind force from a certain direction, you need to have an accurate numeric model of the ship and the force. That's how you get a grip on the limits of what you can do."

**Text:** Helen Karlsen

# Training ups availability

With ABB Marine Academy training, operators become more proactive in operating and maintaining equipment, which result in increased availability. One of the aims of the training is to reduce surprises and improve the operator's ability to handle them.

**S**hips are built and used to achieve tasks such as transportation. Maximum availability of a vessel's installations is therefore crucial for successfully completing these tasks. While availability is linked to profitability, its major driver will always be safety.

According to DNV, "studies show that 80 to 90 percent of accidents are caused directly by human error and that 60 percent of these are related to poor situational awareness." Situational awareness is described as "what you need to know not to be surprised." (Jeannot, Kelly, & Thompson, 2003).

## Regulatory environment

While "type specific" training is common in the aviation industry, and even mandatory, it is virtually absent in the maritime industry. International regulations that define the training requirements of deck, engine and electro-technical officers and crew are, by their very nature, generic.

Traditionally, original equipment manufacturer (OEM) training familiarizes customers with the OEM's products and is generally classroom-based, with some practical maintenance or operational tasks being demonstrated.

## ABB Marine Academy

The ABB Marine Academy in Helsinki was established in 2005 as part of the ABB Marine Service portfolio to provide specific training in ABB products. Since then, the academy has opened branches in Singapore, Rotterdam, Ulsteinvik, Genoa and Houston.

Besides providing technical product information, Marine Academy courses deliver system-wide knowledge to give a holistic view of the ship as a system, rather than a group of products bolted inside a hull.

## Training standards

The IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) was originally signed in 1978 and was then significantly amended in 1995 and 2010. This is the primary document that defines the minimum general training standards for all masters, officers and watchkeeping personnel on board ships. However, the International Convention for the Safety of Life at Sea (SOLAS) also specifies training requirements by vessel type, particularly in Chapter IX, also known as the International Safety Management Code.

Regional (such as European Union), Flag State or port specific regulations may also be applicable to certain vessels. While compliance with these regulations is



the primary responsibility of the owner or operator, ABB Marine continually reviews and adjusts its training to ensure that courses stay relevant.

Starting in 2011, ABB Marine Academy training courses have been aligned with the latest STCW standards to provide the right information to the right personnel on board.

### **Outcome-based education**

The STCW defines outcomes of training rather than specific training. By focusing on outcomes, rather than individual products, the Marine Academy is able to adjust “standard courses” to suit customer requirements so that instructors can address the specific needs of learners. Recognizing that every learner is different, instructors may need to use different training methods to achieve the same outcomes with different courses.

The academy also helps customers develop learning paths, starting with basic safety courses, through product courses (if required), and ultimately high-level system-wide courses.

### **Responding to new technologies**

Many consider marine industries slow to adopt

innovations. In reality there has been a huge change in maritime technologies and the complexity of its installations. As more shipping segments adopt diesel-based electric propulsion, an increasing number of vessels now operate a High Voltage (HV) plant<sup>1</sup>.

While there is no denying the benefits of HV, which are beyond the scope of this article, it does carry different risks compared with low voltage plants. These risks must be identified, understood and mitigated.

The ABB Marine High Voltage safety course has been offered since the Marine Academy’s inception in 2005. This course has attained certification with DNV and the Norwegian Maritime Directorate. After its initial certification in Helsinki, the course has been held at all branches of the Marine Academy that are located near maritime hubs.

### **New training requirements**

However, the STCW has now, for the first time, specified Marine High Voltage training for marine engineers as well as for a new certified position of Electro-technology Officer.

From July 1, 2013, management level officers (Second Engineers and above) with UK Certificates of



Competency in Marine Engineering will be required to take an approved High Voltage course covering, as a minimum, the following topics:

- Following functional, operational and safety requirements for a marine high-voltage system
- Assigning suitably qualified personnel to carry out maintenance and repair of various types of high-voltage switchgear
- Taking necessary remedial action during faults in a high-voltage system
- Producing a switching strategy for isolating components of a high-voltage system
- Selecting a suitable apparatus for isolation and testing of high-voltage equipment
- Carrying out a switching and isolation procedure on a marine high-voltage system, complete with safety documentation
- Performing insulation resistance and polarization index tests on high-voltage equipment

Engineers who do not complete this course prior to their next revalidation will see the following statement on their Certificate of Competence: "From 1 January 2017 this certificate is not valid for service on ships fitted with High Voltage (over 1000V) systems."

Other National Authorities are also likely to enforce the new STCW requirements for High Voltage Safety training in a similar manner. As a result, the ABB Marine Academy is upgrading its current training to meet the UK's present requirements and is seeking Maritime and Coastguard Agency (MCA) approval for ABB's HV safety training.

### Improving quality

The certification process means ABB must be critical of its current training. At all of the academy locations, ABB collects feedback in a process known as eCROL. Collecting student and instructor feedback in a database allows the academy to see what is and is not working according to the type of course and location and to respond quickly when expectations are not met. This information can also be shared with customers, making the training process transparent and ensuring that the Marine Academy delivers on its promises.

For example, ABB was particularly concerned about the high level of theory in the High Voltage safety course. As part of the MCA certification process, certified HV Safety trainers from all over the world have been able to share their experiences and resources to

increase the non-theoretical aspect of the course to 50 percent. Using case studies, practical exercises, role-playing and other active training methods, the trainers now have a portfolio of dynamic training tools to achieve objectives.

In order to have a particular training center certified for HV safety certain training material is required; for example, HV switchboard, protection relays, defined safety and grounding equipment. Building up this knowledge in a secure environment through multiple learning methods and an outcome-based teaching method reduces the “surprise factor”.

### Regulatory environment

Given the ongoing tightening of the maritime regulatory environment for both personnel and equipment, it is vital that ship and shore staff receive training that is relevant, extensive and efficiently conveyed. Marine High Voltage safety training is therefore not the only training offered at ABB Marine Academy – it is constantly looking at ways of improving. Merely gaining certification will never be sufficient.

What differentiates ABB training from that offered by other marine vendors is access to technology specialists and facilities. Course participants are able to visit ABB feeder factories or workshops and ask a team of technical specialists questions that are answered during the training sessions. ABB also understands that people are participating in courses during their vacation time, meaning they and the trainers must be motivated to use this time optimally.

### Working with customers

By working with its customers, ABB supports not only the HR function within a shipping company, but the safety function as well. Under the International Safety Code, companies must meet several requirements with respect to training and, subsequently, availability:

“The Company should establish and maintain procedures for identifying any training which may be required in support of the safety management system and ensure that such training is provided for all personnel concerned.

“The Company should establish procedures for the preparation of plans and instructions, including checklists as appropriate, for key shipboard operations concerning the safety of the ship and the prevention of pollution. The various tasks involved should be defined and assigned to qualified personnel.”

Marine technology will always evolve. With more regulatory requirements being laid down to increase energy efficiency, system redundancies for safe return to port, and increasing operational expenses, owner-operators must ensure a vessel is continually available and able to carry out its tasks. Failure to do so could result in not only financial penalties but potentially catastrophic consequences for the environment and/or human life.

### The human element

The human element in shipboard operation will remain a major contributing factor for the foreseeable future. As human beings, we make mistakes. We lose situational awareness when overloaded or placed in unfamiliar situations and are then surprised when an incident or near miss occurs.

ABB Marine Academy can equip crew with the tools they need to be able to make informed decisions during operations and to plan and execute more effective maintenance that is timed to minimize disruption to the vessel's operation.

As the public spotlight focuses more on the shipping sector, pressure will also be placed on companies and their crews to reduce marine incidents. Ignorance of equipment and systems will no longer be tolerated by Port and Flag States.

As management guru Peter Drucker said in the 1950s, “If you think training is expensive, try ignorance.”

**Text:** Palemia Field

**Photos:** ABB

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1- Marine High Voltage is defined as a system where voltage is generated and/ or transformed to and distributed over 1000VACd.





# Remote but never far away

Being woken at midnight to talk to crew on board a ship at sea is not unusual for Stian Braastad. He tells *Generations* about his work as an ABB remote engineer.

**T**ravelling the world for six years as an ABB service engineer was the perfect ground for his present job at the Remote Diagnostic Service (RDS) facility in Billingstad, Norway, says Stian.

Besides the valuable technical knowledge he gained being on board ships 250 days of the year, be it in China or Egypt, Canada or Dubai, Stian learnt to interact with crew from all corners of the globe. During this period he also spent 18 months commissioning newbuilds at Korean shipyards.

“In the RDS center today, I can talk to a Norwegian who has been sailing the North Sea for 30 years, then an Indian electrician on an LNG tanker en route from Singapore to South Africa.



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## There is always one engineer on duty at any time of the night or day.

“It’s important to understand the mentality of who you are speaking with. I have to be good with people and open to all cultures. It’s part of my job,” says Stian.

Also part of his job, is being woken in the middle of the night to sort out problems in far-flung places. “I know that I can expect a call at any time if it’s my week to be on duty,” he says.

“When you have the duty phone, the typical week is different, especially after hours. Quite a lot of calls come from vessels in Norway, Brazil and West Africa. We get everything from serious technical problems to requests for information, such as manuals or maintenance advice.

“I’m often called late at night, when I have to respond immediately. Typically, the customer calls me, then I ask for information via e-mail and a short description of the problem. By the time I get this, I’m wide awake.”

Since the RDS guarantees a one-hour response time, there is always one engineer on duty at any time of the night or day. Last year Stian was even on call during the Christmas holiday week.

When he's not on stand-by, Stian's typical workday takes place in front of the computer screens at the RDS center. But this is no routine office job. He might have to respond to an urgent alarm or sort out a critical failure on a vessel at any time.

"The day-to-day work involves answering support requests via a state-of-the-art ticket management system on one of the screens. Most of our day is taken with these technical e-mail enquiries. Customers with service contracts get priority.

"But from time to time we have to give urgent support to vessels with RDS on board. They contact us on the 24/7 hotline. We ask for information, then log on to the vessel as soon as possible. Then we initiate a remote connection.

"When we are online with the vessel, we can chat with the crew, including the chief engineer and electrician. We can see what they see. We go through the event list, the fault list and try to find the root cause of the problem. Then we'll tell the crew to, say, replace a component or do a measurement."

When the RDS centre gets a technical enquiry through the 24/7 system, the system automatically connects to the right vessel.

"Our system will pick up the ABB installed base on board so we already know what ABB equipment is there. We can find the fault based on that information. A lot of these processes are automated so we can do this in a safe, fast way."

Another important part of a remote engineer's day is reporting.

"This is a big part of our job. We constantly monitor the equipment on board and this data is collected and stored locally," he says.

The team also gets fault messages and events data automatically transferred from vessels. If a propulsion drive trips, for example, an alarm goes off at the RDS control center, almost even before the customer knows about it.

"On some vessels maybe the cargo pump or one of the drilling drives from a mud pump has tripped. Or maybe there is even a planned shutdown from the crew. We see that something has happened and we can expect to get a call or e-mail," says Stian.

All the RDS sites are monitored automatically, so there's a 'heartbeat' from the computer on board to the RDS server. The monitoring of this Internet connection between ABB and the vessel is critical.

If the 'heartbeat' stops, the scene is like that in a hospital. An alarm goes off and engineers race around like doctors with a critical patient.

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We constantly monitor the equipment on board and this data is collected and stored locally.

"It's crucial to our customers that we have one hundred per cent uptime on the remote connection. If they have a problem, they expect us to go online as soon as possible, so we don't want to waste time troubleshooting the remote connection," he explains. So, while Stian's job title may say he's remote, he's really only a heartbeat away. No matter where in the world you are.

**Text:** Helen Karlsen

**Photo:** Johs Ensby

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For technical insight see *Remote Diagnostic Services - always on board* on page 136





# First steps for high-tech wonder child

Born five years ago, ABB's remote diagnostics service (RDS) is still in its infancy. But this brainchild of service technology is growing fast – and its future looks bright.

A new control center in Norway and RDS connections being fitted to vessels still in the yards are among the first steps ABB Marine's high-tech service technology has taken.

RDS is one in a range of global ABB remote solutions that moves the quality of after-sales service up a notch. From a control center just outside Oslo, systems specialists are available to troubleshoot faults in electrical installations on board ships anywhere in the world.

And for customers who have signed up for 24/7 RDS, engineers are on call around the clock to offer this support. (See also page 61.)

They also help with periodic maintenance and provide continuous monitoring. With the data they collect,

## Tailor-made contracts

RDS is just one element in a total service and operations package. Vessel owners/operators can pick and choose modules from three levels of ABB service contracts.

- Level 1 - Priority support
- Level 2 - Preventive maintenance
- Level 3 - Performance optimization

The Global Service contract, which can include RDS and technical support, allows monitoring of equipment lifecycle and provides a maintenance plan.

## RDS customer portal (under development)

An important part of RDS is its customer portal, where customers can log on to find all the information they need in one place, including:

- Status of ongoing support cases
- Equipment availability
- Maintenance recommendations
- Life-cycle status of equipment
- Service bulletins

these engineers are also developing the capability to tell owners how to improve operations, up availability and reduce maintenance costs.

### Began life on an FPSO

RDS monitors, measures and alerts to faults on vessel thruster systems, propulsion systems, drilling systems, motors, drives and switchgears through to protection relays, instrumentation and automation systems.

Rune Braastad, Vice President of ABB's Marine Services, says the service began as a pilot project on an FPSO in the Gulf of Mexico in 2008: "The owner wanted 100 percent uptime but was operating on the Mexican side of the Gulf, where it was difficult to get service engineers on board. So we offered them the RDS that they're still using today.

"We slowly started to roll it out to other vessel segments. LNG tankers, some of which operate in high-risk areas, are quite big on it now. In the last five years satellite has been a revolution on all vessels from a very simple connection. Now it's standard, even for sailing ships, so connection isn't a problem any more. That's why RDS is more available to any type of ship."

Currently 27 vessels are connected to RDS. From this year, the service is offered on all newbuilds delivered from South Korea and Singapore, covering the entire ABB package on board.

### Worldwide support

But the technical competence isn't limited to Norway. While RDS gives immediate support when a customer calls, a query can be routed to a marine service center closer to the customer. A service engineer may then be dispatched, but often this isn't necessary because the problem is solved from the RDS center.

The team in Norway consists of 14 technical support engineers, but callers can access the resources of 600 ABB personnel around the world.

"Being able to offer a single point of contact is important. Customers don't have time to navigate through the different vendors in the organization to find the right person. They need help there and then.

"This isn't just to minimize downtime but also for safety. Some vessels operate in harsh environments and they don't have much time to act when there's a failure.



“Newbuilds with ABB equipment on board will automatically have this service but the existing fleet could also use it,” says Braastad.

### Looking to the future

A future scenario where remote engineers are alerted to a ship’s problem, before the crew on board knows about it, is not that far-fetched. “We are looking into continuous monitoring and alarms. So, in the future, an engineer on duty could get an alarm on a mobile phone, see the failure, then call the customer. This is already possible.

“Already we detect problems before they happen through our reports. For example, we see pressure drops in the internal cooling system of propulsion drives by looking at the trend for the last three months,” says Braastad.

But the future of RDS as a bigger team being more available to more ships doesn’t end there. It could alter the investment case for a new vessel by assuming more of the risk for the ship to be profitable. “We are not there yet,” says Braastad, “but we’re moving in that direction. As we go, we’ll gather more

and more information. Then we’ll be able to calculate risk based on historical data.”

RDS also has the potential to move from technical to commercial management. “We get a lot of valuable information that we can use to give advice about operations,” says Braastad.

All of this is not bad going for a five-year-old. It’s clear this 21st century whiz kid is going places. (See also page 71).

**Text:** Helen Karlsen

**Photo:** Johs Ensby

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For technical insight see *Remote Diagnostic Service - always on board* on page 136.

# Hand in hand with the crew

As systems on board become more complex, owner-operators struggle to find crew with the right skills. But Remote Diagnostic Service (RDS) may lessen the need for specialists on board, turning crew into competent all-rounders instead.

**W**ith crew costs one of the highest expenses in the maritime sector, it makes good business sense to have a team of generalists on board who can access specialists 24/7.

But does this lead to a passive crew who merely wait for a call from the RDS center? Far from it, says Rune Braastad, Vice President Marine Services at ABB: “We don’t take responsibility away from the crew and we don’t do anything in the remote center that they usually do on board. Rather, we help the crew maintain their competence.”

“Let’s take the example of a complex failure on a propulsion drive. Before we had RDS, we sent an engineer on board to fix it. Now we help the crew to do it via the remote link.

“After analyzing data, we tell them a component might have failed and could they please go and measure and verify this. They will go and trace the fault. So, in this way, we educate the crew,” says Braastad.

## Chat function

With so many different nationalities working on board vessels, this interaction is usually in English. The chat

function on RDS often makes communication easier when the phone connection is bad or accents are hard to understand.

The crew use chat to describe their problems in writing and the engineers at the RDS center use it to write down a procedure for the crew to carry out.

“We can even follow on the remote link and see what they’re doing. We can tell them to do certain tests and then monitor and guide them through. They can do tasks that the service engineer used to do but with a long delay and at high cost,” says Braastad.

The RDS team does not do any remote changes to the vessel. Its function is purely one of monitoring.

## Increasing complexity

“Vendors in several segments have RDS where they sit in an operational system and they do the changes on board. When we started developing our RDS, a few customers we spoke to said it was risky to have things changed remotely,” says Braastad.

One example came from a customer in Brazil whose supplier went online to upgrade a drilling system without informing the crew. Major problems ensued



when measurements were changed from metric to imperial.

Because systems are becoming more complex and integrated, sometimes it's difficult for crew to see where there is a failure.

"Is it on the propulsion drive, on the power system, in the automation system? By combining RDS for all the systems, we can see what happened. All systems are time stamped against each other so we can see exactly where the fault has occurred. A failure in the power system might cause a failure in other systems," says Braastad.

"I think the other advantage of RDS is that it really connects us to the customer. We developed this service with the clear goal of becoming a partner for the customer. We usually know the name of the electrician on board and vice versa."

### Pin pointing faults

Braastad adds that the role of RDS is "to keep what ABB has promised – to make sure we have people available and that we are capable of handling any situation professionally. It's a question of managing the customer's risks."

Since the RDS is directly connected to the component level of the equipment on board, engineers can fault trace down to a single component.

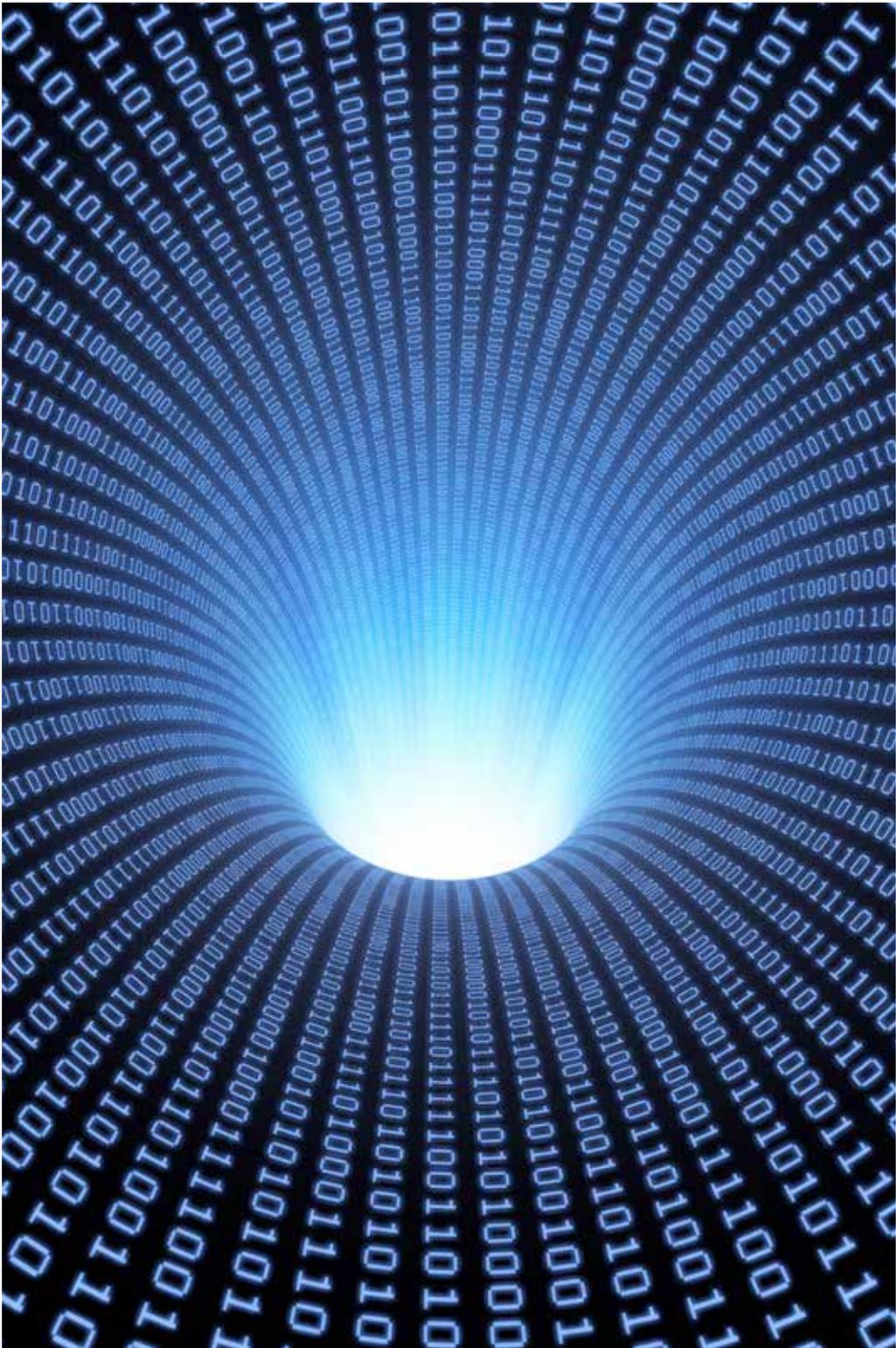
"People tend to think of RDS as being similar to the automation or HMI [Human-Machine Interface] systems on board, which give slow, general information about power trends. But we get high-resolution data showing events, alarms, faults and data loggers," says Braastad.

According to him, this is the big difference between ABB's RDS and those of other vendors. "They just have a remote computer reading the automations. In our view, that's not RDS. It's a remote system but not a diagnostic system. We are at a much more basic level; we can pinpoint problems on a component level."

It seems this RDS is as much about being tuned into the crew as it is about being plugged into the nuts and bolts of the system; in other words, getting right down to basics.

**Text:** Helen Karlsen

**Photo:** Rune Braastad



# Priceless data

One spinoff of remote diagnostics service (RDS) is the valuable historical data the system collects. Class societies, manufacturers and other shipping players will all want a piece of this wealth of information.

It could also change the face of equipment maintenance and mandatory surveys. That is because the need for upkeep can be based on the actual condition of machinery, gleaned from continuous monitoring, rather than on the traditional timeline.

“While customers may have a fixed schedule of doing maintenance, say every six months, we tell them we recommend you do these tasks now, based on what the data tell us,” says Rune Braastad, Vice President of ABB’s Marine Services.

He adds that ABB has “started to talk with the class societies about how we can use our system to prolong the operation of certain equipment. Customers are asking us to do this. So, maybe you don’t need to do maintenance on a thruster after the usual five years, but after seven, according to its condition,” says Braastad.

Storing data, in addition to giving technical support, has other advantages for the customer. “If they want to know the history in 10 years’ time, we can give them the full fault history. Because we log everything and store it all in the database, we can detect failures in the system early – over a whole fleet,” he says.

## Benefits passed to manufacturers

With RDS, data from all the connected equipment on board can be stored on the vessel for up to two years. When a failure occurs, the engineers can go back to this data to see when a failure mode started and what recent modifications could have caused it.

“Then we can tell a customer they might need to upgrade certain components in the system. They have time to put this into budgets, to plan the service,” says Braastad.

But customers aren’t the only ones to benefit from this treasure trove of data. Some information is already being passed on to manufacturers. “We see, for example, that a component fails say every second year. We can get this info almost popping up in our system. Then we have to do some research to see why it is failing. It is much easier when you have a centralized bank of data,” says Braastad.

Like his colleagues at RDS, he knows that when you’re sitting on a pile of riches this big, you don’t keep it to yourself.

**Text:** Helen Karlsen

**Photo:** Shutterstock





# Human factors top priority

Human factors have become a lot more important in the design of HMI (Human Machine Interface) than when Grethe Tausvik entered this field in the 1980s. This Oslo-based consultant tells *Generations* about her work.

**You've been working as an HMI discipline lead at ABB for several years. How did you become involved in this field?**

I started work as a draftswoman back in 1983. The switch was just starting from analogue to digital and to screen graphics for control systems. I worked on the early versions of HMI systems, which were very simple. Then I was recruited to a huge oil platform project in 1986. This was my first real HMI project. From there it spiraled because not many people did this work at the time. It was either technical drafting or engineering. This was sort of in between.

### **What other type of projects have you worked on?**

I've worked mainly in process industries for things like paper, pulp, plastic and oil and gas. I spent time in Canada working on a magnesium plant and with oil terminal projects in India. I've also worked on supply vessels and subsea projects.

### **What has changed in HMI since the 80s?**

Now there is increasing focus on human factors and ergonomics. It's the ambience, chairs, screen, sounds, lighting, keyboard, mouse. This is in part due to rules and standards. Almost all companies now follow ISO 11064, which concentrates a lot on ergonomics. Control rooms also look a lot better nowadays. So human factors have become much more important. Every company has to have a human factors specialist.

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It's my job to make the end user happy – within the boundaries of the system, the guidelines and the rules and regulations.

### **What is important to the operators?**

Unlike a lot of human factor specialists, I have always worked very closely with the users. Every one I've met wants as much information as possible on one display. This gives them an overview. That's not what the human factors people say. For the project I'm working on now, we had system problems because the operators wanted so much information. The display became too heavy for updating so we had to split the information across two screens.

The operators tell me what's relevant and if there is too much information, I suggest ways to filter out small parts, put in other displays, maybe split the display into two. It's my job to make the end user happy – within the boundaries of what is required.

### **How can HMI improve safety and availability?**

The big safety issue in HMI at the moment is the question of alarms. ABB engineers are focusing on making smart alarm systems to prevent operators from being annoyed by unnecessary alarms that follow other alarms. They only need to hear or see the important ones.

Several companies have separate projects to manage their alarms. When they upgrade their plants to new systems, they set aside separate projects to clean up their old alarm system. What almost all plants have now are these large screens that fill the whole wall and reflect mostly only information. Part of that screen is the alarm list and it only shows the key alarms. The screen is dull during normal operation and when something happens you see quickly where and what it is.

### **How do you understand which alarms are important?**

I work with the instrument automation and process engineers. I need to have a good overview of the process, how it works and how it connects to the shutdown systems. The most important safety concerns are fire and gas. Statoil, ConocoPhillips, BP, Elf, they all have their own alarm philosophies, which ABB has to try to fit into its system. When I design the displays or when I design the systems, I try to make the critical parts stand out more than others. The less important parts may even go into separate displays.

### **What is the biggest challenge in designing an HMI?**

To make the user interface as close to the process reality as possible. The engineer makes a technical drawing of the process, which is a simplified version of the process. But that's not what the operators want. They want it to resemble reality. It's a challenge to convert the drawings into user-friendly interfaces.

The whole thing is a team effort. I work with human factors experts, the vendor and the end-users. If it's an upgrade job, then the operators and engineers on site are important to have on the team. They know how it works. If it's a new project, say a new platform engineered from the bottom, we need to add process and instrument engineers to the team. They have designed it, so they know how it should work.

### **Some operators work 12-hours shifts. How do they cope with these long hours in front of screens?**

They have good chairs, a pleasant environment, long breaks, attractive areas to relax in. Their job can be boring. If everything works, there's "nothing to do". That's actually the ideal situation. So then they focus on maintenance or helping staff out in the field. They move around a lot, they talk to each other. It's not supposed to be very stressful. Many operators in oil and gas use the big screen, which gives them an overview of the whole platform. If nothing

is happening, they can find other things to do on their work computers, which are also connected. Even keeping themselves occupied on the Internet is allowed. The days are long and the work extremely important. If they are tired and something happens ... I know I would want an alert operator.

### **What do you like most about your job?**

The challenge of making these complicated customers happy. I try to juggle between the engineers, the users, the system vendor, the bosses and everyone else who has an opinion. In all this, it's always good when the product works for the end user.

Since I have worked with these people so much and for so long, I have got to know them. They are kind of the same type of people. I know all their quirks. That's a good part of the job.

### **What do you like least about it?**

Sometimes the teams can be too big and there are too many opinions. Eventually we end up with what just a few of us said in the beginning. I can see the need for following company and other standards but sometimes the standards are interpreted too literally. I like to keep things simple.

### **What is the future of HMI?**

It's getting more remotely operated and automated. Instead of having the operator pressing things in a sequence, we are moving towards pressing just one start button. Control systems are getting more sophisticated and we can program sequences of the process to act as they are designed to.

One way to rationalize offshore operators is to move part of the control offshore, like BP did with the operation of their wells. They have a control room on the top floor of their building in Stavanger. There they can work closely with the geologists and the people who plan operations. They sit onshore anyway. That's one way of reducing costs. Also, on their new platform, the process is more or less automated so it's less operational and more a case of monitoring. But then the job can become boring.

So I'm not so sure it's a good idea to move from the operator doing the work to just monitoring the process. When we upgrade systems there are new sets of rules and regulations that come in. Sometimes the operators lose some of their previous possibilities. They are not allowed to do certain things any more. They find this very frustrating because they might

have done it for 20 years. They feel that their expertise doesn't count for anything.

### **What other trends do you see?**

One of the trends that is coming is to have what we call integrated operations, where other systems, such as maintenance systems, are tightly connected to the control systems. Instruments and equipment are getting more advanced with their own separate computers attached. So, if a valve starts to get close to its maintenance period, the operator gets a message. Things are getting more and more connected. Now these data communication protocols are standardized, so when a vendor comes in, he can easily plug into the control system.

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I'm not so sure it's a good idea to move from the operator doing the work to just monitoring the process.

Apps for the iPad are also being developed. So you can hook the iPad up to the control system and take it with you to the plant, effectively bringing your operator station with you. In the future it could even be possible to use your phone to hook up to parts of the plant.

**Text:** Helen Karlsen

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For technical insight read about ABB's new user interface on page 119.

# In Control

One of the benefits of being a major solutions provider is the fact that big investments in R&D in one area of expertise can be adapted and used in others. This type of knowledge sharing is a key element in pushing forward technology at ABB.

**T**he Marine and Cranes business unit is poised to take advantage of developments in ABB automation systems that have been used in process industries all over the world for many years. They can be found in sectors such as food, mining, water and waste treatment, power, traffic, oil and gas and more.

Best known is the company's flagship System 800xA Extended Operator Workplace (EOW), which is able to show an entire process plant in fine detail on huge screens. To date ABB has sold almost 200 EOWs.

Besides operator work stations, ABB offers a complete ergonomic control room environment that takes lighting, noise level, traffic, collaboration and even air quality into consideration.

The consolidation of systems and moving operators into a centralized control room is also in the future of the marine environment. ABB's new marine Remote Diagnostic Centre near Oslo (see pages 63 to 73) is a case in point.

As our interview with HMI expert Grethe Tausvik reveals (see page 75), human factors are the top priority in the design of today's control centers.

Constant research is underway at ABB to strive for the most ergonomic operating environments based on an "operator in focus" philosophy. This knowledge base will prove invaluable in the design of control centers for the marine environment.

As Eero Lehtovaara, Senior Vice President BU Marine and Cranes, says: "We are not re-inventing the wheel every time we come up with breakthrough technology, but rather using our expertise to push forward other industries that may benefit from our already-proven solutions.

"Of course, the systems have to adapt to their industry specific solutions, but one of the advantages ABB has over its competitors is its overall knowledge and technology base."

On the next few pages we showcase some of the process industry control rooms that use ABB systems.

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For technical insight see *Process industry automation meets maritime needs* on page 112.



Processes and power systems for the electrification of Anglo American's Grosvenor metallurgical coal mine are controlled from this operator room in Queensland, Australia. Metallurgical coal is a key raw material in steelmaking.



The control room at the Statoil-Hydro Tjeldbergodden methanol plant in Nordmøre, Norway. Warm spillwater from the plant is fed directly to a nearby fish farm. Wind measurements and temperature readings of the spillwater are integrated into the system.

The onshore control room of Norske Shell's Ormen Lange gas processing plant is situated on one of the largest natural gas fields on the Norwegian continental shelf. The well-heads on the ocean floor are connected to the process terminal at Nyhamna near Kristiansund.







Kansas City Power & Light runs its Hawthorne Station 5 from this control room on the Missouri River. This coal-fired unit represents 26 percent of the company's total production capacity.







# Pit stop in the dry dock

Roberto Ongano, project manager for an Azipod® service team, prepares for drydocking in much the same way as a Formula One pit-stop team.

**T**he operation is carefully planned in advance. Every team member knows exactly what to do and everyone is focused on getting the machine back in operation as soon as practically possible. These are the similarities facing a Formula One pit-stop team and an Azipod® team servicing a ship's electric propulsion system. But there are some big differences. First of all, the tasks are much more complicated than changing tires. Secondly, the focus is on cost as much as on quality.

"I think a comparison to the ground crew servicing an airliner is more relevant than the Formula One crew; we have much more in common with the aviation service technicians," argues Ongano. His challenge is to stay competitive in the rough and tough ship repair business, where there is no lack of people offering their services – and at a very good price as well.



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Coordination between each team is essential and any of them could be the bottleneck that delays the ship.

There are certain service tasks a customer would never hand over to non-ABB engineers, but ABB is not even close to being in a monopoly situation. “We have to provide quality services at the right price. Our customers trust the brand and might be willing to pay a little bit more for having the ABB team service the Azipod®, but driver number one in the repair business is cost,” says Ongano. Azipod® service costs have come down compared to 10 years ago, according to Ongano, who attributes this to improved training and tools as well as to cost cutting in logistics.

#### Learning from Airbus

The Azipod® service team has adopted some techniques used by Airbus service technicians in a pilot project. That entails preparing for specific jobs, and all possible repair scenarios, using training and tool kits. There is no time to run around looking for the right piece of equipment; the technician brings with him a toolbox with all the right tools laid out ahead of time.

The safety of passengers, the criticality of keeping the time schedule and the competitiveness of the entire aviation industry apply also to the cruise industry, which accounts for a large chunk of the Azipod® service team’s business. Until the Azipod® unit can be turned on again, the ship cannot leave the repair site.

The technicians responsible for overhauling the propulsion equipment on a cruise ship are under tremendous pressure. But this is even more the case for the person Ongano plans his activities with – the ship’s superintendent who is responsible for coordinating all dry-docking activities.

#### Waiting to get on board

Imagine a cruise ship for 4,000 passengers that has already been marketed as refurbished – tickets have been sold, but cabins and restaurants are still being rebuilt, carpets are being ripped out and replaced, new equipment is being installed, and rewiring and piping is going on. As many as 500 contractors are on site trying to get their job done in just a few days.

Coordination between each team is essential and any of them could be the bottleneck that delays the ship. Servicing the propulsion system used to be one of those tasks that was completed closest to the deadline. That is no longer the case, according to Ongano, who worked on the operator side seven years ago and has seen servicing turn into a highly effective turnkey solution.

## The complete package

“We can move in with as many as 30 men to get the job done in a minimum amount of time,” says Ongano. “Improving from this point on is more a question of improving the process than adding more people.” His crew arrives on site with all the tools and consumables they will need, making them entirely self-sufficient. Ongano has prepared the job in advance and is on site with the ship’s superintendent to avoid any surprises.

“When the service crew arrives they are ready to attack the job not from not day, but from hour one. There is no time for ‘politics’; every man knows what to do, and we work shifts around the clock until it’s done,” says Ongano. The service team agrees on the scope of the work and sequence of tasks in advance to avoid causing any delays or interruptions for other teams under similar pressure to carry out their tasks. In parallel with the actual service work, the needs of the class society must also be served and this of course goes through the ship owner. However, the Azipod® service team ensures documentation and quality controls are taken care of and that they are available throughout the process for any inquiries the class society may have.

## On contract or ad hoc

The more the service team can provide a complete package, the better for the supervisor in charge of the entire operation. Some ship owners have a 5-year or even a 20-year service contract to make sure that the performance of the Azipod® units is entirely ABB’s responsibility. This is especially the case in the cruise industry, where minimizing time in the dry dock is of the essence. On the other hand, the operator of a commercial freight ship might prefer enlisting ad hoc services.

When a ship needs to be in dry dock for a longer period, a smaller Azipod® service team can do the job and even work normal shifts with Saturdays and Sundays off. However, the basic approach is still the same, Ongano says: “The most cost-effective solution is to send in people with the right training and the right tools to do the job well the first time so we don’t have to go back and redo anything later.”

Servicing the Azipods on a cruise ship





# An insider's job

Azipod® technician Markus Leskinen is certified to work inside a podded propulsion unit in case it needs servicing while at sea.

**T**his makes it possible to carry out even extensive tasks like changing bearings while a vessel is at sea, significantly reducing downtime.

Asked whether it is scary to work inside such a narrow space under water, Leskinen replies: “not scary but very hot”.

When temperatures inside the unit can reach 40 to 50 degrees Celcius, it is important to drink lots of water as the work can be heavy and take time. On a job in Turkey, Leskinen says they worked for 12 hours to complete the mission.

To become certified to work inside an Azipod®, he was put through both a health and psychological test.

### Safety first

In addition to making sure that the technician selected for this work is mentally and physically fit for hard work in a very confined space, security measures are also put in place in case the technician runs into problems. Carrying safety belts enable

the technician to be hoisted out of the pod, and he also has a companion – for safety reasons Azipod® technicians always work in pairs.

### Inside the pod

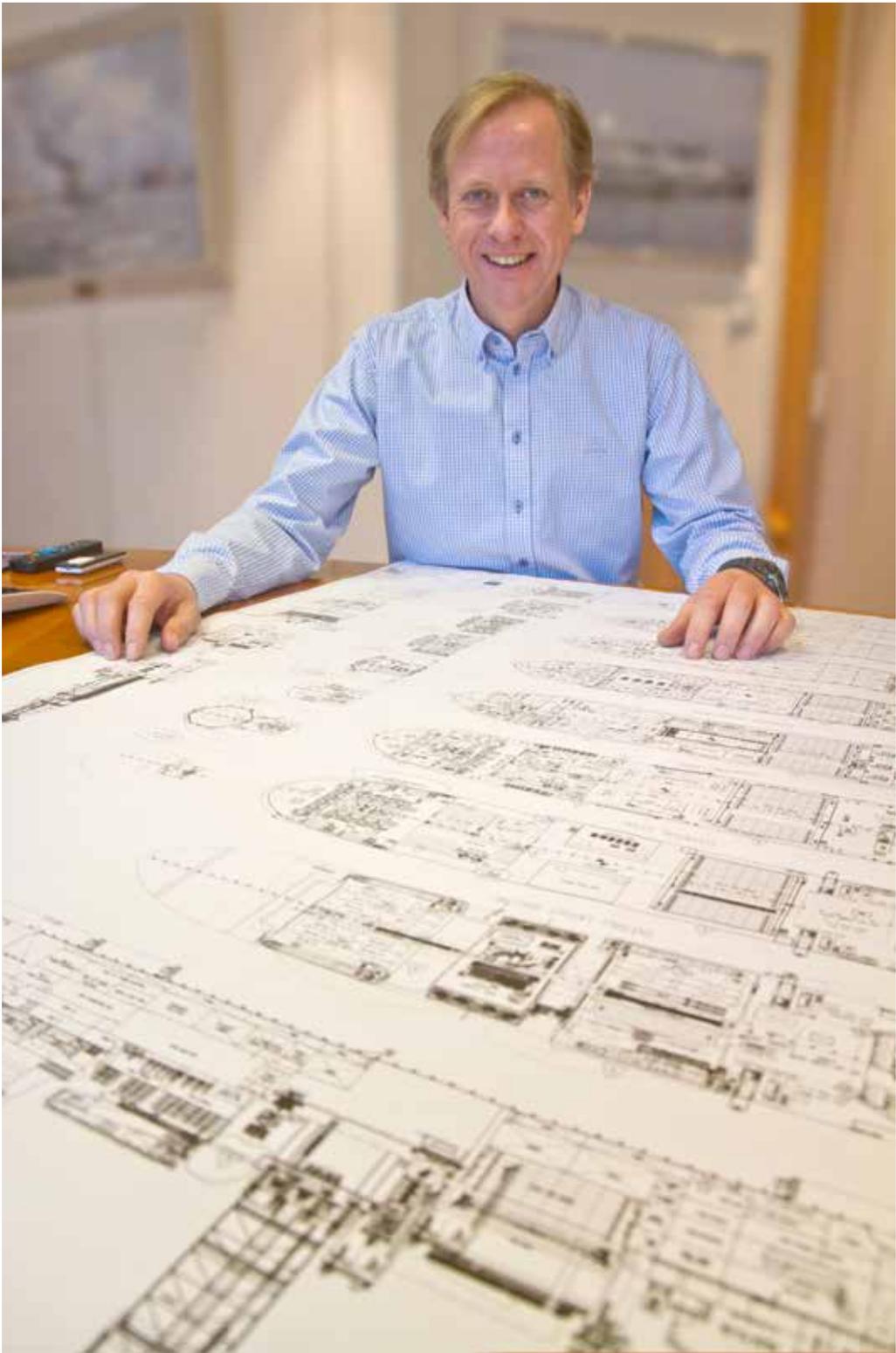
To enable our readers to share the experience, we equipped Leskinen with a helmet camera and sent him inside an Azipod® unit. This time he went into a unit still at the factory with the inspection hatches open.

[Scan the code to follow Markus Leskinen inside the Azipod®](#)





Azipod® XO being built



# Independent and connected

As a technology coordinator for the design of new drillships to be chartered to Brazil's Petrobras, Torger T. Kyvik knows what the key to success is in drillship design – close connections with leading equipment manufacturers.

**K**yvik is the Offshore and Systems Manager at LMG Marin, the design house based in Bergen, Norway that is one of the world's leading independent designers of drillships. Having good connections with major drillship equipment manufacturers around the world is critical for a company involved early on in design. "Our most valuable resource is our network," says Kyvik.

Any engineer can solve detailed engineering, but to solve problems at the concept stage you need to focus on the important things with support from various technology specialists, Kyvik says.

## Introducing bold ideas early

Novel ideas need to be introduced before basic design starts; that is during a conceptual or initial study when there is time to consider solutions that might entail class societies adapting rules to address new technologies.

For a drillship, the main design concerns revolve around position, power and control systems. As an example of recent technological advancement Kyvik points to the so-called "closed bus" in dynamic positioning systems (see page 93).

Petrobras specified these requirements before they were covered by class rules, and designers and equipment manufacturers are now making this a reality to reduce fuel costs. The DP3 system has traditionally been split in a way that could require several engines to run at low loads, while the closed bus system promises more optimal operation with the same level of safety.

## LMG Marin – innovative design and engineering

LMG Marin – one of Europe's leading independent naval architect and maritime engineering companies – has been serving the maritime and offshore industries for more than half a century.

The Bergen, Norway-based company has references from more than 1,000 ships built at yards around the world, including Arctic vessels, offshore vessels, naval vessels, LNG-powered ferries, bulk carriers, tankers and cargo vessels. Some of the company's projects include:

- Navis Explorer (now Belford Dolphin), deepwater drillship built at Samsung
- KNM Svalbard ice-class coast guard vessel
- E39 212 PBE Gas Ferries (21 knots LNG powered ferries)
- Ramform Sovereign, the world's largest seismic vessel built at Aker Yards
- LNG Gas Ferries for Vestfjord built at Remontowa Yard
- FPSO Conversions
- Espadon class drillships

LMG Marin was founded in 1943 by three naval architects – John Lund, Johan Mohr and Karl Giæver-Enger – whose initials formed the basis for the name of the company. From the first decades when the company founded its legacy on reliability, experience and innovation, LMG Marin has since contributed to the development of the modern maritime and offshore industries in Norway.

Espadon class drillship



The closer to the yard a project gets, the less a technology provider can influence its design. While new technology can influence design at an early stage, the makers list at the yard needs to make room for competing suppliers.

### Multi-discipline coordination

Designing drillships is especially challenging because of the various operational modes as well as the wide range of equipment that must be aligned. That means ensuring that interfaces are in place and various control systems are integrated.

“We don’t have detailed knowledge about every system, but we know enough to bring the right people to the table for discussions that need to be taken between the various disciplines,” Kyvik says.

His background is in electro and control systems engineering. Before joining LMG Marin in 1998, he worked with condition monitoring systems for ships. The years when he spent 100 travel days installing systems in cooperation with yards all over the world were invaluable experience, Kyvik says. Learning how people on board ships work and how yards differ in their approaches prepared him for the coordinator role he has now.

Kyvik describes his colleagues in the offshore group of LMG Marin as a very dedicated team with a keen interest in technology. The company’s Managing Director Geir Lasse Kjersem, who came from Oddfjell, initiated their venture into the offshore segment and brought in new ideas based on his experience with drillships with production capabilities used in the North Sea.

### Secrecy versus shared knowledge

While Kyvik points to the company’s open dialogue with multiple stakeholders as crucial to staying up-to-date, he acknowledges that exclusive partnerships

and formal agreements on IP (intellectual property) rights are also needed in some cases.

Partners often offer engineering support and detailed drawings that are not shared widely. However, before a design reaches the yard, a level playing field should be created for the competitors on the makers list. “As a designer, we need to make sure that the design is open for competing suppliers,” Kyvik says.

If an early stage design is based on technology from a specific equipment manufacturer, the decision to go in this direction must be made by the owner the vessel is being designed for. The only way a manufacturer with a unique solution can make it to market ahead of the competition is to influence the ship owner directly.

The challenge, however, is that the engineering and equipment packages that go into a drillship have to a large extent already been formed, making them much harder to alter.

### Clear responsibilities

Three packages have evolved with their own distinct responsibilities: the drilling package, electro and finally DP with automation. In the Brazilian project, a new combination was introduced as the so-called marine package: thrusters, generators, electro and DP. However, Kyvik sees this more as a one-off consortium than a new type of standard package.

These distinctions have their roots in the actual operations of a vessel. Here responsibilities are divided between drilling operations, the well itself, and work that is distributed between the different third parties involved in the various phases of a drilling operation. This distinct set of responsibilities is deeply engrained in the industry; each party specializes and takes a clearly defined role that is well known to the entire market. Earning a position in this market takes long, tough, global efforts.

### Step by step

Given the deeply rooted division of responsibilities and the fierce competition to deliver well-defined equipment packages, it comes as no surprise that improvements usually come incrementally.

The drillship itself is a small part of a much bigger picture, starting with the exploration for oil and gas itself. Whenever a new challenge comes along – like taking on the pre-salt oil reservoirs in Brazil – the specification changes, giving rise to opportunities for new ideas.

## Dynamic positioning – vital to safety

Dynamic positioning (DP) systems are becoming increasingly important to operational safety as offshore activities move into deeper waters and environmentally sensitive areas, and the number of vessels outfitted with such systems is rising as new technologies bring down costs.

These computer-controlled systems minimize fuel consumption and keep a vessel at a defined location or on a pre-determined track against the forces of wind, wave, tide and current by using its own propellers and thrusters. Position reference sensors, wind sensors, motion sensors and gyro compasses provide information on the vessel's position and the magnitude and direction of environmental forces. This information allows the computer to calculate the required steering angle and thruster output for each thruster.

This technology has allowed vessels to operate where mooring or anchoring is not possible because of, for example, deep water or congestion on the sea bottom from pipelines, templates, etc. DP is not limited to offshore vessels and mobile drilling units. Cruise ships and oceanographic research vessels, for example, also use DP, which locks a vessel's position either to a fixed point or relative to a moving object like another ship.

Under guidelines issued by the International Maritime Organization (IMO) in 1994 to provide an international standard for DP systems on all types of new vessels, the IMO grouped requirements into three equipment classes – the greater the consequences, the more reliable a DP system should be:

- Equipment class 1 – Loss of position may occur in the event of a single fault.
- Equipment class 2 – Loss of position should not occur from a single fault of any active component or system (such as generators, thrusters, switchboards, remote-controlled valves, etc.). Normally static components (such as cables, pipes, manual valves, etc.) will not be considered to fail where adequate protection from damage is demonstrated, and reliability is satisfactory.
- Equipment class 3 – Loss of position should not occur from any single failure, including for items listed for class 2 as well as all for components in any one watertight compartment, or in any one fire sub-division, from fire or flooding.

The classification societies have their own notations based on IMO guidelines.

A joint venture with Statoil to design a drillship suitable for the harsh Arctic environment is also such an example. The initiative started five years ago, now Statoil is broadening the effort and bringing in more partners to meet the challenge.

This is typical for early stage studies, according to Kyvik. One design study builds upon the other until someone is ready to order a drillship and build the first vessel. As a design and consultancy firm, LMG Marin generally relies on fees for the work itself, and design fees per unit.

When asked to name the most noticeable changes in drillships in recent years, Kyvik points to the remote control work of the drilling operation itself. The manual drill deck of the 70s and 80s was a dangerous place to work, and doing the job from an operations chair in a drilling cabin revolutionized the working environment.

At present Petrobras has spurred innovative development with its closed bus DP specifications. Another area in which Kyvik expects to see innovation in the future is in mud.

Last year he participated in an interview session with Aker Solutions where cross-discipline knowledge sharing was a main objective. Developing a network of close partners who share ideas will remain crucial to bringing about innovation. While new technology will always be a driver of change, the main drivers will still be costs and meeting requirements for local content in the emerging offshore markets, says Kyvik.

**Text:** Johs Ensbj

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For technical insight into DP see *Analysing DP incidents* on page 150; see also pages 27 and 154.

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# Broad approach ensures safety and availability

**ALF KÅRE ÅDNANES – Ever since shipping began, seafarers have depended on the safety of their vessels and skills of their crews. International regulations, classification rules and national legislation have been developed through the years to set standards for shipping. Taking a broad approach from the design stage onwards is also necessary to ensure safety and availability.**

**T**oday's vessels are advanced constructions that perform complicated tasks or can be part of a complex set of logistics. Safe and effective operation demands higher and new competence from the crew, as well as from designers, builders and suppliers and also regulatory and advisory bodies.

There is no single simple way to achieve safety and high availability of a ship's systems, but it is a fact that the optimal and best solution will be more challenging to add on as a modification to a system, than when a broad approach is taken from the design phase, building and verification, and through to operation. This is illustrated in Figure 1.

In this issue of *Generations* we present articles that cover a variety of concerns and solutions to enhance availability of the installations, in different phases of the life-cycles of vessels.

Safety and availability are related, though not completely overlapping, terms. While safety is mainly about the risk to crew, passengers and others who

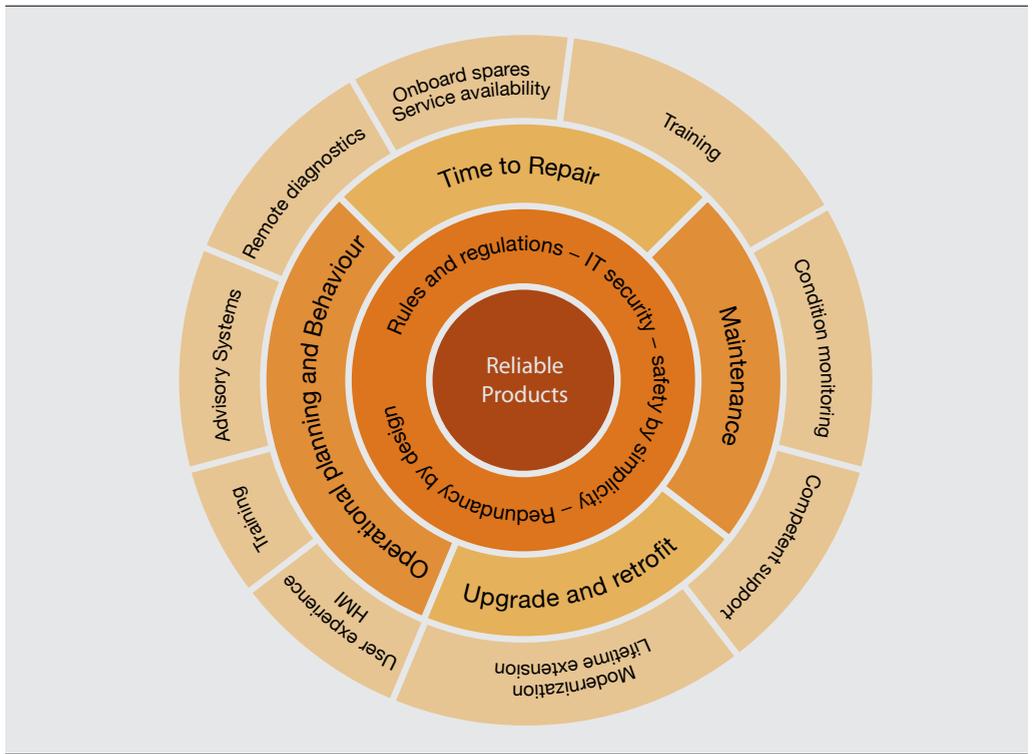
may be affected; eg, through environmental spill and pollution, availability is more about using the vessel for its intended purpose and keeping up a steady flow of income.

However, it is fully possible to build up the availability of the vessel's installations and at the same time improve the level of safety. This requires a broad approach to design and risk analysis, as well as proper risk mitigation. And firstly, it requires the ability to understand the risks inherent in today's solutions and to take note of the lessons learned from operations, as well as the ability to solve reliability issues without creating new ones.

## **Reliability versus availability**

In order to better understand the terms used a few definitions are needed:

Reliability ( $\lambda$ ): The probability that a component or system (set of components) will maintain their intended functions; often represented by a statistic number such as MTTF (Mean Time to Failure).  
 $\lambda = \text{MTTR}^{-1}$

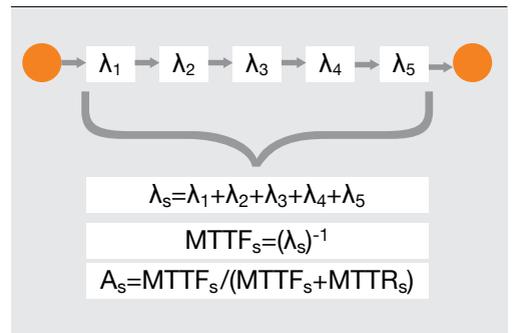


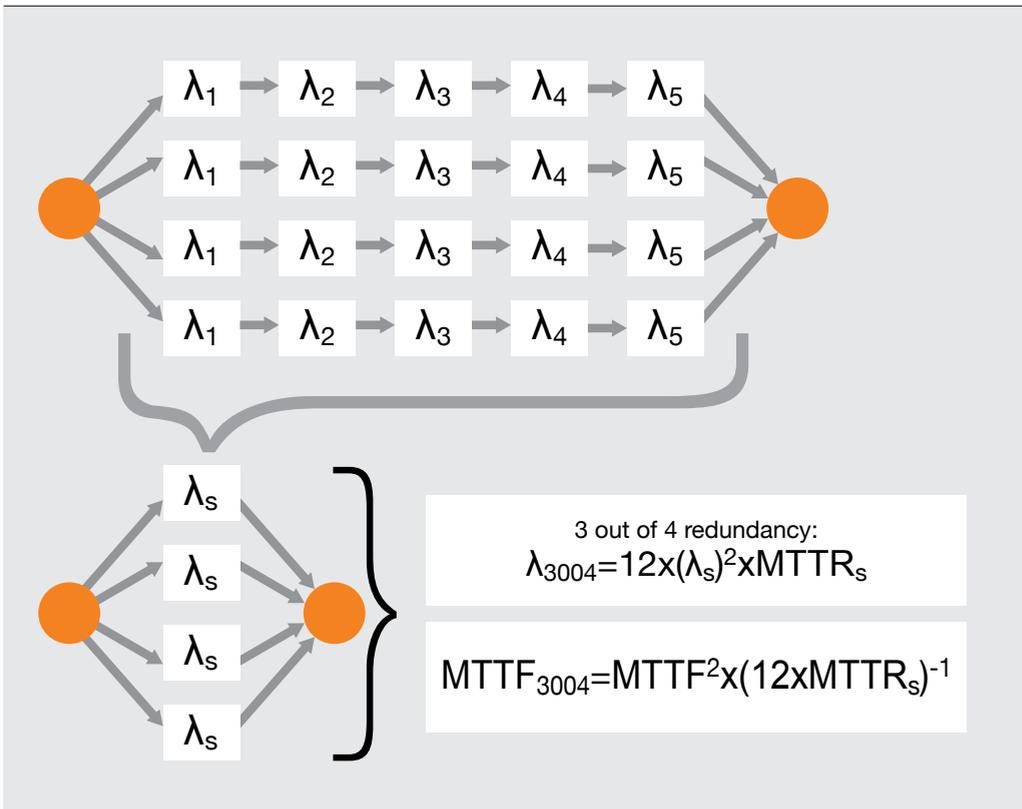
Availability (A): The degree to which a component or system (set of components) is in its functional condition; the term functional condition being understood as capable of carrying out its intended operation within defined constraints. For one system or component with failure rate MTF, the availability is calculated as a percentage number:  $A = \text{MTTF} / (\text{MTTF} + \text{MTTR})$ ; where MTTR is Mean Time To Repair.

Safety: How well something or somebody is protected against damage, accident, or other undesirable events. Safety cannot be quantified in absolute measures and must be considered relative to the consequences of being in an unsafe condition. Safety assessment is typically approached by a risk analysis, where the risk for entering an unsafe condition is assessed against the consequences of not being safe; and a definition of what is a safe situation. For example, in running an oil well, a safe condition can be to shut down all process, while for an aircraft that would obviously not be the case.

A simple system with one chain of events that can lead to loss of the intended function is shown in the single-path reliability diagram of Figure 2.

2 Redundancy diagram for a simple installation without redundancy





There are several ways to approach high availability, Figures 3 and 4a show two different philosophies, presented in a reliability diagram.

For propulsion systems, availability and safety targets largely coincide as the ability to maneuver and control a vessel require both; not unlike the case with aircraft. While the approaches in Figures 3 and 4a may give an apparent increase of availability, the concept in Figure 4a includes additional components that, by pure parts count, increase the overall failure rates and may also contain common hidden or undetected failure modes. These additional components may also make it difficult to identify the risks and to quantify reliability, and may result in real reduced availability.

ABB prefers to work with systems that are designed to keep redundancy on a system level to a feasible maximum. Having clear lines with minimal interdependencies and cross couplings makes it easier to design and analyze the system with less risk of hidden failure modes. And even more important, it makes it

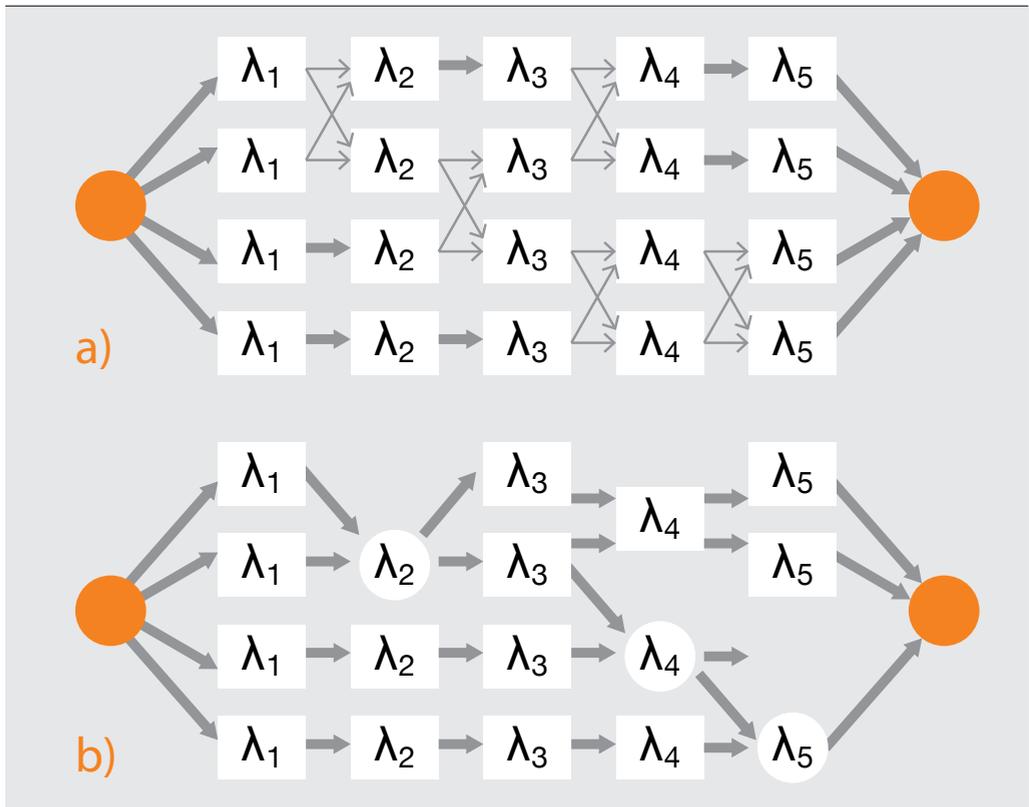
possible for crew and service engineers to more logically understand the redundancy philosophy of the design in order to take the right operational actions and to correctly repair and test after a service job to ensure system integrity.

From these simple examples, it is clear that availability will be increased by:

- Using components with high reliability (MTTF)
- Increasing the number of redundancy segregations, represented in the diagram as independent paths
- Avoiding interdependencies between the redundancy segregations and, where cross connections are necessary, avoiding common failure modes for two or more of the paths shown in Figure 4b.

**Computerized control and IT**

The continuously more advanced systems for control and monitoring, navigation and reporting make computerized systems and IT necessary installations



and working tools for the crew and fleet management. Modern control and IT systems offer huge advantages in terms of running the vessel and installations at optimal and safe conditions. Gundersen's article (see page 127) on the emergence of IEC61850 and GOOSE communication in the protection of power generation and distribution systems is a good example of how modern IT solutions both simplify the hardware installations and, at the same time, pave the way for the improved protection of power plants, eg, with closed bus transfers.

Automation systems are also used to perform safety critical monitoring and control of process plants, and Hansen and Duran's article on SIL systems (see page 112) shows, with reference to the oil and gas industries, how such systems may be used to adopt a systematic approach to set safety targets.

From land-based industries, and computers at home and in the workplace, the precautions taken against virus attacks, or cyber security, are already well

understood. However, while shipping industries and ship installations have so far avoided larger interference from cyber pirates, there is still work to be done to increase awareness and implement protection against cyber attacks. Hansen and Rahman (page 106) discuss how cyber security issues are handled by ABB in offerings of systems and support to the industries.

The human factor in safe operation must not be underestimated. Even with a high degree of automated control and safety functions, the user of the system, whether on the bridge or in the engine control room, will have to make decisions and interact with the system in both normal and failure situations, based on information provided by the system. The human machine interface (HMI) is the communication portal for the user of the system and it is essential that it is designed to meet the user's need for information and control input under both relaxed as well as stressful conditions. The computer systems may have access to thousands of events, alarms and dates.

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## Safety and availability are not ensured by one-off or simple means alone.

The importance of providing useful data to match the situation is obvious, although difficult. Azhar et al discuss the design process and fundamentals derived from it, in the design of the HMI for automation systems (see page 118) while Jehkonen and Matilainen describe the Intelligent Maneuvering Interface (IMI) for Azipod® propulsion systems (see page 122).

### **Redundancy for availability**

With the entrance of dynamic positioning (DP) in the offshore fleet, a set of guidelines, rules and regulations have evolved that aim to define acceptable designs and procedures to obtain safety and availability. In order to understand the challenges, it is useful to learn from the past. Giddings, technical advisor of the International Marine Contractors' Association (IMCA), presents statistics collected over years on the failure of DP vessels (see page 148).

A fundamental requirement for such installations is the performance of FMEA analysis during the design, and continuous verification from sea trial through the lifetime of the vessel. Bhattacharya and Steven Cargill give their views on how FMEA processes should be done and how hardware-in-the-loop testing (HIL) can complement the traditional FMEA to make a faster, safer, and wider test footprint of automation system (see page 171). Adegeest presents the Octopus advisory system that extends the static DP capability plots and failure effects analysis with forecasting the vessel's behavior based on dynamic modeling and weather forecasting and is able to monitor and forecast vessel movements (see page 144).

As technologies evolve, and energy efficiency also becomes a competitive factor in the offshore fleet, there is increasing interest in solutions that give reduced fuel consumption, without compromising the safety and availability of the plant. DP operation, up to class 3, with closed bus transfers and ring connection on the main electric distribution system is a good example. Oil companies see the benefits of lower fuel bills and more stable voltage supply, and classification societies follow up with notations for enhanced reliability to permit such designs. Wendt shows in his article on page 154, how the use of IEC61850 communication, and autonomous systems helps to meet such requirements; while Hjukse's article (see page 161) on extended diesel-generator monitoring presents a solution for detecting power plant failures that were previously considered undetectable by traditional protection systems and hence could lead to a cascading failure of the power plant.

Also for vessels with single shaft propulsion, the concept of redundancy may be feasible by optimizing the design; where the additional cost of redundancy should be balanced with the reduced cost of main engine and fuel consumption. Vänskä (see page 185) shows how ABB has approached the in-line shaft booster/generator system for container vessels, where waste heat is converted to usable energy and, together with auxiliary power, can supply booster and take-home redundancy, giving the opportunity to optimize the propulsion design for reduced CAPEX and improved OPEX – to find the most cost effective balance.

### Improving reliability and availability

Reliability and availability may not only be built at the system level to increase reliability of components and sub-systems and to use control methods to reduce the disturbing effects on the power plant that do not necessarily show up in the reliability diagrams. They may also have a significant impact on the final safety of operation.

Eriksson presents the solution for drilling drives and their control systems (see page 175). Although this is often regarded as a separate system to the DP installation, they are directly dependent through the common power plant and their safety aspects are coinciding. Design of the two systems should be well coordinated, with both physical and functional integration, to avoid mutual disturbances.

The use of Liquid Natural Gas, is expected to grow significantly this decade. LNG is a competitive energy source, with less environmental emissions, provided that proper solutions become available for transportation and tanking, as well as controlling the engines for optimized combustion process to avoid methane slip and large frequency fluctuations. Pestana presents an article on how electric propulsion fits well with the use of LNG engines (see page 175) and how electric propulsion allows for much more precise load control with lower load variations and more stable network voltage and frequency.

### Reducing down time and MTTR

No technical installation lasts forever, and maintenance and upgrades are necessities. Instead of considering maintenance to be a non-deterministic cost over the years, Pajala's article (see page 190) points to ways to predict lifetime and plan maintenance at more practical and less painful times, such as during scheduled dry docking. Maintenance

should be carried out in cooperation with suppliers, and the workload may be shared between the crew and supplier's service engineers to find the right balance of costs and resources for the ship operator.

ABB has implemented a remote diagnostics and support system, which allows our specialists to connect to the onboard installation and perform diagnostics similar to what used to be possible only by sending a service engineer on board. In combination with adequate spare parts storage on board, remote diagnostics already has numerous examples of how faulty systems can be made fully available through remote guidance of the crew.

### A broad approach

Safety and availability are not ensured by one-off or simple means alone. The process of learning from experience and improving functions, solutions, and operational behavior is necessary. The articles in this issue of *Generations* give a broad overview of various approaches to make operations safer and more available for their intended work by reducing downtime. The overview is by no means a full picture of methods and solutions, but hopefully it will increase awareness and inspire designers, operators, and maintenance personnel towards even more improvements.

In conclusion, I thank all the authors of these articles for their contributions to this very important topic in the marine industries of today.

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# Cyber threat to ships – real but manageable

**KAI HANSEN, AKILUR RAHMAN – If hackers can cause laptop problems and access online bank accounts or credit card information, imagine the havoc they can wreak on a ship's control systems. But is this a real threat or science fiction?**

**T**he Information Age has brought enormous benefits. But progress typically brings new problems, and our dependence on computers raises the threat of hacking. This has led to the development of a body of technological processes and practices known as cyber security. Cyber security protects networks, computers, programs and data from attack, damage or unauthorized access.

Vessels have also started to increasingly depend on information technology (IT), taking solutions that offer high functionality at moderate cost out of the office environment. This means we must also take cyber security in the marine sector seriously. EU and US government reports on security in the shipping and transport sectors confirm this view.

Cyber security is much more than a simple technical fix that solves all problems, as it is sometimes portrayed in the media. It is just as much a question of culture and attitude as it is technology. The best encryption algorithms in the world are useless if someone writes the password on a Post-it note and leaves the door open. Security must be in focus

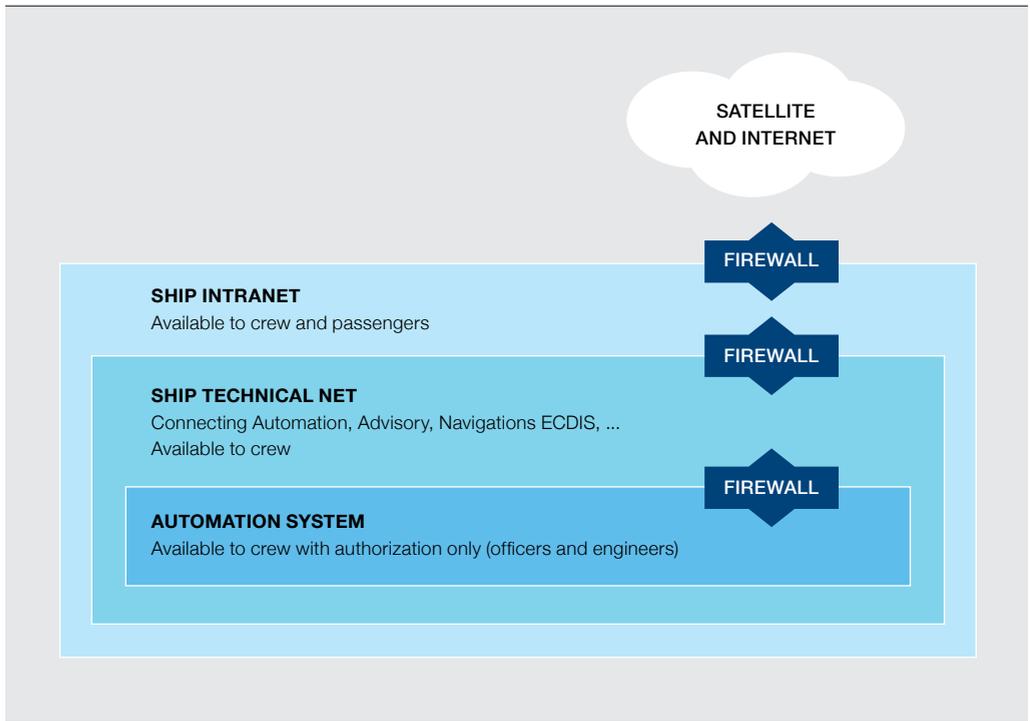
during the product design, planning and engineering of a vessel, as well as during the commissioning of the IT equipment and operation of the ship.

## **Cyber-threat proof solutions**

Even if the yard and the ship owner carry final responsibility, ABB takes security very seriously. We provide products and solutions that have been developed with security in mind and that, used correctly, provide a vessel with good protection against cyber threats. ABB can also evaluate the security level of a fleet to ensure it is cyber-threat proof.

ABB also takes security into account during product development. Internal R&D processes have a checklist of questions on security, ABB has a dedicated robustness test center at its research center in Bangalore and the main systems have been tested at US cyber security laboratories. ABB also has processes in place to handle new security issues that may arise.

One central concern when delivering electrical propulsion systems, electrical generation and protection equipment, and automation and advisory solutions is how all these are connected in a network



architecture and how the network is connected with other systems on the ship and on land. The key word here is defense-in-depth, with security zones in place. Defense-in-depth refers to multiple, independent and redundant layers to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon.

Traditionally the different technical solutions have not been connected together in a proper computer network; this has been used to argue that cyber security is not relevant to vessels. This is only partially true. In a disconnected system, there is no risk of a problem occurring during normal operations.

However, typically these systems will occasionally be connected to a maintenance computer, a USB stick or a modem. In these instances, the system is as vulnerable as a connected system. And if a security culture and measures are not in place, malicious code could end up disrupting the system.

A better approach is to accept that security measures always have to be in place and take advantage of the increased functionality a connected system provides

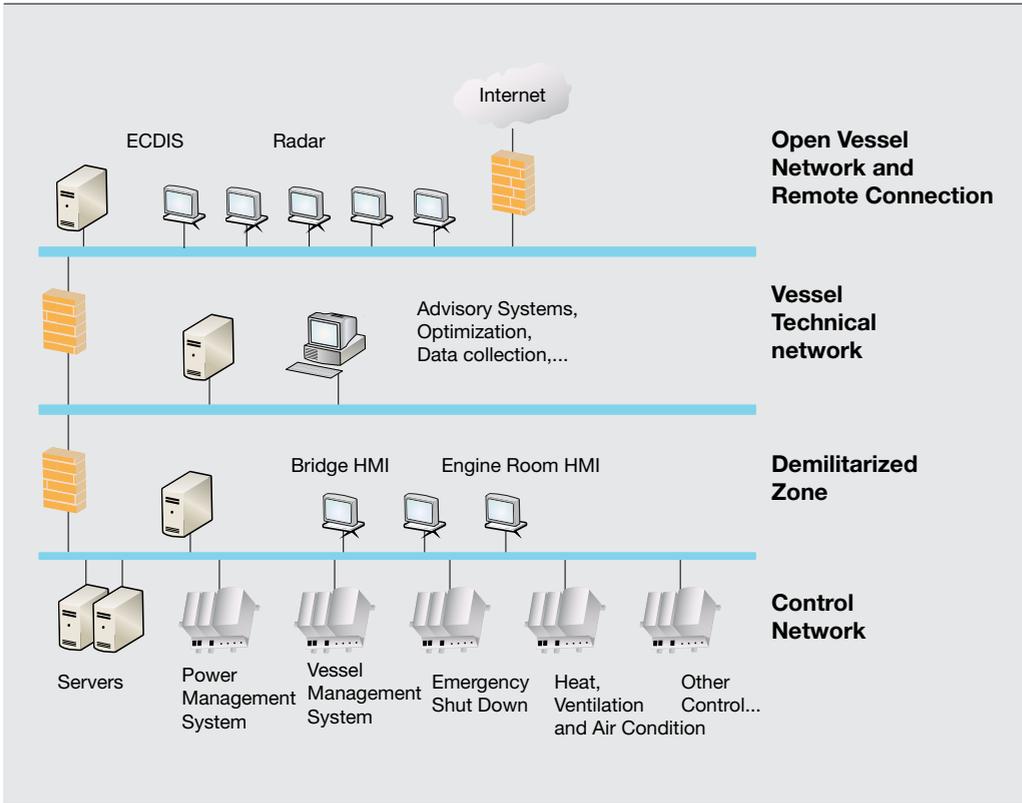
– then take the effort to design good network architectures.

### Defining security zones

The security zones illustrated in Figure 1 are a feature of the principle of network architecture. This is also called defense-in-depth because the more critical parts that need better protection there are located deeper into the core of the system – you have to pass a barrier that typically includes a firewall to enter from an outer zone to an inner zone.

A simple threat analysis should be done to define the security zone hierarchy for marine solutions. Critical systems include those that handle propulsion, and power that is part of the marine automation delivery. Typically, all these marine automation systems will be located in one inner security zone as indicated in Figure 1.

Other equally important security zones could include the navigation system network. At the next level up, a zone connects some of the most critical areas, which could also include systems not as critical for running the ship safely. This zone is called the Ship



Technical Net (see Figure 1). It could be connected through a firewall to an open ship network, which is then connected to the world through a satellite link.

Many people access an open ship intranet, such as that of a cruise ship or ferry. On other vessels, off-duty crews use the network for getting news, contacting friends and family, etc. Such generic Internet traffic is valuable and should, of course, be used; however, use should be restricted to the part of the network where malicious code or simple mistakes cannot influence the operation of the vessel. Using the right firewall protection to secure zones can ensure that this does not happen.

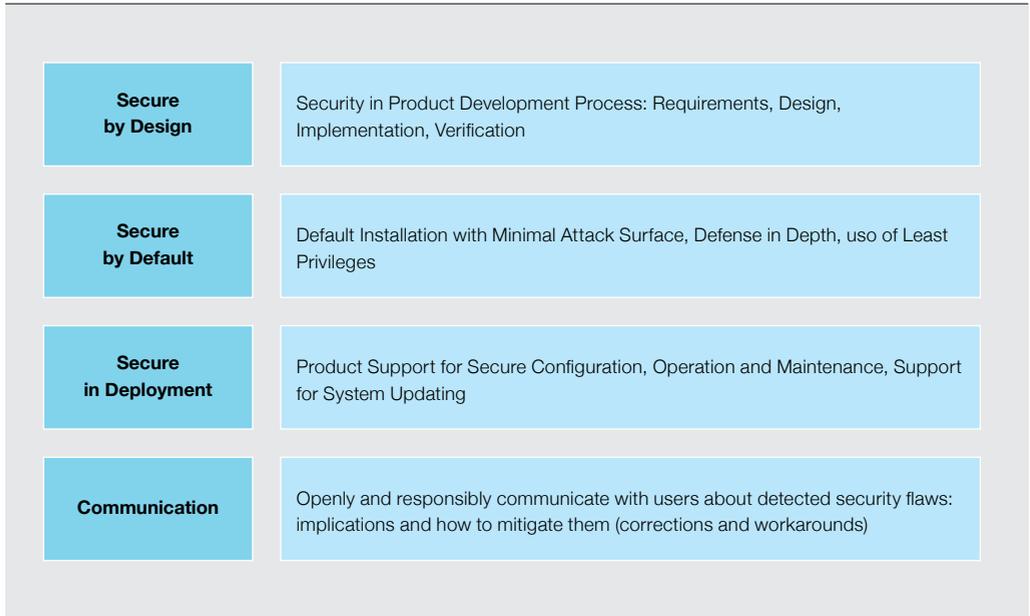
Figure 2 is a representation of the conceptual zones, shown in Figure 1, as boxes and links. Here a different type of zone, called a demilitarized zone in security language, has been added. This special type of security zone is suitable for systems that are less critical than those of core automation, but closely linked to the automation system.

### Maintaining a secure level

Assuming a vessel is delivered with a state-of-the-art security design, it is equally important that there is a high security level in the operation of the ship. The crew needs to have a basic understanding of the rules and act accordingly.

The vessel owner or operator should at least do the following:

- Have a policy for secure operation and maintenance of the system
- Not connect the secured network to any unknown network or point not in the original design of the plant network
- Not use portable media without virus scanning
- Update security patches and antivirus software as recommended by the vendor of the system
- Keep the ports and services not required for operation closed
- Have a process and system in place for system change management



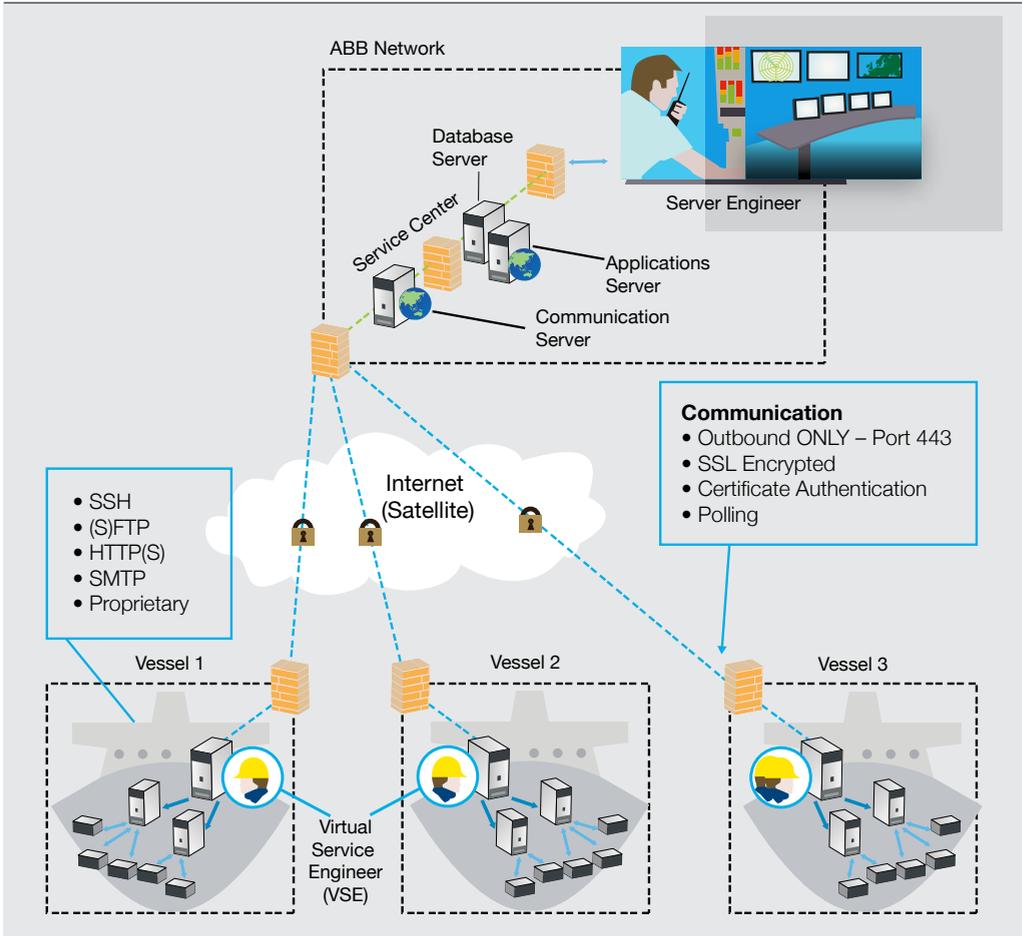
- Back up the system and have a procedure to validate and recover the back-up
- Monitor the system for any suspected security risks, including user rights and activities
- Inform and get support from the system vendor for any security vulnerability and incident in the system

It is not realistic to expect every vessel to have access to IT and cyber security expertise; however, most people today have some level of IT knowledge and security awareness through using their private computers. It is very much about awareness. For example, no crew member will install a computer game in the automation computer if he or she understands that this could increase the risk of a total blackout during a hurricane. Making sure a maintenance computer has an updated virus scanner before connecting it to the control network is a simple step – but it must be remembered and may require a few minutes' delay.

Different industries have debated whether cyber security in the technical network is the responsibility of IT or automation experts. With more awareness in the maritime industry, ABB also expects this to become a hot topic. Who is responsible: the chief engineer, the bridge or someone else? There is no simple answer yet; it will be an interesting discussion.

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It is not realistic to expect every vessel to have access to IT and cyber security expertise.



### Designing robust products

ABB’s philosophy regarding security in product design and deployment is called SD3+C. This abbreviation reflects four key concepts:

- Secure by Design
- Secure by Default
- Secure in Deployment
- Communication

ABB follows the Secure by Design principle when making a new product. This means carrying out the architecture with an understanding of security issues, and coding software in a way that minimizes the risk of bugs being introduced by hostile hackers. Conducting a threat analysis highlights the parts of the product that need special attention.

Secure by Default implies that the product has an acceptable “out of the box” security level. Active engineering work will be necessary to enable features that are not always needed because using all additional functionality in a product increases vulnerability.

Secure in Deployment indicates that the commissioning of equipment was done with security know-how, that proper documentation was provided, and that functionality supporting operational needs is in place to maintain a high level of security.

Communication is essential to security. Accepting that any system can have flaws is the most important step in a continuous improvement process; this is the only way to ensure a high level of security for ABB solutions.



**Offering secure remote access**

ABB offers secure access into a remote system. The well-proven solution is called Remote Access Platform (RAP) and is, for example, used in the Remote Diagnostic Service (RDS) that links a number of vessels to the ABB service support center.

A sketch of the RAP is given in Figure 4. The core of this solution consists of an encrypted connection between the ABB Service Center through the open Internet and into the customer's technical network. In the customer network, software called Virtual Service Engineer ensures that only registered clients are allowed to access only predetermined parts of the system. This ensures that only ABB Service engineers have access to a vessel. The advantage is huge; complex problems with drives or switchboards can be solved directly without the need for an engineer to travel to a vessel. This saves both time and money for the customer – without compromising cyber security.

**Providing security services**

ABB is a global company with long experience in security. ABB Marine and Cranes can access this experience through the wider company's resources worldwide. It can also offer direct service consultancy. The ABB Cyber Security Fingerprint identifies strengths and weaknesses for defending against a cyber attack within a vessel's control systems. It does this by gathering data from system configurations and key personnel and comparing this against best practices using ABB's proprietary analysis tool.

The resulting analysis provides detailed recommendations for reducing cyber security vulnerabilities while helping to develop a focused and sustainable security strategy for control systems.

The ABB Cyber Security Fingerprint reduces

security risks by exposing gaps that could endanger employees, assets and uptime. ABB's approach compares customer security policies and settings to industry standards to establish a benchmark and ensure customer control systems have multiple layers of protection.

Based on Security Fingerprint analysis, owner-operators can use ABB services to implement or improve the cyber security of a vessel or fleet. Some services available are:

- security policy for a vessel/fleet
- software patch update
- anti-virus update
- system hardening
- user management and network configuration

Cyber security threats are real and growing. However, with a coordinated approach between owner-operators of marine vessels and vendors like ABB, the risks to business and stakeholders can be minimized. Security needs to be addressed not only as a one-off activity but should also be an ongoing process during the life of vessels, automation products, and systems. A security policy for vessel operation and security solutions and support from vendors will help achieve these security goals.

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# Process industry automation meets maritime needs

**KAI HANSEN AND LUIS M. DURAN – Automation systems perform critical monitoring and control at process plants. Such systems may also be used to set safety targets in the maritime, and particularly oil and gas, industries.**

Sea travel has always brought with it a certain level of risk. For centuries, navigation was a challenge many thinkers and craftsmen tried to solve. Today, a ship's crew continues to face the dangers of bad weather and loss of propulsion, which can sometimes lead to fatal accidents.

At the same time, modern ships face risks such as accidents involving cargo or problems related to a ship's systems and infrastructure. As more types of vessels are involved in the growing offshore oil and gas industry and in the transportation of hydrocarbons and chemicals, dealing with such potential disasters is crucial.

It is therefore essential to oversee a ship's functions and cargo and to take appropriate action before a situation gets out of control. This requires using computerized systems, which provide users with a high degree of trust. ABB's safety controller ensures a high level of confidence and also acts as an integrated part of the extended automation system 800xA – a complete solution within one framework. This means a ship's crew does not have to access too many different interfaces and hardware; they can rely on the same system, whether handling an emergency shutdown after an accident or simply checking generators or ballast water.

In addition to providing the highest level of safety and control, 800xA can be integrated into a collaborative solution whereby onshore offices and vessels can share information and work tasks in a way that was not possible before. This is already the case for sophisticated oil producing platforms and vessels and is now being used in other parts of the maritime industry, with examples given in other articles in this and the previous edition of *Generations*.

## **New challenges, new solutions**

Oil and gas is, of course, vital to today's industrial civilization as it accounts for a large percentage of the world's energy consumption. The challenges facing offshore oil and gas development have driven innovation. Developing large production facilities, such as the Troll A platform, which stands at a depth of 300 meters, also entails major investments. Other types of offshore platforms, which float using a mooring system to keep them on location, bring their own challenges.

While it may cost less to use a floating system in deeper waters compared with a fixed platform, the dynamic nature of the platforms introduces other challenges for the drilling and production facilities as the ocean can add several hundred meters or more to the fluid column. The additional depth increases the equivalent circulating density and down-hole

pressures in drilling wells, as well as the energy needed to lift produced fluids for separation on the platform. This puts pressure on operations and increases criticality and related hazards.

Offshore manned facilities also present logistics and human resource challenges. They are a small community in themselves with their own sleeping quarters, management, cafeteria and other support functions in addition to the production and storage facility. Today, much effort goes into relocating as many of the personnel as possible on shore, where management and technical experts use remote access technologies and video conferencing to stay in touch with the platform.

### Collaborative solutions

One type of floating system is a Floating Production, Storage and Offloading (FPSO) vessel, typically a tanker-type hull with wellheads that sit on a turret, allowing the ship to rotate freely – pointing into wind, waves or currents. Such vessels usually operate in water depths of between 200 and 2,000 meters. The main processing facility is located on the deck, while the hull is used to store and offload to a shuttle tanker or, in some cases, to a pipeline. While offshore operations have the complexity of any production facility, this is increased exponentially by limited space, weight capacity, harsh environments and other factors. While an FPSO needs to have a standard process control and safety system as with other installations, it also requires efficient operations on board and accessibility from a remote, onshore operations center.

The emerging trend is to create a collaborative system instead of segregated control solutions. So-called “integrated operations” are characterized by increased cooperation (independent of location) between operators, maintenance personnel, electricians, production and business management, and suppliers to provide more streamlined operations. For a big oil producing platform, this system is operated from the Central Control Room (CCR) using a combination of graphical process displays, alarm lists, reports and historical data curves. Console displays are often used in combination with a large wall mount display. With modern systems, the same information is available for remote locations such as an onshore corporate operations support center.

The goal is that, regardless of the technology used, CCR operators can access information seamlessly

from a multitude of systems to run the facility safely and productively. Under abnormal conditions, timely decision making can prevent hazardous conditions, equipment malfunctions and process downtime.

Under such operating conditions, the control system is designed to allow users to:

- Access alarms and events from anywhere in the process (process control or safety systems)
- React seamlessly to diagnostics
- Assess initiating events from sequence-of-events data from the safety system in the context of other relevant information in the process history
- Create personalized work spaces, from which the operator can respond and make decisions

Within an integrated control environment, the operator can maintain a high level of alertness and understanding of progress through the production cycle. Real-time access to critical information enables operators to make correct decisions as soon as circumstances dictate, or to get remote assistance from experts on shore.

Similar collaborative solutions can also already be used on the bridge today and in the engine control room in more traditional vessels. The main difference is that navigation plays a more central role in a moving vessel and the process control system is much simpler.

### Safety automation

Safety applications, such as the Emergency Shutdown (ESD) system, are essential and critical in vessels equipped for hydrocarbon handling or storage. The system kicks in when a process malfunctions or reaches a dangerous level.

A Fire and Gas System (F&G) automatically mitigates the consequences of a potentially hazardous occurrence (rather than preventing the hazard) and is normally implemented using certified controllers. The F&G is not generally related to any particular process for a vessel with oil or gas processes. Instead, it is divided into fire areas according to the location in the vessel.

Each fire area should be self-contained; that is, it should detect fire and gas by using several types of sensors, as well as control fire protection and fire-fighting devices to contain and fight a fire within the fire area. In case of fire, the area will be partially shut off by closing ventilation fire dampers.

In a more traditional vessel, fire zones in the ship and a fire detection system detect and warn of a dangerous situation. The Emergency Shutdown systems are then activated, closing fire dampers, etc., and ensuring that other systems take appropriate actions. In contrast to a processing facility on a production vessel, the ESD will normally not automatically execute the actual firefighting, but leave this to the crew.

### Safety standards

Governments in many countries now enforce compliance to the safety standard IEC 61508 for the critical safety standards in the oil and gas industry, including floating units. This is a generic standard, which has a “functional safety” approach. There are also application-oriented standards that are based on this standard, implying that it not only addresses the technical solution but also takes a complete life-cycle approach to the system and its use.

The Safety Integrity Level (SIL) concept is the core of the standard. Levels are numbered from one to four and must be approached from two directions: the risk-and-consequences approach determines the required SIL, while the technical solutions approach fulfills the SIL requirement. The first approach involves evaluating what kind of incidents can happen and their consequences for people and the environment.

From this consequence analysis, an overall safety integrity requirement is determined. After taking into consideration how to reduce risk through mechanical and physical means, and by procedural and similar methods, the remaining requirements decide which SIL level the computer control system still needs to fulfill. This generic standard looks at several different models that can be used to determine a SIL level.

Finding out which methods to use, how a situation should be analyzed and the right SIL level must be done for each type of application according to the accepted risk level in a given case.

Even if it is difficult to come up with absolute numbers for such calculations, the standard does define numerical values for the SIL levels. For applications where an ESD system is triggered very infrequently (eg, once a year), safety standards in the table below apply. This shows how frequently a dangerous failure is accepted if the ESD function requires the system to take action. This refers to complete failure probability, including sensor, communication, electronic, software and actuator failures. For example, a SIL 3

Table 1 Numerical values for SIL

Safety integrity level	Average probability of dangerous failure on demand of the safety function
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

cannot face a dangerous failure more than one out of 1,000 times.

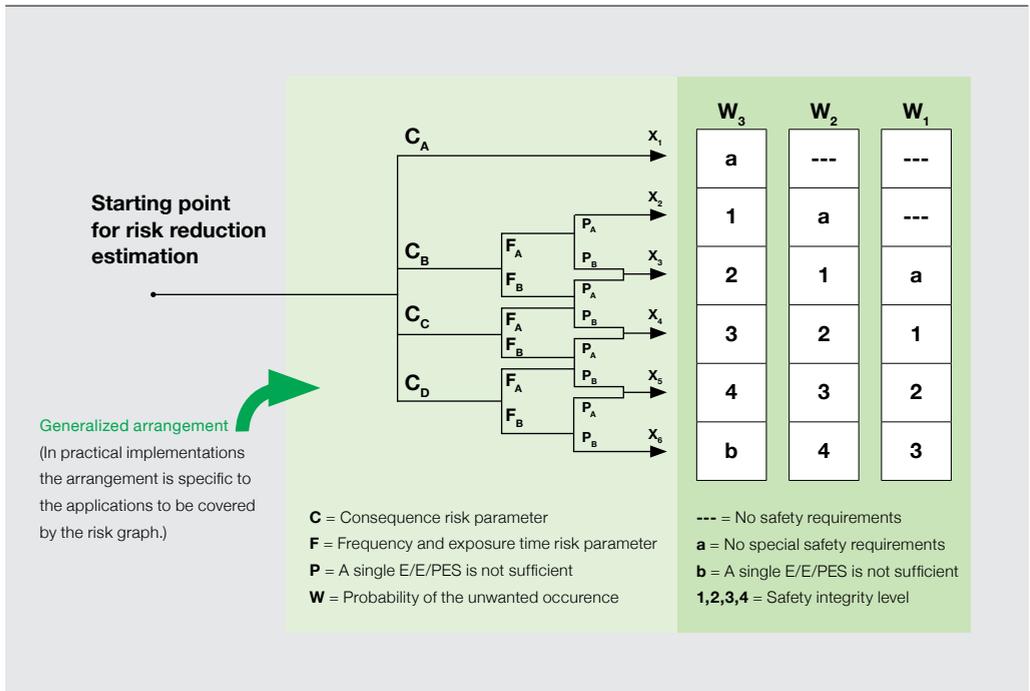
Even if the standard gives quantitative numbers as in Table 1, qualitative methods must also be used because it is difficult to make exact calculations.

In order to determine the necessary SIL, the concrete case must be evaluated. There are several ways of doing this. Figure 1 shows an example of a risk graph method, which basically evaluates the consequences and probability of an unwanted incident. By following the arrows, we can find out which systems do not need a special safety requirement, which systems need SIL 1, SIL 2, SIL 3 and SIL 4, and which systems should be redesigned because of unacceptably high risk. In the process industry, solutions that require SIL 4 as a control protection would be redesigned to reduce the computerized safety system to a SIL 3 level.

When the required SIL level is determined, the next question is how to reach this SIL level with the electronic components and the software. This is done by combining a number of well-known techniques proven to improve the reliability of the system so that it works as intended. The safety standard has long lists of these techniques, but to put it simply: hardware is made with redundant components, while system design and software is developed in accordance with state-of-the-art methods. It is also important that good safety requirements are in place and that they are tracked throughout the lifecycle of product development. Higher SIL levels require the use of more methods and stricter development processes.

### High Integrity

For years, process industries relied on independent protection layers to reduce risk. The concept assumes that the Basic Process Control System (BPCS), process alarms, operator actions, safety



instrumented systems (SIS), Fire and Gas Systems, and any other system intended to reduce risk in the processes are capable of acting independently from each other. This means each layer must perform properly without being influenced by others and without failing, which would potentially disable two or more of the protection layers (defined as Common Cause Faults).

Traditionally, common cause was reduced by using totally different systems for the BPCS and the SIS and by using different hardware and software to reduce common cause failures. If these systems are purchased from different automation providers, common cause failures can probably be excluded; the user can assume that different development organizations, knowledge and manufacturing processes, as well as different installation, operation and maintenance procedures were used in the logic solver's manufacturing process. All of these, however, work against the idea of integrating solutions into a collaborative solution for marine applications.

### Diversity of Design

This new degree of integration challenges the commonly accepted practices of satisfying and

demonstrating that the SIS is not subject to common cause failures. Furthermore, even though the safety system and the normal process systems are integrated, both systems can provide independent protection layers and meet the safety standard's requirements. ABB chose an alternative approach while designing 800xA High Integrity, which is to build such independence into the design process of the Integrated System. It is possible to achieve independence by using diverse design engineering and programming teams who are provided with different software architecture specifications and guided by an overall concept for diversity from the start of the detailed design specifications.

In this way, dangerous failure modes can be designed out and more than 99 percent diagnostic coverage can be provided to protect safety integrity without resorting to duplication. Technology has evolved to the point where multiple options can address similar technical problems. For example, by using two or more of these technologies, diversity is embedded in the system design. Diversity can be achieved in the embedded software by using different operating systems and then by using different teams to develop the software on multiple compatible modules.



Security does not become an isolated activity after product development is complete, but is part of the design considerations early on in the process.

By combining two different technologies – such as Micro Processor (MPA) or Micro controllers and Field Programmable Gate Arrays (FPGA) – to perform the same functionality in parallel to each other, the design becomes truly redundant and diverse with minimum possible common cause failures. This diverse implementation with the System 800xA integrated control and safety system makes it a great solution for the challenging requirements of the offshore marine and oil and gas industry. Using an integrated system not only meets the safety standards for diversity in terms of layers of protection, but also brings significant benefits in operations and maintenance over the system's lifecycle.

### Security in integrated control

With the advent of Integrated Control and Safety systems, security and safety have become inseparable. In addition to the implementation of access control, password protection and firewall configuration, logical separation can be added in the form of memory management. A memory management unit (MMU) allows different partitions of memory areas to be independent. These memory partitions are then connected to different execution processes of the CPU, such as regulatory process control or safety instrumented function. This approach ensures that only the memory area belonging to that process is accessible while the CPU is executing one of its processes.

As such, security does not become an isolated activity after product development is completed, but is part of the design considerations early on in the process. This includes not only threat modeling but also security checkpoints in the code design and review. In a similar fashion, testing does not become an isolated activity after the fact, but is embedded with functional testing. Independent teams, third-party assessors or both can perform tests and issue certification as applicable.

The option of taking an interfaced approach, instead of an integrated control and safety approach, will push the user to perform the following activities to satisfy security requirements:

- Perform a full vulnerability assessment/threat modeling and testing of the different subsystems
- Define the best security mechanism for each of those subsystems to cover any identified gaps
- Perform a full vulnerability assessment/threat modeling and testing of the entire interfaced architecture

- Implement and maintain the security mechanisms throughout the system lifecycle

Based on these, the challenge most users face is establishing a Security Management System of the interface architecture and supporting it over the system's lifecycle. Installing an integrated solution can help reduce the complexity of securing the control and safety systems, while also making it easier to maintain over time.

### **Peregrino FPSO**

In 2008, with only one commercial voyage on its log books, the *Nova* returned to the shipyard for its conversion from a Very Large Crude Carrier (VLCC) to an FPSO vessel. At a cost of more than \$1 billion, the conversion was the largest investment in a single vessel in the history of the ship's owner.

With a daily production capacity of 100,000 barrels of oil, 350,000 barrels of liquid, and 7.3 million standard cubic feet of gas, the FPSO *Peregrino* has a storage capacity of 1.6 million barrels of oil, equivalent to 16 days of round-the-clock production. The topside consists of two identical production trains and 15 modules for crude oil separation, water treatment, chemical injection, metering, power generation, power distribution, power and process control, and accommodation for 100 staff.

On the electrical side, the ABB solution for the FPSO and wellhead platforms distributes power for the entire production process, including the electric submersible pumps in the production wells below the seabed.

A multisystem automation solution, including field instrumentation and telecommunications systems, was supplied by ABB. The solution includes systems for process control, power management, production information management, condition monitoring, fire and gas, and emergency shutdown. These are all integrated within the same System 800xA Extended Automation platform and operating environment.

Each system is operated from a System 800xA Extended Operator Workplace (EOW-x) control room on board the FPSO. EOW-x offers an ergonomic operator environment that facilitates operator decision making and produces measurable improvements in plant productivity, safety, information flow, and operator job satisfaction. Some 14,000 I/O on the vessel and platforms are controlled by AC 800M

process controllers and AC 800M high-integrity controllers.

### **Conclusion**

As shown in the example of the *Peregrino* FPSO vessel, technology has played a crucial role in addressing the challenges facing offshore oil and gas production facilities, including seamless access to information, independent secure layers of protection, and an optimal footprint. This example describes how an Integrated Control and Safety System (ICSS) can address operational challenges by supporting both local and remote operations seamlessly using System 800xA.

ABB has not only addressed the fundamental design elements needed to maintain independent protection layers but has also fully integrated safety systems into the 800xA control and operations environment. By providing the technology for integrating safety into the core of a company's operations, ABB is delivering a safe and reliable integrated operations solution that is perfectly suited to meet the challenges facing today's marine and oil and gas industry.

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# New user interface supports crew

**SAAD AZHAR, ELINA VARTIAINEN, KAI HANSEN AND OLA HJUKSE – One of the most important safety concerns on a vessel is that those in charge take the correct action based on information they receive. By presenting information more efficiently, ABB's new automation solution helps them do just that. The development team is also keeping its eyes on the future.**

**A**fter long experience in automation and the marine industry ABB has produced a new integrated automation system for marine application. A major product upgrade, it features a redesign of the user interface. The core technology used in the system is the well-proven, award-winning 800xA extended automation platform, which continues to rank ABB as the largest automation supplier within process automation.

An essential goal in developing the new system was supporting safe vessel operations in all situations. Fast access to critical information is the best way to ensure correct decisions are made, especially when it comes to critical events. With this in mind, professional designers with maritime experience, as well as ABB's own research team, focused on identifying users of marine systems and how they interact with marine automation products. The designers and researchers also looked into new technology to lay the foundation for future interactive design. With an eye on fast developing technology, combined with an understanding of operational needs, we are able to create a better workplace for the crew in years to come.

## Studying users and their tasks

The first step in designing a user interface is to conduct user studies in the form of interviews with, and observations of, different types of crew members. With the help of these studies, we identified the main users of automation systems and their needs. This led to the creation of the terms persona and scenario to help designers and developers understand the work situation.

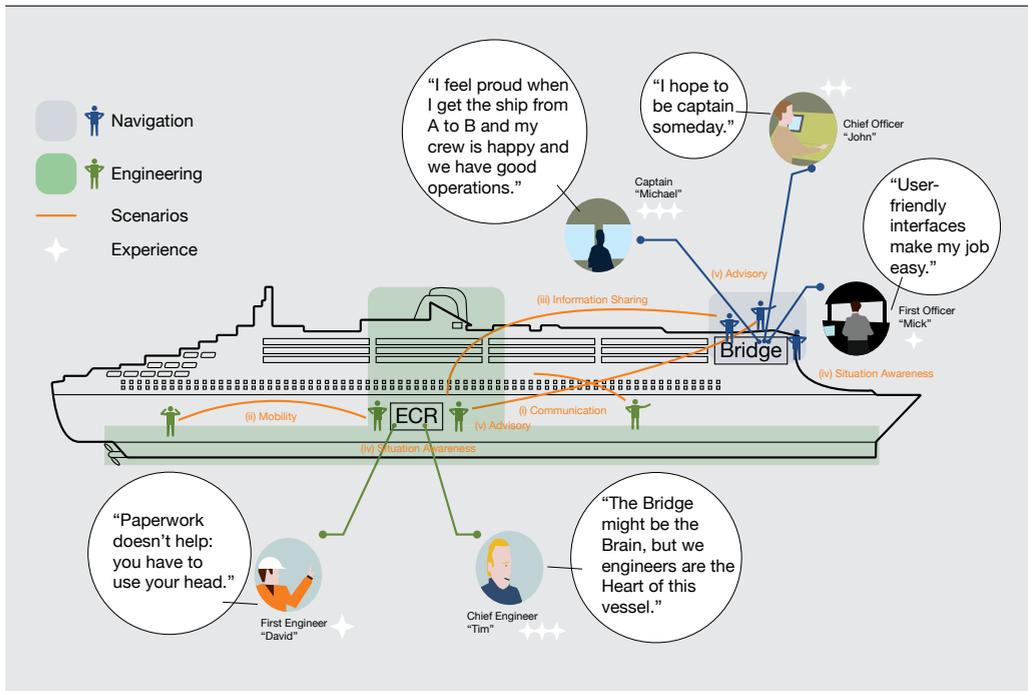
A persona is a stereotypical user of a system with a specific job, according to *"Engaging personas and narrative scenarios – a study on how a user-centered approach influenced the perception of the design process in the e-business group at AstraZeneca"* (L. Nielsen, PhD Thesis, Copenhagen Business School, 2004).

We gave these typical users names and personal histories to make them more realistic. A scenario is a story that puts a persona into the context of his or her needs and usage situations. The use of personas and scenarios helps development teams design systems from the users' perspective and keep them in focus. User feedback on designed systems is also important in developing human-machine interface (HMI).

## Personas

We identified five main personas who use automation systems on board a vessel: Captain Michael, Chief Engineer Tim, Chief Officer John, First engineer David, and First Officer Nick. These personas have different backgrounds, experiences, goals and concerns. Their work practices differ during the course of a day, an important point to keep in mind when designing functionality, which must address the needs of all these personas.

Here is a description of each of the five personas: Captain Michael likes responsibility, tough work and challenges. He has overall authority for the ship and communicates extensively with his shipping company, port authorities and charter companies. He usually works with the vessel's maintenance planning software and manages human resources on board.



Michael's main tasks are:

- Having overall responsibility for the vessel with the goal of ensuring the wellbeing, safety and effective operations of the vessel and crew
- Delegating jobs to other personas; however, if a problem arises, he is ultimately responsible

Chief Engineer Tim has been a mariner for 25 years and is proud of his long career. He also has a secondary responsibility as the vessel's fire chief. He is a craftsman at heart, used to working with his hands but lately he has been forced to rely more on computers. Tim thinks his job would be easier if there was less paperwork; he spends most of his time on reports and has to delegate the actual work to his first engineer. Tim's main tasks are:

- Ensuring the engineering side of the vessel works as intended
- Being responsible for all machinery on board – everything from electrical circuits to the huge engines used for electricity generation and propulsion

Chief Officer John is pleased when he is able to manage a big cargo efficiently. The best part of his

job is maneuvering the vessel alongside the pier. He likes personal communications with his colleagues best but prefers email for official communication with the company. John's main tasks are:

- Being responsible for loading, discharging, and ensuring the stability of the vessel
- Being in the cargo control room during cargo operations to operate ballast pumps, supervise loading and do the necessary paperwork
- Managing maintenance on the deck side

First Engineer David has been in his job for some years and enjoys it. He knows all the technical details about the vessel and has full responsibility for practical maintenance and repair work. David is the hands of the chief engineer. He often instructs the junior engineers and electricians on how to do repairs. When he cannot find a solution, he consults the chief engineer. David's main tasks are:

- Ensuring processes are optimized and working properly
- Monitoring the ship and its engines
- Preparing pumps, engines and all equipment relevant for departure

2 Tabs improve situational awareness without the user losing the ability to navigate quickly.



3 Alarms are presented in the navigation system to increase the situational awareness of the operator.



Understanding the user is the first step in making effective and efficient marine systems.

- Ensuring maintenance tasks are done on time
- Making sure replacement parts are in place.
- Distributing tasks to the second engineer and electrician

First Officer Nick is young and has been a junior officer for a few years. After six years of maritime education, he hopes to one day be promoted to Chief Officer and then captain. He is comfortable using modern computer systems and gadgets and prefers electronic charts to paper charts. Nick's responsibilities include:

- Keeping navigation watch and preparing safe and optimized passage plans for the voyage
- Being responsible for all navigation equipment and charts
- Sharing the responsibilities of life-saving measures, maintenance and fire-fighting with his fellow first officers

### Scenarios

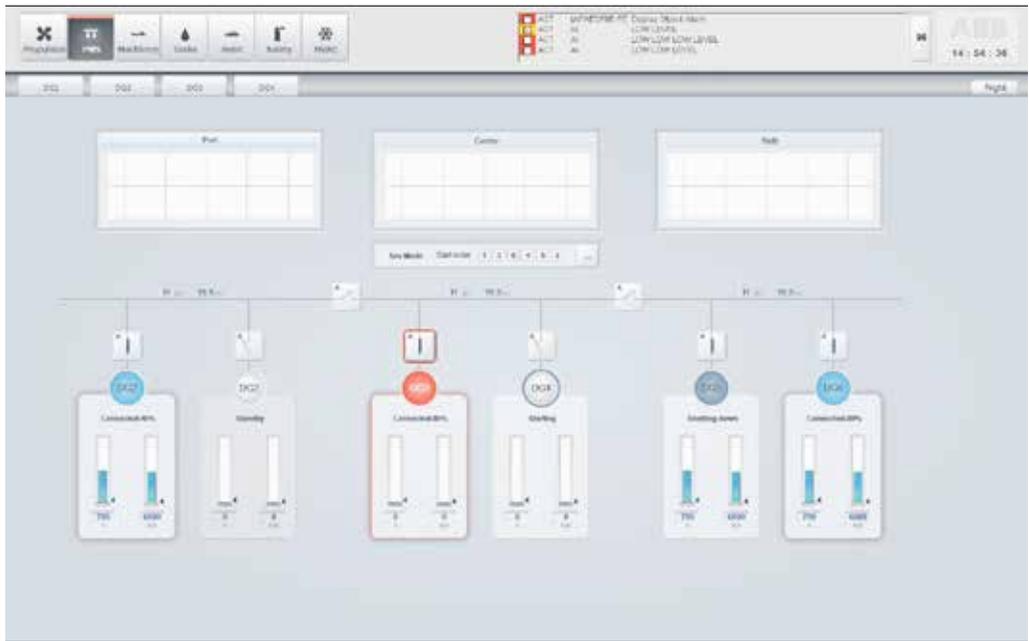
Based on the user studies, we identified five scenarios to show typical situations on board, where users interact with automation systems and each other. These scenarios describe:

1. Communication and collaboration between personas while interacting with the automation systems as well as carrying out daily tasks
2. Engineers and officers maintaining and monitoring the vessel on the move
3. Information sharing among personnel during operations
4. Situational awareness of the current state of systems, machinery and running conditions as well as navigation
5. Advisory information about the performance of the vessel

### High-performance user interface

Understanding the user is the first step in making effective and efficient marine systems. Designing a user interface that provides high performance in operating the systems is the next step.

ABB Marine developed user interfaces built on the philosophy of a high performance user interface (see B. Hollifield, D. Oliver, I. Nimmo, E. Habibi. *The High Performance HMI Handbook*. PAS, 2008). This means that the user interface should be easy to use and learn, provide a harmonized look and feel among all the systems, follow the latest trends in technology and have an attractive design.



These were the goals of the design process for the user interfaces from the very start. The result was not only a good design but also the presentation of the right information at the right time in a simple yet effective and understandable manner.

Special emphasis was given to harmonizing graphic design, integration, interaction, and navigation possibilities of the different ABB Marine applications.

### Computer screen navigation

To make it easy for the operator to navigate to the correct information in big systems, they need to be categorized into smaller sub-systems. A well-proven way of categorizing a system in the user-interface is to use tabbed navigation.

We used a three-level structure in the navigation scheme that gives enough options for categorizations but still remains manageable and easy to navigate. An example of this for a cruise ship is given in Figure 2.

The tabs provide situational awareness for the operator without him or her losing the ability to navigate quickly between screens. In fact, the maximum number of clicks to navigate to any screen is three, no matter where one is in the sub-system.

### Alarms

In addition to the traditional list of alarms, the tabs are used to display alarms. Each tab indicates whether an alarm is present on the associated process screen. This increases the operator's situational awareness as the alarms are easy to trace through the system structure and the relevant alarm list may be opened from the tab itself.

In the graphics, the alarm is shown as a red frame. An example of this is given in Figure 3, where a measured value related to the starboard shaft has reached a high level. Here the representation of the measured value has a red frame and all the tabs related to the shaft line, the starboard line and propulsion are marked in red.

### Data presentation

In addition to making system navigation intuitive, the design team focused on presenting data so that it can be quickly interpreted correctly to improve the operator's work situation.

The most important information on a screen should be obvious at a glance, while less crucial information should still be easily visible and able to be interpreted but not grab the attention of the user.



New technologies provide new possibilities for collaboration that could also fit well in the maritime environment.

We have divided information into three levels of importance:

1. Deviation from normal operation by alarms and warnings should get the operator's attention on every screen. By using strong contrast colors only for alarms, this information immediately sticks out, as illustrated in Figure 4.
2. Process/control information. When no alarms are present, information about the state of the system as well as control information should be the most dominant graphical elements on the screen. It should be easy for the operator to see process values and differentiate between clickable dynamic objects and static objects. In Figure 5 the clickable objects, such as the upper left elements, have a three-dimensional feel, while the static objects, such as the lower left elements, are simpler.
3. Static auxiliary graphics. Graphic elements that are not dynamic, and are used purely to gather information or indicate the physical shape of a process object, should be as simple as possible and not steal attention. By using colors that blend into the background, the graphics are not very prominent but still visible. This effect is used in Figure 4 to indicate the shape of the diesel engine and generator.

Ending up with screens that look grey and dull is a risk when adhering to the high performance user interface philosophy. These screens, although functional, may not be visually pleasing for the operator. One may be tempted to “spice up” such screens by adding visual effects to static objects, but this takes away focus from the more important information. To avoid this pitfall, we tried to make the dynamic graphics more visually exciting. Figure 6 shows how the analogue representation of values comes to life.

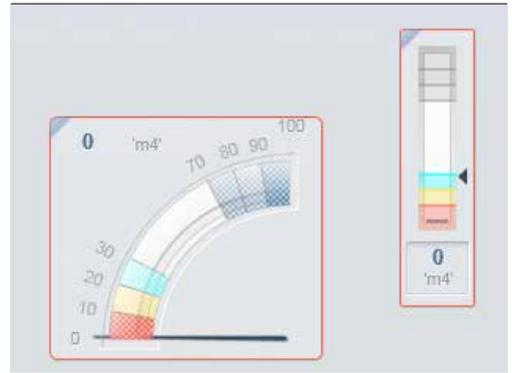
### What lies ahead?

By combining our understanding of users and their tasks with the philosophy of high-performance user interface, we were able to create a new user interface design that focuses on the most important aspects and is efficient, safe, and pleasant to use. In addition to providing compelling solutions that can be used today, we are also keeping an eye on future technologies that can improve marine user interfaces.

An interesting technology already on the market is transparent LCD displays. The bridge of a vessel has a large window that enables crew members to observe the surroundings of the vessel. These windows can be used as displays with the new LCD technology. Then, while looking outside, the crew can simultaneously view navigation and other vessel information displayed on the window screens. Transparent LCD displays and virtual windows can also be used to extend sight to blind zones, or augment the view in low-visibility situations.

Collaboration between crew on a vessel is crucial. Engineers, officers and other seamen need to work seamlessly together to ensure fuel-efficient, safe and on-time voyages. Today onboard computer systems largely do not facilitate collaboration and many tasks require using paper documents, radio and face-to-face communication. New technologies provide new possibilities for collaboration that could also fit well in the maritime environment. Big collaboration boards, such as Microsoft Surface, could be installed on a bridge, in the engine control room and in the cargo control room for maintenance and safety planning between the rooms. Mobile devices could be used more efficiently on board a vessel to access system information and communication and also to track people if an emergency arises.

Even more futuristic technologies have great potential in marine settings. Small remote-controlled unmanned helicopters, known as quad-copters,



could observe the surroundings of a vessel to reduce the risk of collisions. This could be especially useful for supply vessels that need to position themselves next to an oil or gas platform and stay put during loading and discharging. The quad-copters could be used to ensure that safe limits are maintained between the vessel and platform and to warn of possible accidents or bad weather conditions.

ABB Marine will keep a lookout for future technological developments in different domains and consider how they can be applied to maritime environments to improve energy-efficiency and safety.

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# Bridge control system manages data better

**TEEMU JEHKONEN AND ANTTI MATILAINEN** – For decades navigators have controlled ships with simple devices. Nowadays, bus technology allows huge amounts of information to be placed in front of the operator. Applying the latest technologies is not mandatory but improves the safety and availability of ship control. ABB's Intelligent Maneuvering Interface (IMI) is a control system that improves the working environment by managing the information flow.

One of the major problems related to bridge control systems is information overload that causes disturbances and leads to loss of situational awareness. Blinking and colorful panels, as well as a variety of beeping alarms and buzzing, are not conducive to a peaceful and comfortable working environment. Minimizing the amount of information in front of the navigator saves his energy for the vital task of monitoring the surrounding traffic. Furthermore, safety can be compromised by control devices that do not give an accurate feeling of the system status and leave room for ambiguity.

The link between the engineers who developed the "old school" control systems and the operators who used them was obviously missing. Navigators used the devices as they saw fit and not necessarily the way the engineers intended.

## Designing usability

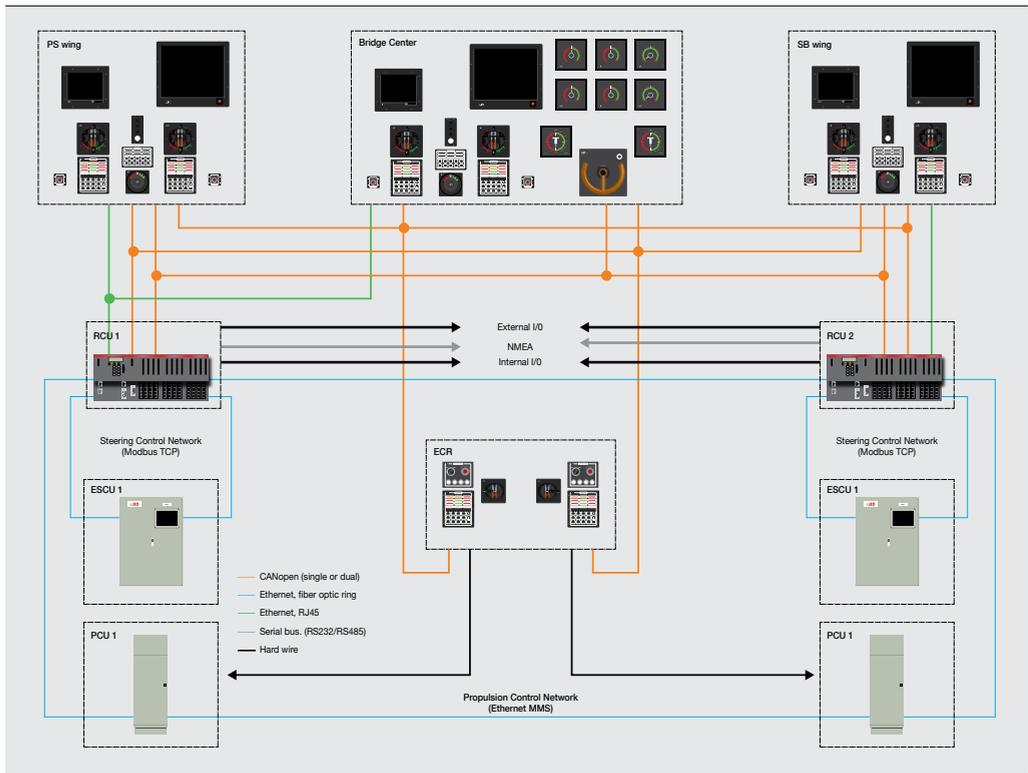
The development of the IMI system was a long-term project carried out with users of different vessel types at an independent research institute. It involved

1 The 800xA High Integrity controller.



navigators spending hours behind a virtual wheel in a laboratory. This showed the design team the reality of the navigator's role and helped it make the right changes in the system interface. The results were consequently confirmed by usability tests in simulators.

The IMI system limits the amount of information available to the navigator according to real need in a particular operational situation because the human



brain can only absorb a certain amount of information at a time. The system guides the operator's focus on the essential controls, selections and indications depending on the user profile. Furthermore, the essential information is not only provided as a visual stimulus. The operator's other senses are stimulated by colors, shapes, sounds, placement of controls and tactile points.

Intelligence comes from advisory messages on the screen, such as warnings for propeller cavitation and unfavorable steering angles. This information helps the ship operator control the vessel in a cost-effective and passenger-friendly way by eliminating undesirable hull vibrations. These features are also related to the life-time management of propulsion.

### Reliability through redundancy

The IMI system is based on the latest bus technology that allows simple cabling and installation. The amount of control devices is thus not limited due to heavy cabling inside the control desk. Redundancy is secured by duplicating the most important buses in addition to

processors and I/O cards. The design is based on the principle that a single technical failure will not put the system's operation at risk under any circumstances. Also, a wide range of optional control areas with separate control units, hardwired backup systems and telegraph devices give the operator confidence.

A critical production phase for the IMI system is factory testing before delivery to the customer. The complete system is assembled for HW and SW testing on a test bridge. This is the first time customers take the wheel, allowing them to give feedback directly to the system engineers.

### Easier to use Azimuth lever

The Azimuth lever is used in Azipod®-powered vessels to control the ship's propulsion motor speed and steering angle. The propeller speed is controlled by moving the horizontal axis of the lever, while the steering angle is controlled by rotating the lever around its vertical axis. The new lever design is easier to use than the existing models and carries ABB corporate branding.

### 3 Test bridge installation



## Facts and features

- Safety through ease of use
- Clear and simple human machine interface for the navigator
- Precise and predictable control for different vessel types
- Programmable feeling points
- Award-winning design

Azipod® units deliver huge amounts of power and the captain on board obviously needs precise and accurate control of these units. The latest technology enables the use of programmable detents (feeling points) in the lever for both RPM and steering scales. This feature gives feedback about the current lever position to the user without him or her having to look at the lever scales. The feedback is generated by stepper motors and allows the navigator to pre-adjust the resistance of movement and position of the feeling points.

The shape of the lever is designed to fit easily in the hand, allowing for accurate and predictable control. The lever direction can always be felt by its shape, giving a haptic reference of the status of the process. The scale lamps can naturally be adjusted to maximize visibility in darkness or in bright daylight.

### 4 The Azimuth lever



reddot design award  
winner 2013

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# IT solutions that boost power plant protection

**BØRRE GUNDERSEN – A safe, reliable electrical distribution system is essential for a vessel’s safety and availability. Traditionally, DP-3 vessels have run the power system in split configuration with open bus transfers to avoid single failures that may cause complete loss of station-keeping capability. However, running the system with a closed, or ring, bus configuration has important benefits.**

**A** power plant is more robust and less sensitive to normal disturbances if the connected power plant is larger, allowing for better utilization of running engines and improving fuel consumption. Even though closed-bus configurations have been applied to DP-3 vessels, there has been a general reluctance towards using them because of the much higher requirements for integrity towards failures and for safety and protection performance.

## **Blackout prevention and recovery**

Blackout prevention and recovery are two of the most critical functions of the electric power plant in a dynamically positioned (DP) vessel. These functions are highly integrated within several parts of the entire system, including power generation, distribution protection, loads like thrusters and drilling, and the automation system. As fuel costs increase and the awareness of emissions also comes into focus in the offshore industry, fuel consumption becomes more important for vessel operators and charterers. Therefore, improving reliability and energy efficiency cannot be seen in isolation.

Since the early beginnings of DP vessels in the 1960s, the understanding and technical capabilities of electric power and thruster systems have gradually

improved, resulting in higher reliability and availability of station-keeping installations. The use of AC variable speed drives for drilling and thrusters, for example, made a major contribution to reducing blackouts during the 1990s because they were better able to control the largest loads.

A range of new products with improved functionality has become available over the years, and the systems in operation today are designed to minimize the risk of blackouts and reduce the blackout recovery time.

However, on the road towards the ultimate blackout-free and energy-efficient design, there will always be room for improvement. The traditional approach to achieving the high integrity needed for a DP-3 vessel is to operate the power plant in two or more systems such that in the event of failure of one system, at least one other system will remain in operation, this will provide sufficient power to maintain position and safe operations until the power system is shut down or restored. The number of system segments will depend on the type of vessel and environmental criteria – they can be split in two, three or four, and in some cases even more. Dual-supply or change-over circuits for thrusters and other critical loads are also used to increase station keeping after a fault.

Running the power plant in split mode is efficient, though not perfect, for mitigating the risk of single failure blackouts.

But there are disadvantages. As the system consists of several smaller sub-plants (segments), each is more vulnerable to disturbances likely to occur during normal operations; the power generation capacity is smaller, and any disturbance is relatively higher than in a closed system. This contributes to a higher rate of failure of a segment of the system, known as a partial blackout. Also, load sharing between segments in a split operation is not possible and the total spinning reserve tends to be higher than in closed systems, leading to sub-optimum load operations of the diesel engines. This reduces the engines' efficiency, and in turn leads to higher fuel consumption, more maintenance and more emissions.

These characteristics of split-system operations are increasing demands to connect the segments together and operate the power plant in a closed radial, or ring, configuration. The trend began already some years ago when drilling operators in particular started to look into the overall commercial impact and effect of going beyond the minimum classification rules, resulting in so-called DP2.5 designs.

Classification societies have now introduced class notations with rules and guidelines formalizing these common sense design criteria. These new rules contain certification criteria and notations for the design of closed-bus, or closed-ring, operations, such as DNV DYNPOS-ER (Enhanced Reliability) and ABS EHS (Enhanced Systems).

Operating the plant with a closed bus-tie requires close attention to reliability and integrity between redundant groups, putting new and more stringent requirements on protection performance, documentation and testing.

The new generation of protection relays that can communicate on the IEC 61850 standard opens up new possibilities for optimizing power plant design and increasing safety.

First of all, the bus communication between each relay and to/from IAS/PMS simplifies the construction of the switchboard, nearly removing the need for interface wiring, both within and between systems. Furthermore, when controllers and protection relays can communicate with the same standard, it makes

it easier to include additional supervisory protection functions, such as Diesel Generator Monitoring System (DGMS) and Power Management Systems (PMS), which can be both physically and functionally integrated within the main SWBDs.

Communication and integration can also be easily extended to include power consumers that communicate over the same network, such as variable speed drives for thrusters and drilling systems. This creates new opportunities for improving the functional integration of load control and blackout prevention. The fast communication between the power producing elements and consumers allows for fast load reduction, reducing risks for blackouts or partial blackouts.

This article will first describe the characteristics of the new protection relays and the power system configuration, and then look at how this improves performance and reduces risks for blackouts.

### **New generation of protection relays**

The introduction of the IEC 61850 standard represents a technology milestone in power plant automation by standardizing and simplifying the integration of protection relays and the power plant as well as process automation.

The standard defines the communication system, data models and abstract services to access data, ensuring interoperability between devices. In IEC 61850-based architectures, conventional wiring has been nearly eliminated and signals are transmitted and received via the communication interface. Thus, the communication interface in the new IEC 61850-based IEDs (Intelligent Electronic Device) must be able to process communication data quickly and efficiently. Two communication methods for data exchange are applied:

- MMS – Client / Server Communication specifies a method of exchanging non time-critical data through local area networks. The use of MMS supports both centralized and distributed architectures. This standard includes the exchange of real-time data, indications, control operations and report notifications.
- GOOSE – Publish / Subscribe Communication, GOOSE (Generic Object Oriented System Event) is used to model the transmission of high-priority information like trip commands or interlocking information. The model is based on cyclic and high-priority transmission of status information.

IEC 61850 uses Ethernet as the basic communication technology. In order to ensure high performance and reliability, a switched Ethernet network architecture is used. Benefits include:

- Real-time network performance to develop deterministic systems
- Security and reliability
- Manageability and ease-of-use features
- Flexible communication topologies
- Use of standard Ethernet protocols, eg, SNTP for time synchronization, SNMP for network supervision and QoS for priority transfer of time-critical data

### ABB's Relion® protection and control product family

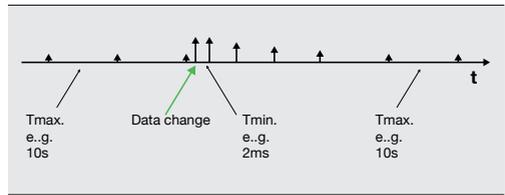
ABB's Relion® protection and control product family was one of the first to undergo the IEC 61850 transformation and was designed from the beginning for a native implementation of IEC 61850. The new platform architecture integrates communication services and data representation into the core protection and control applications. Protection and control algorithms, which provide the protection relay core functionality, are modeled and implemented fully according to IEC 61850 standard rules. The data models are thereby supported directly in the protection and control functions and the data is directly accessible from the communication services. Because no time-consuming additional data mapping and conversion processes are required, data in the protection relay is directly available – a crucial factor in communication performance.

### IEC 61850 Communication, GOOSE

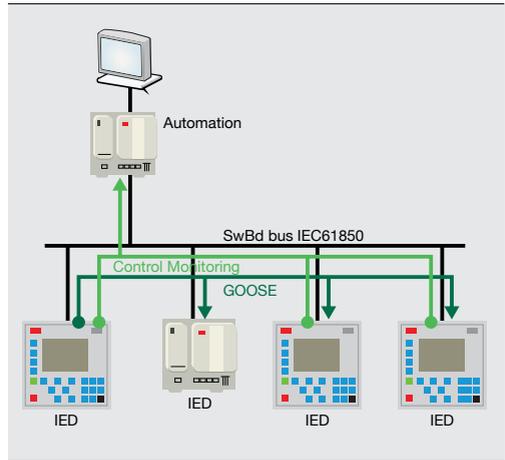
GOOSE is used as a communication method in medium-voltage switchboards between protection relays as well as in high-priority information to the automation system. GOOSE messages are user defined data. When a change in a data item is detected, the data is immediately sent at high priority multiple times to ensure it is received (see Figure 1).

GOOSE provides a fast and reliable peer-to-peer information exchange between the output data values of one IED to the input data of many other IEDs (multicast) based on the publisher and subscriber mechanism. In principle, all measurement and status values can be shared between IEDs and IEC 61850 supporting control systems. GOOSE communication replaces hardwired signals within the switchboard and towards the automation system, making more information available without the need for additional hardware.

1 GOOSE communication time line

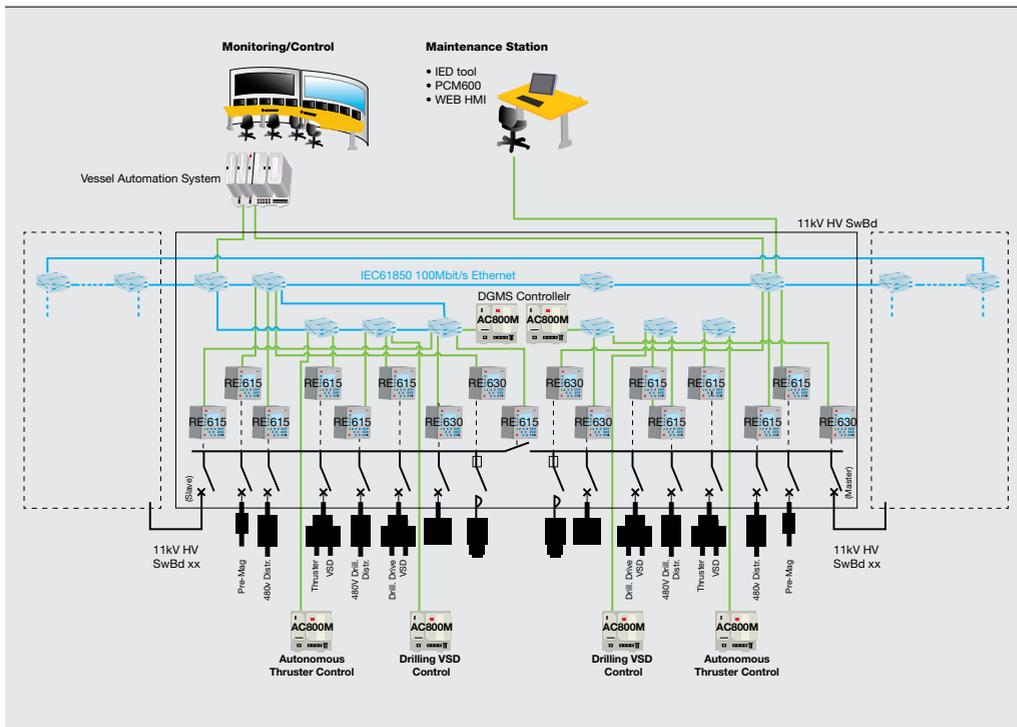


2 Typical communication topology



All measurement and status values can be shared between IEDs and IEC 61850 supporting control systems.

3 In drilling vessels, each sub-system of the power plant is often equipped with a local bus tie. This configuration shows such a typical sub system, one of multiple sections in the total system, connected with bus transfers.



The IEC 61850 standard allows for faster peer-to-peer signaling than traditional hard-wired loops. ABB's new Relion® 615 and 630 series of products achieves the performance class T1AP1 with transmission time <10ms in all normal operating conditions. The high communication performance and increased amount of signals between protection relays makes more advanced protection feasible.

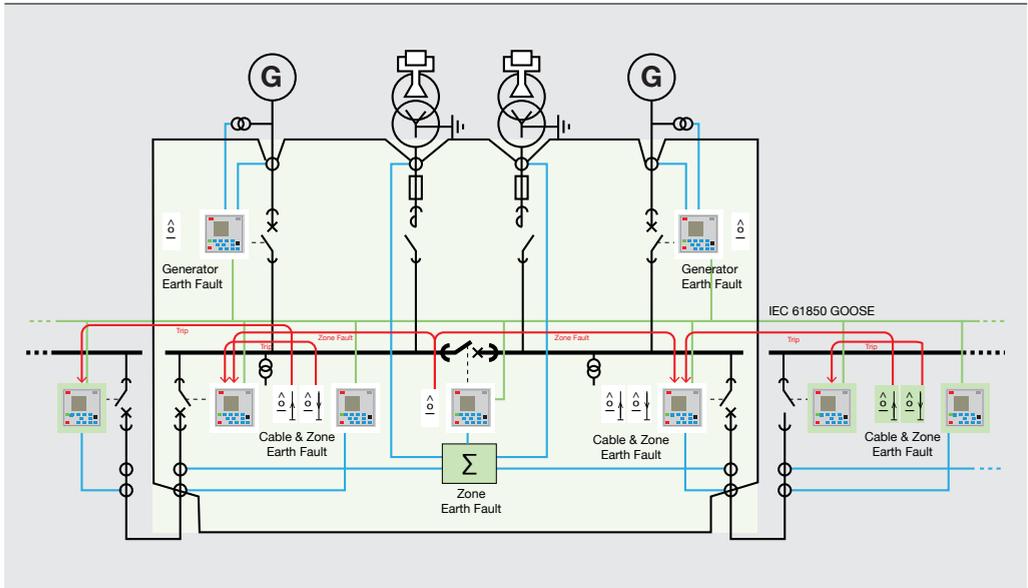
Further benefits of GOOSE communication are:

- Automatically supervised connections
- Connection failures are always detected
- Data quality sent to peer IEDs along with event enable data validation
- Preconfigured fail-safe value in case of failure
- Indication of communication loss
- More I/O without hardware changes or additions
- Expandability
- IED retrofit installations with mall wiring changes
- New functionality can be introduced
- Flexibility
- Possibility for easily adding functionality afterwards
- IEDs can share unused I/O

### Utilizing IEC 61850 in Marine Switchboard Design

Using IEC 61850 in a marine switchboard introduces a common switchboard communication network. The switchboard network is designed as a private, isolated local area network (LAN). On the physical layer, the Ethernet network operates with a speed of 100 Mbps in full-duplex. A switched Ethernet configuration is used where all devices are cross connected through switches. The arrangement of Ethernet switches and the connection between them defines the network topology.

A switched Ethernet provides fast, reliable transmission by giving each device full bandwidth in both directions, forming a collision-free domain. This configuration is crucial for fulfilling requirements for time-critical signal transfer in IEC61850. Redundancy is managed within the communication network by connecting the Ethernet switches in a multiple ring topology. Every Ethernet switch has two inter-switch links. Thus any two end nodes (IED, controller, PC, etc) not connected to the same Ethernet switch have two paths between them when all components are in operation.



All signal transfers between protection relays, signal interfaces to the automation and monitoring system, data communication for diagnostics use this common communication infrastructure. With fast peer-to-peer communication between protection relays, new switchboard protection schemes are feasible. Figure 3 shows a setup of an IEC 61850 configuration in a marine power system.

Advantages include:

- One communication network with one communication standard simplifies the network topology
- Ring communication provides network redundancy and increased availability
- A minimum of hardwired signals reduces yard cabling
- Every signal between protection relays and to controllers is loop monitored, enhancing safety
- Fast peer-to-peer communication between relays and to PLC controller improves the performance
- More information can be transferred, eg, for diagnostics
- New switchboard protection schemes allow for higher fault integrity
- Accurate time synchronization increases traceability and diagnostics after a failure

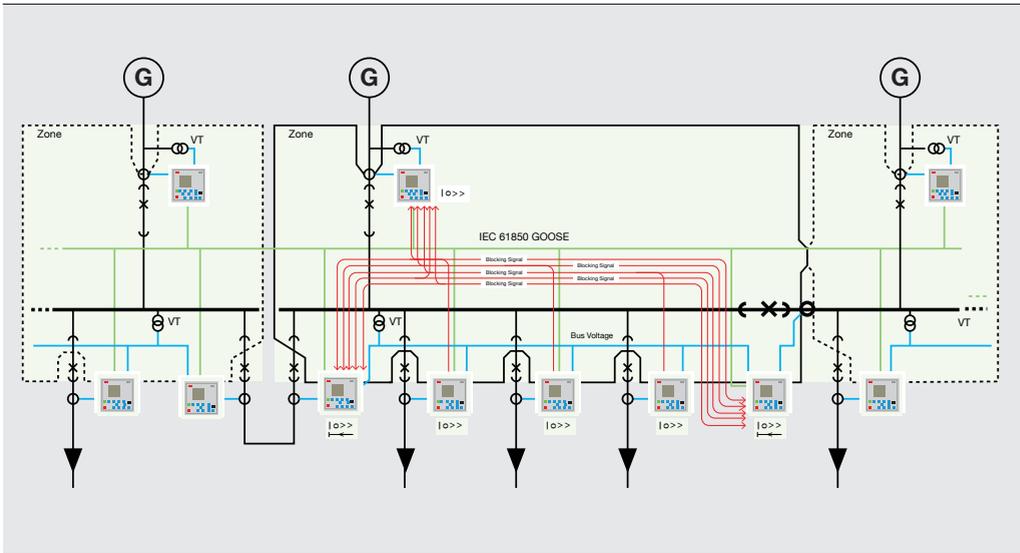
The following three examples illustrate some opportunities.

#### Example 1

Switchboard earth fault zone protection (see Figure 4): Switchboards require multiple signal connections between protection relays within and between switchboard sections. With IEC 61850, most signals are communicated through GOOSE messaging. In contrast to traditional hardwired solutions, the signals are loop monitored, reducing the risk of hidden system and component failures.

#### Example 2

Switchboard short-circuit zone protection (see Figure 5): Blocking-based protection schemes are well-known and widely accepted with the use of hardwired interlock signals, although they are not used much because of the additional complexity and extensive wiring. With IEC61850 and GOOSE, the features are inherently built into the infrastructure. When a fault occurs on an outgoing feeder, the protection and control IEDs of both the incoming feeders and the faulty outgoing feeder will detect the anomaly and initiate protection actions. When starting, the IED of the outgoing feeder, however, blocks the fast-acting stage of the incoming feeder IEDs. In contrast, if a fault arises on the busbar system, the outgoing feeder IEDs will not trigger protection actions and the incoming feeder IED is allowed to operate after a short delay and trip the CB of the incoming feeder. With IEC 61850, most signals are sent through GOOSE



messaging. Due to the number of signals between the protection relays, blocking-based protection is feasible on larger scale than in previous, hardwired configurations.

### Example 3

Alternative actions that isolate the faulty component are vital to maintaining the high integrity and reliability of the system when operating in closed-bus configurations. By using IEC61850 and GOOSE messaging, alternative actions can quickly be issued to back-up protection relay(s). A typical example is if a circuit breaker fails.

A circuit breaker is a necessary component in the fault clearance system. If it fails, an alternative action must be performed quickly to minimize the consequences. If a circuit breaker fails, a backup-trip action must be performed. The protection relay detects the failing breaker and may quickly command a backup trip action to the bus-tie or bus transfer feeders to segregate the faulty system. Due to the high-speed communication of IEC61850 and GOOSE messaging, alternative fault clearance time is much faster than using conventional time-amplitude selectivity schemes.

Advantages include:

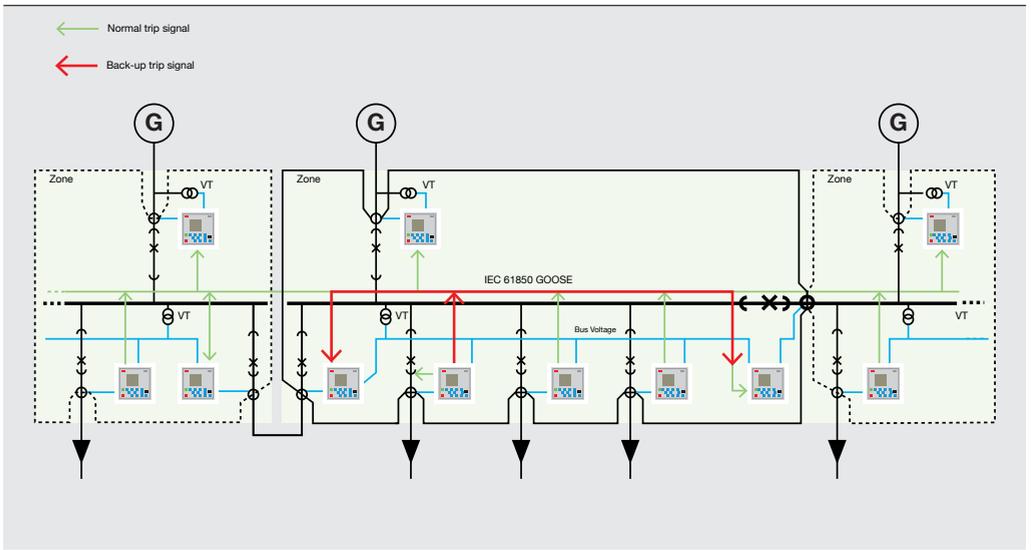
- A fast, robust and easy-to-install busbar protection scheme that can protect the system faster and with fewer installed components than traditional differential protection

- Independency of a central unit; as the protection logic is implemented in the relays, a centralized unit is not needed, reducing vulnerability to its operability
- No additional differential protection CTs and compensation are circuits needed, reducing the complexity and installation costs
- Fast-fault clearance time in the range of 150ms, reducing network disturbances and consequences in power system availability after a failure
- Less wiring and fewer components reduces installation costs, thereby improving reliability
- Loop monitoring and heartbeat signals between relays and self-supervision reduces the risk of hidden system and component failures
- Breaker-failure detection with protection-tripping decision as an alternative action to removing the failure, improving the response time to failures compared with traditional time-amplitude protection schemes

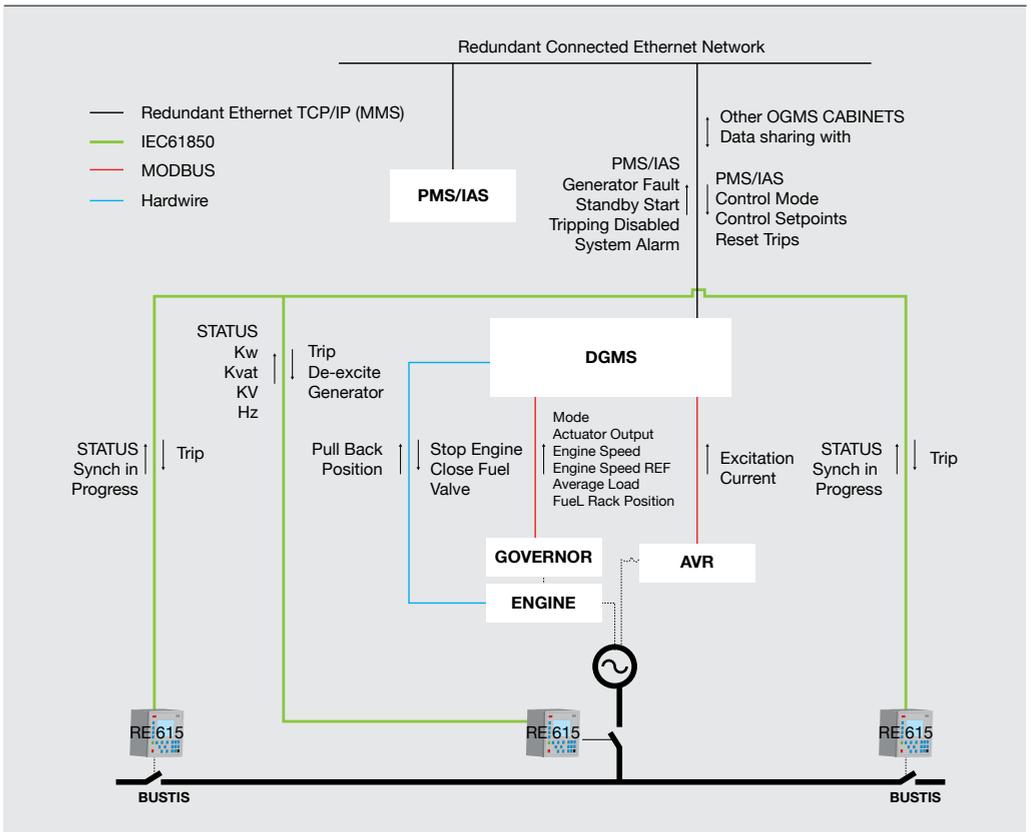
### Interface and integration with power plant control and monitoring systems

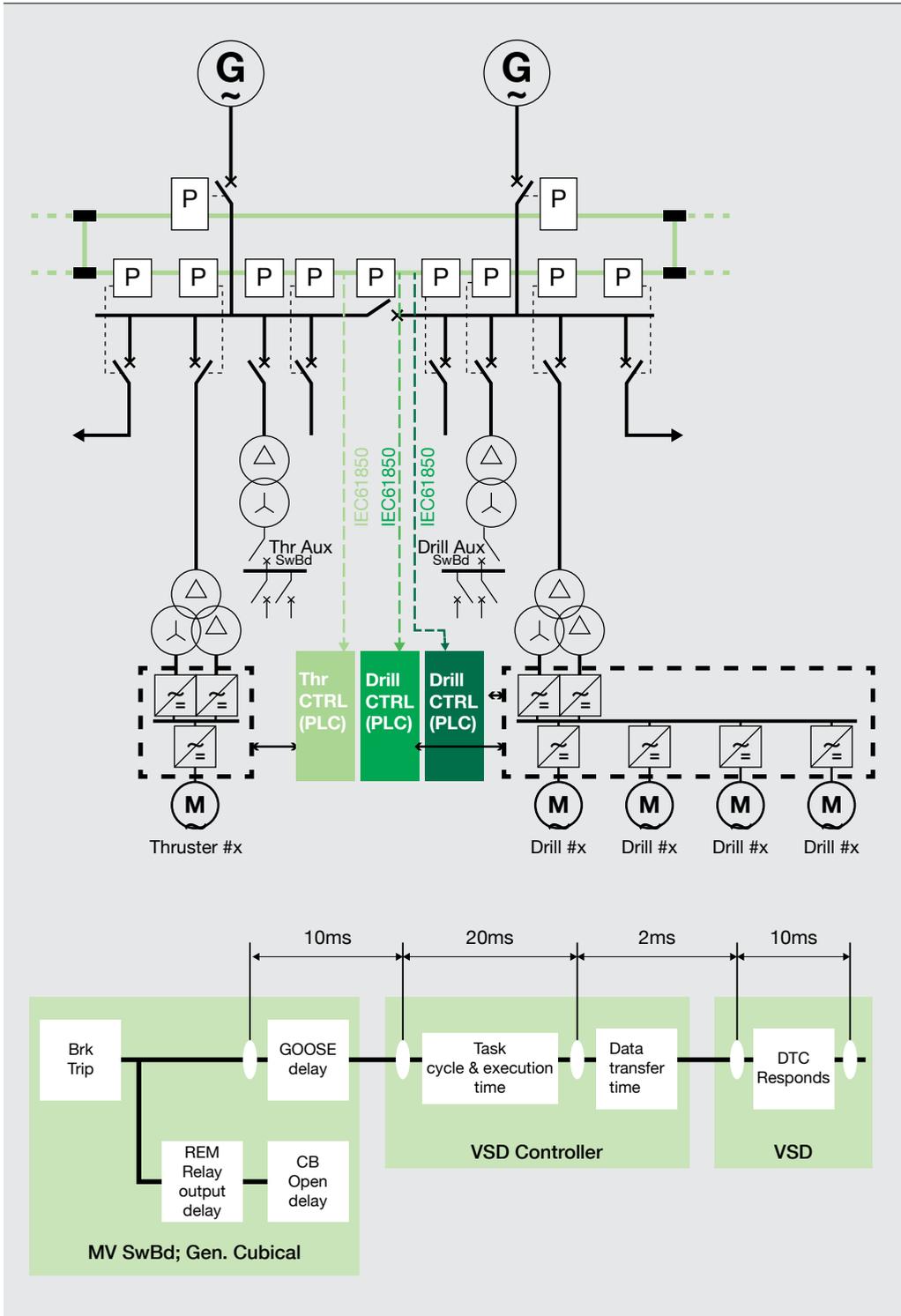
In a marine vessel's conventional power system, the protection of the power plant comprises the protection relays connected to each feeder and incomer of the main switchboard. Furthermore, a higher-level Power Management System is needed to ensure that enough power is available according to actual operating conditions.

## 6 Example of circuit-breaker failure protection



## 7 Diesel Generator Monitoring System integration scheme





This conventional protection scheme focuses on failures like short circuits, over current, over and under voltage and frequency, and earth faults. Lately, more advanced protection schemes are being introduced to monitor and respond to failures that are not directly observed by the protection relays, such as monitoring of malfunctioning control systems in the diesel-generator sets that are not detected by traditional protection methods. These advanced protection systems will typically be implemented in the control systems at a similar architectural level as the power management system.

However, it is important to distinguish between the protection functions and the controlling functions. Protection functions have much stricter requirements for response time and fault integrity because, in most cases, the consequences of a fault become more serious with the time of action. This requires a much tighter integration with the switchboard and its protection compared with the control system. One can also argue that protection and control should be independent from a safety perspective, although independence in this context does not necessarily mean physical segregation.

An interface between the power and vessel management systems and the power plant is needed regardless of the system architecture. The IEC 61850 is a feasible platform for such automation to power system communication, enabling all supervisory control systems, advanced protection, and basic protection to exchange data on the same platform – reliably and quickly.

Furthermore, this also allows for physical integration of the control and advanced protection units inside the main switchboard, reducing the footprint dimensions and simplifying the shipyard's installation and cabling. Figure 6 shows a proposed interface between these systems.

### **Interface to variable speed drive controls**

With the IEC 61850 communication standard, other systems like variable speed drive controllers can also easily be connected to the same network. This means that in practice all information and variables in the power generation and distribution system can be made known also for the consumers. This can be used to design load reduction schemes in the load controllers that are tailor-made for possible power generation events, reducing the risk for blackouts and partial blackouts.

Any of ABB's drive application controllers, such as thruster drives and drilling drives, can communicate via this standard. Figure 7 shows a typical configuration scheme for such an integrated system. The timeline indicates that in case of a circuit breaker trip, actions and responses in the variable speed drive system may be initiated within a range of 50ms, which is also needed for a generator incomer to open. This means it is possible to reduce the load of the thruster faster than it takes to disconnect a faulty generator from the main switchboard. Because a conventional power management and DP system's response time is 500ms to several seconds, that could result in the survival of the power system, rather than a blackout.

### **Summary**

The development of electrical systems in marine applications has mostly been characterized as an evolution with only few major, revolutionary steps. The introduction of variable speed drives in the 1990s was a major change that really did affect the realization of the reliability potential and energy efficiency for propulsion and DP installations.

The introduction of the IEC 61850 communication standard into marine power systems is close to a revolution in electric power plant design. This standard opens up new opportunities for design solutions with improved functionality, performance protection and power system monitoring for marine vessels. Already today, tangible and valuable solutions are ready to be implemented, but the platform itself is a key enabler for functionalities yet to be explored.

For DP class drilling vessels, the standard enables fast and accurate communication between the power plant's primary protection system and the upper-level protection systems, such as PMS and DGMS. For shipyards, this means fewer cabinets need to be installed and fewer cables need to be connected. For operators, this means more accurate and faster protection functionality, improving reliability and availability and reducing stress and damage on components if a failure arises. It also provides for much more sophisticated remote diagnostics of the system, reducing the time it takes to detect and repair a fault.

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# 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.

Availability 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

The screenshot displays the ABB ACS6000 STBD diagnostic interface. On the left, an event log table lists various system events with their family names and timestamps. A specific event is highlighted with a red 'X' icon and a callout box:

Events	Family	Stamp
MCB TripCmd		2012-06-16 00:44:08.804
MCB OpenCmd		2012-06-16 00:44:08.804
DBC POM ChangeReq		2012-06-16 00:44:08.841
EXU OffCmd		2012-06-16 00:44:08.840
INU OffCmd		2012-06-16 00:44:08.804
INU StopCmd		2012-06-16 00:44:08.805
EXU StopCmd		2012-06-16 00:44:08.840
INU Tripped		2012-06-16 00:44:08.840
<b>7NT1 15TL OVERCURR</b>	<b>OCURR.MOTCURR.MOTSPO.MOTTRQ</b>	<b>2012-06-16 00:44:08.838</b>
PUB: INT1 Faulted	- - Warning Without family : 50	2012-06-16 00:44:08.038
7NT1 Overcurrent	OCURR.MOTVLT.MOTCURR.MOTSP...	2012-06-16 00:44:07.888
*AMC: Fault Class 2	-	2012-06-16 00:44:07.885
*NT: Fault Class 2	-	2012-06-16 00:44:07.884
EXU RunCmd		2012-06-16 15:16:51.969
EXU RunCmd		2012-06-16 15:16:51.738

The callout box contains the text: "Fault message indicating an OVERCURRENT Fault detected in INU2 of ACS6000".

On the right side of the interface, the 'ACS6000 STBD' diagnostic panel is visible. It includes sections for:

- Meaning:** First fault of INT: Overcurrent
- Possible Causes:** Overcurrent in a phase, Poor cable grounding or shielding between LEM and CVM2, CVM2 failure, Current scaling print (DCA on CVM2) failure
- Hints for Rectification:** Check IGBT's and Diodes respecting short circuit, Check current (160.07) compared to the trip value (186.01)
- Drive Time:** 2012-06-16 22:42:08.8330
- PSDT Buffer:** Download...
- Related Variables:** A table with columns for Variable, Value, and Stamp. The entry is: Variable: IAC.D1.OVERCURRENT\_TRIP, Value: 0001-01-01 00:00:00

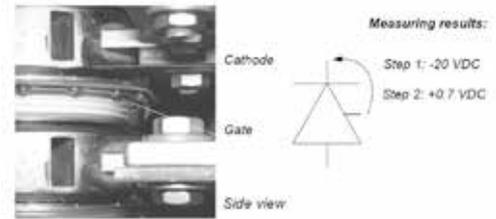
Besides the safety benefits of an RDS, the availability of the system and reduced downtime has a direct economic benefit. But, an RDS is more than just an internet connection to the ship; certain essentials, such as a proper and safe IT infrastructure and organizational support also have to be in place.

### 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.

## 2 Measurement points for testing IGCT



**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).

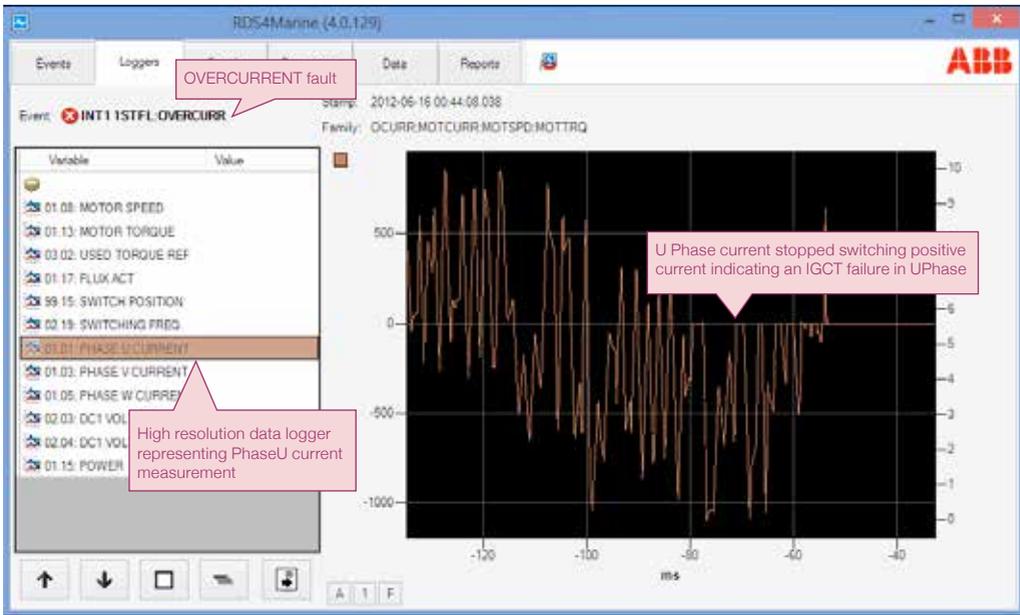
The specialist and chief engineer on board, both of whom had simultaneous access to the information, could together browse through the event list from the frequency converter and discuss this case via the chat function. The result of their shared investigation was to indicate the possible cause to be 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.



**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 triggered 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.

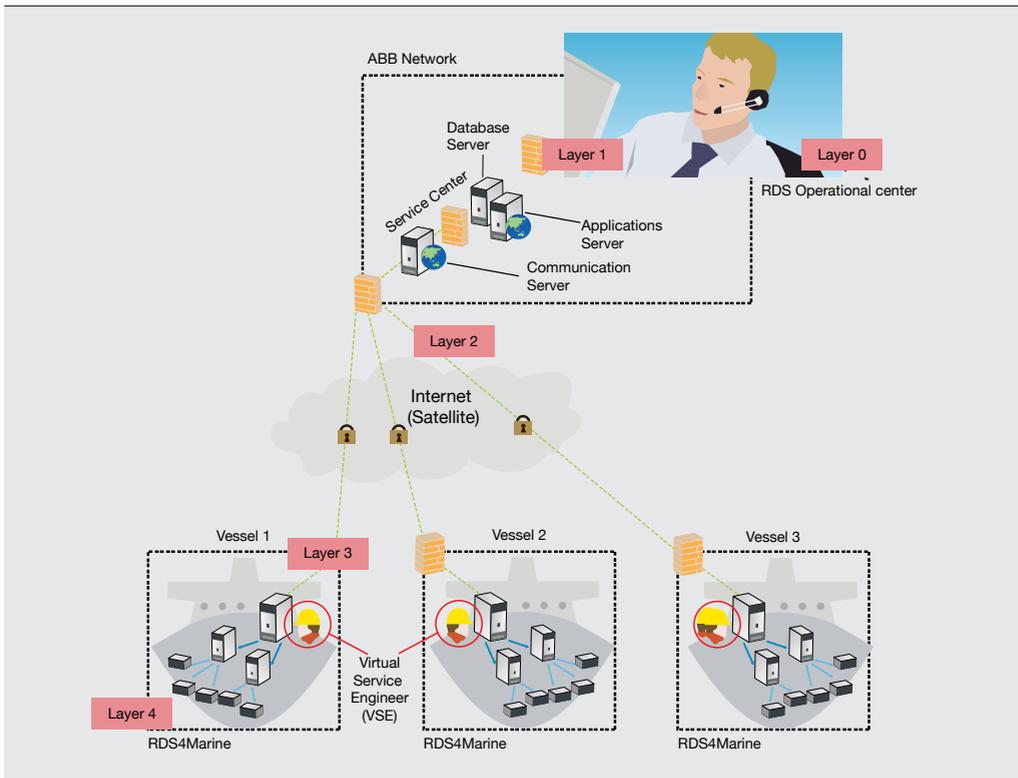
## Sensor fusion approach to deliver preventive techniques

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

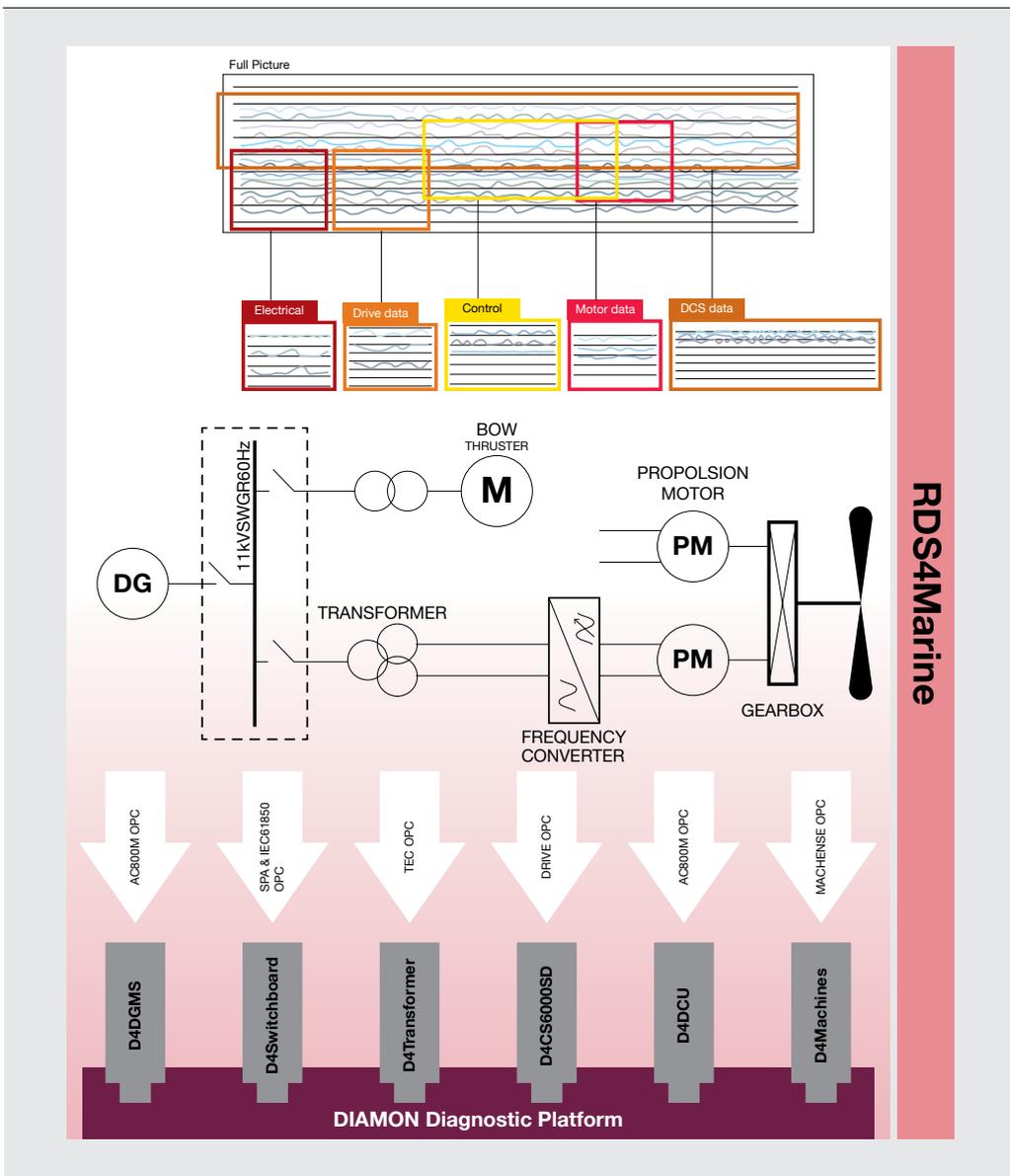
A well-defined business concept and processes, a support organization in place, secure infrastructure for remote access – these are the building blocks of effective remote diagnostic services. The leading performers, however, are tools, a software platform and techniques used on board and that can bring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

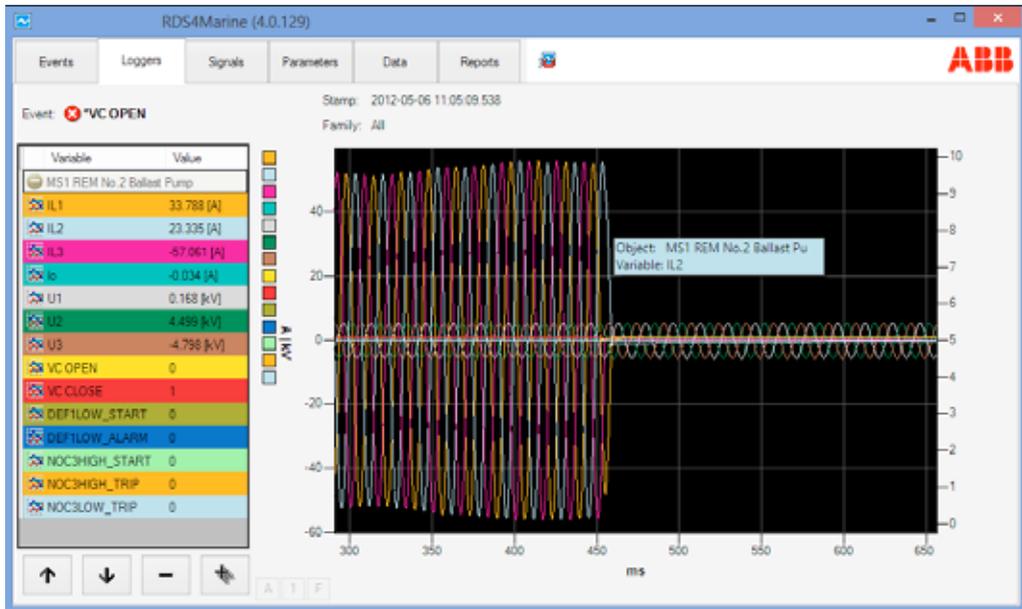
Diagnostics for the DGMS (Diesel Generator Monitoring system) collect alarms, events and signals from the controller running the DGMS application. It may be crucial for the DGMS application engineer to look into the application performance. Therefore, alarms and internal variables are continuously monitored 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 facilitates 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.

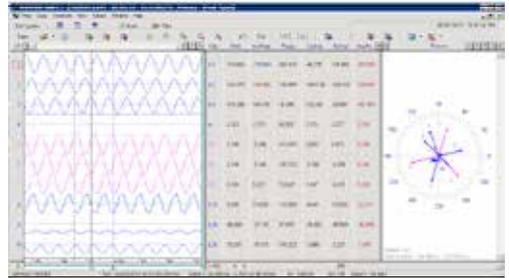
The combination of electrical and mechanical measurements offers almost unlimited possibilities for enhanced condition monitoring. For a long time introducing such advanced techniques was possible only with the use of an off-line system equipped with a number of portable data collectors that could be 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.

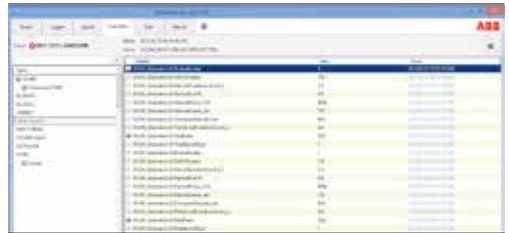
The highest level of asset management methodology that operators want is proactive maintenance. Besides the information that the component is in early fault stage, the system and service provider should also be able to advise to the customer on the remaining lifetime estimation. In other words, operator 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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# OCTOPUS- Onboard: a vital tool for offshore operations

**LEON ADEGEEST – The tasks of an officer on watch a ship or floating structure become even more difficult during the unpredictable and often extreme weather conditions of offshore operations. OCTOPUS-Onboard – the most advanced system for decision support during offshore operations – makes this job easier through continuous monitoring as well as simulation and forecasting.**

**E**ach phase of an offshore installation – DP setup, air lifting, crossing the splash zone, lowering the payload until it is just above the seabed and the landing phase – has different limiting criteria. For example, during landing, the vertical velocity should not exceed a certain value to avoid unacceptable impact loads on the fragile equipment to be installed on the seabed.

Due to increasing water depths of offshore operations, there is also an increasing risk for resonance in the lowering system that could result in large vertical motions when landing or tension in the cables that could lead to overloading or slacking.

Extensive analyses calculate the design sea state in which an offshore operation can be done. A frequency domain analysis can be carried out for a large range of environmental conditions, while a fully nonlinear time domain analysis is only done in certain cases.

These analyses are valuable in the engineering phase to get an idea about how a vessel will operate. During actual operations, however, it is difficult to interpret

the environmental conditions and their impact on the vessel, in particular for the crane tip and the motions of the payload in the hook. The design sea state is therefore only a theoretical description of environmental conditions. When offshore, it is important to be able to monitor and forecast whether motions or loads will become critical for any type of sea state.

The best method is to combine onboard measurements with accurate prediction models for the motions of the vessel, the hang-off point and the payload in the hook. The following sections describe how Amarcon's OCTOPUS-Onboard can help do this.

## **Motion Measurements**

OCTOPUS-Onboard features a flexible motion monitoring system. It can interface with various widely-used motion sensors (MRU5, MRU5+, Octans, MiniPos, etc) and these signals can be displayed within OCTOPUS. The Seven Borealis installation can also read and display the ROV's motion sensor via its umbilical; when the ROV is connected to the subsea structure, the motions of the structure can be monitored. An alarm goes off within OCTOPUS when a certain level is exceeded.

### Virtual Motion Reference Points

An unlimited number of Virtual Motion Reference Points can also be defined within OCTOPUS. It will calculate real-time motions, velocities and accelerations in these user-defined points based on physical sensors. To achieve accurate results for these virtual reference points, very accurate sensors must be configured to accurately measure motions in all six modes, or a grid of sensors such as OCTOPUS TMS-3 must be used.

By using three 3-axis accelerometers spread around the vessel (aft/fwd; starboard/portside; high/low), very accurate motions, velocities and accelerations can be measured in any location.

The difference between virtual measurements and measurements using a physical sensor in the Virtual Motion Reference Points are negligible. However, this is not the case for, for example, the DP's MRU5, which will result in large errors for locations in which all the modes of motion contribute (mainly due to inaccuracies in the rotations as well as filter settings).

When OCTOPUS is interfaced with the crane to receive parameters like the slewing angle and boom angle, the time-varying (x,y,z) coordinates of the hang-off point can automatically be calculated within OCTOPUS. This way, the crane tip can be specified as a dynamic Virtual Motion Reference Point, for which OCTOPUS can monitor the motion, velocities and accelerations in 6DOF.

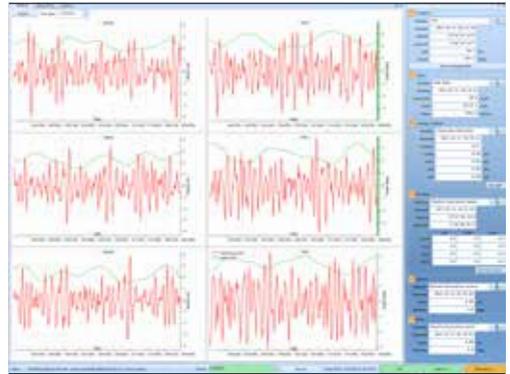
### Recording motions

OCTOPUS can store all measured data on board. However, because this may result in large amounts of data in a short period of time, it is possible to start a motion recording when needed. The data is stored on disk and the recordings (in ASCII format) can be used for off-line analysis and post processing. Pictures 1, 2 and 3 show different screens shots of how motion monitoring can be done (time traces, spectra or spectral parameters).

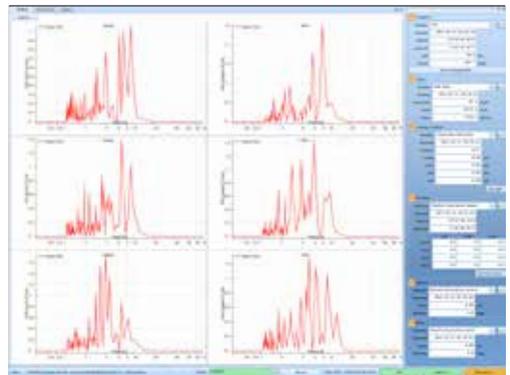
### Dynamic behavior of payload in the hook

The recorded motions of the hang-off point can serve as input for a separate analysis of the motions of the payload in the hook while it is lowered, allowing DAF and loads in the lifting equipment to be calculated offline. On board the *Seven Borealis*, the motion recording of the crane tip is used as input for an offline Orcaflex analysis (similar procedure as described in reference 1).

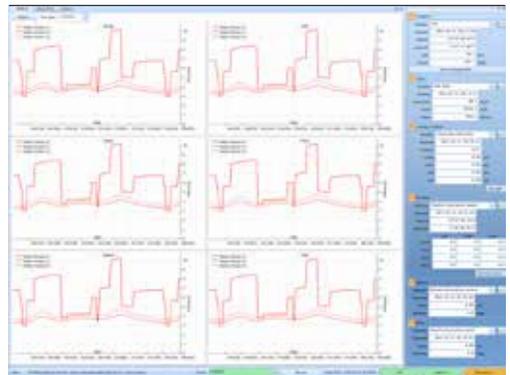
1 Display with motion recordings of physical or virtual sensor positions



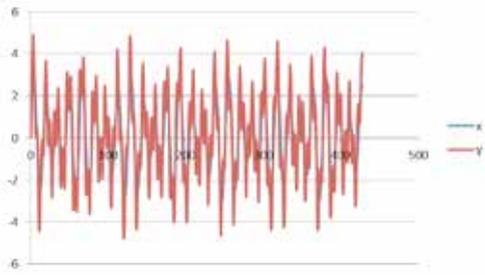
2 Real-time display with spectra of measured motions



3 Display of spectral parameters like Tz, Tm or Tp



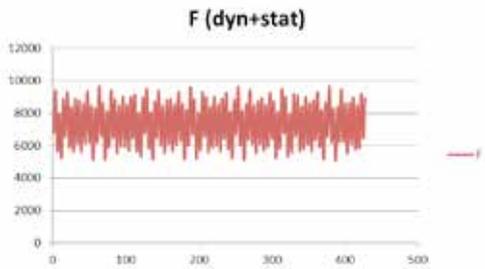
4 Motion at top (x) and of submerged payload (y)



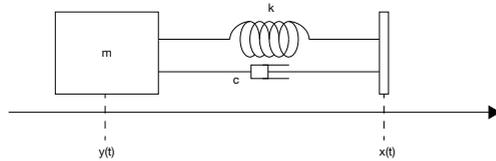
Such post-processing of recorded motions of the crane tip gives the best possible estimate of the situation during actual operation at that moment. When simulation results all fall within the limiting criteria, this is the best possible indication that the operation can be done safely (if the conditions remain constant).  
 Embedded simulation (not implemented yet)

It is possible to implement such a simulation within OCTOPUS, allowing real-time simulation of the motions of the submerged payload. Similarly, the load in the line and the DAF can also be calculated and monitored real time.

5 Resulting loads in lifting wire

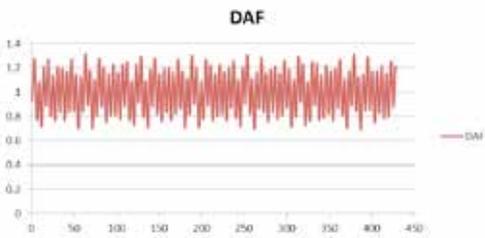


If we simplify the simulation of the submerged load in the hook to a 1D-damped mass-spring model, excited by a vertical motion of the crane tip, the equation becomes very simple and easy to do in real time on board. A schematic model is given below:



$$m \frac{d^2y(t)}{dt^2} + c \frac{dy(t)}{dt} + ky(t) = c \frac{dx(t)}{dt} + kx(t)$$

6 Resulting DAF



In this equation,  $x(t)$  is the vertical motion in the crane tip (known; measured),  $y(t)$  is the vertical motion of the hook with payload,  $M$  is the mass (including added mass),  $C$  is the damping and  $K$  is the stiffness (similar to engineering phase; may be fine-tuned).

This simple differential equation is solved in the time domain using an integration scheme like Runge Kutta f.e.

The tension in the line can be calculated as:

$$F = K (y(t) - x(t))$$

Also, the Dynamic Amplification Factor (DAF) can be calculated in real time:

$$DAF = (F(t) + F_{stat})/F_{stat}$$

Using such an embedded simulation feature ensures that the best possible control is maintained during the actual lowering or lifting process itself (as long as there is no motion sensor connected to the subsea structure).

Figures 4,5 and 6 show an example, simply solved in Excel.

## Planning the operation

Knowing the actual motions through monitoring is one thing. But knowing how the motions can be reduced by changing the heading, or how they may develop over time given the weather forecasts, may even be more important. OCTOPUS is the most advanced tool for onboard motion forecasting:

1. OCTOPUS can use pre-calculated motion RAOs, for example those used during an engineering study.
2. OCTOPUS can calculate the RAOs on board using an actual or simulated loading condition. OCTOPUS motion solver is based on a 3D-diffraction solver (WAMIT or WASIM), nonlinear treatment of viscous damping in all modes of motion, stochastic linearization, anti-roll tanks, etc.
3. OCTOPUS can import various weather forecast systems, wave buoys and wave radars, for which the motion forecast is made for all vessel headings and speeds.
4. Manual input of wave observation is also possible.
5. Motions can be calculated for any number of Motion Reference Points.
6. Motion forecasts and motion measurements can be plotted in the same graph. This makes it very easy for the operator to judge the current situation and compare it with what is coming up, or how the situation on board could be improved by changing the vessel's heading.

## DP-capability forecasts

The best way to enhance a critical lowering operation or lift is to reduce the motions of the crane tip. As explained above, OCTOPUS calculates the motions for any heading and indicates the optimum heading, defined as the heading where the response envelope has its minimum.

The next step is to evaluate whether the vessel really can maintain its position and optimum heading. For that purpose, OCTOPUS calculates the forces acting on the DP system (wave drift, wind and current). Figure 8 indicates which headings the vessel is able to keep based on available and required thruster power. Green indicates where the vessel can keep its heading and position.

## Operational windows

The operational window forecast is the result of post processing the operation-critical RAOs with one or more weather forecasts and applying the limiting criteria.

7 Display indicating the response envelope as a function of vessel heading. Using this display, the operator can easily find the optimum heading, for example the heading where the motion response at the crane tip is at its minimum.

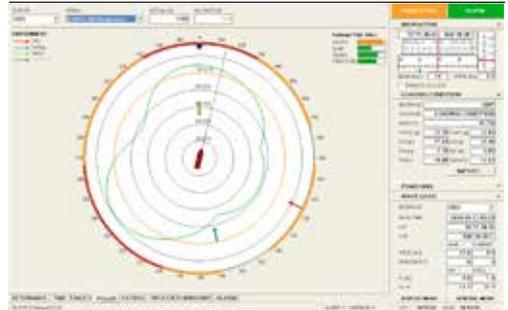
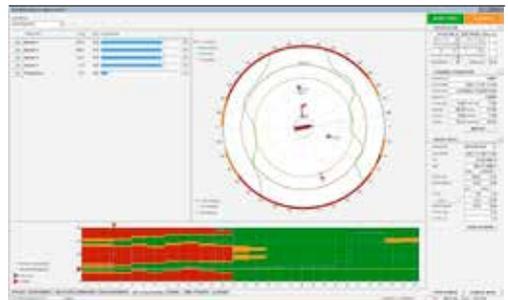
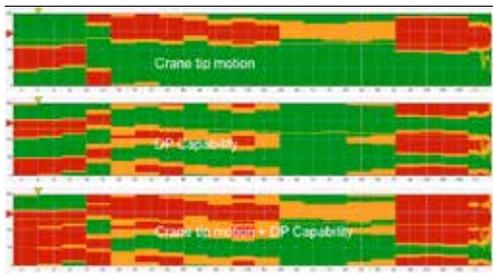


Figure 8: Display of the vessel's DP-capability as a function of heading and time. NB: Sensitivity to available power or thrust can be investigated by reducing or increasing the thrust.



9 Display of the forecast of the operational window. The operational window is defined by the vertical crane tip motion (upper window) and the DP capability (middle window). The lowest graph represents the net operational window.



10 Tracking the vessel.



All data recorded and logged on board is available in statistical form online.

The 2D operational window is plotted below. It consists of two critical parameters: the crane tip motion and the DP capability. The vessel heading is shown on the vertical axis of the graphs. The horizontal axis is the time span of the weather forecast. The graph at the bottom clearly shows how the optimum heading changes over time from NW (330 degrees) via South (after 20 hours) to East (90 degrees) after 24 hours. This is important information when an operation becomes critical and a decision has to be taken to change heading or abort an operation. The same information is also needed prior to starting or restarting an operation, which heading to set up for DP, when to mobilize, etc.

### Sharing information

All the data collected on board is uploaded to a cloud-based database. Status reports, system settings, alarms and warnings can also be made available. All data recorded and logged on board is available in statistical form online. The data includes, when configured, motion measurements, wave measurements, any other connected sensor, weather forecasts, motion forecasts, tracks, loading conditions, etc. All the data can be downloaded in Excel format.

### Summary

OCTOPUS-Onboard is a state-of-the-art system for decision support during weather-sensitive offshore operations, and is actively used in many different types of offshore operations. A typical onboard application for an installation vessel could be as follows:

1. During the engineering phase, design limitations should preferably be established in terms of maximum allowable crane tip motions, loads and DAF (the exact list of parameters depends on the type of operation); and not only by use of design wave limits, which is a back calculation from design loads from the theoretical environmental conditions.
2. OCTOPUS-Onboard is configured to monitor motions, velocities and accelerations in a set of user-defined virtual motion reference points, such as the crane tip.
3. OCTOPUS-Onboard is configured to calculate the RAOs and motion response statistics for the same locations using measured or forecasted waves as input.

4. The recorded motions of the crane tip can be used offline as input for an Orcaflex or SIMO simulation. Motions, line tension and DAF can be checked for actual conditions. These results serve as input to decide whether to start the lowering. A simple 1D-simulation could also be done using a spreadsheet.
5. During the actual lowering, OCTOPUS could calculate real-time line tension, motions and DAF using the measured crane tip motions as input (this feature has not been implemented yet).
6. If the situation gets critical, OCTOPUS-Onboard is used by the Master to optimize the vessel's heading, taking into account the motion forecasts and the forecast of the vessel's DP capability.
7. OCTOPUS-Onboard calculates the operational windows using weather forecasts as input. The calculated operational windows form the basis for the decision whether to start operations, whether the vessel's heading should be changed or whether the operation should be interrupted or cancelled. Any number and combination of responses can be considered when calculating operational windows. Typically, the vertical crane tip motion, roll, pitch and DP capability should be included.
8. Using OCTOPUS as described above allows you to plan better for optimum weather windows, optimize headings, and keep motions, loads and DAF as low as possible over time.
9. All the data can be shared over the Internet within the project team, and operations can be evaluated afterwards using the logged data.

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**References**

1. Legras, J-L., Jue Wang, Criteria for the operation of lowering a structure to the seabed based on the installation vessel motion, OTC 21250, 2011

11 Graphical display of measured motions.



12 Tabular display of measured motions

Time	Vertical Motion	Roll	Pitch	Yaw	Line Tension	DAF
00:00:00	0.000	0.000	0.000	0.000	0.000	0.000
00:00:10	0.120	0.050	0.020	0.010	1.200	1.100
00:00:20	0.050	0.010	0.005	0.002	0.500	0.450
00:00:30	0.150	0.080	0.030	0.015	1.500	1.400
00:00:40	0.020	0.005	0.002	0.001	0.200	0.180
00:00:50	0.180	0.090	0.035	0.018	1.800	1.700
00:01:00	0.080	0.030	0.015	0.008	0.800	0.750
00:01:10	0.200	0.100	0.040	0.020	2.000	1.900
00:01:20	0.050	0.020	0.010	0.005	0.500	0.450
00:01:30	0.100	0.040	0.020	0.010	1.000	0.950
00:01:40	0.030	0.010	0.005	0.002	0.300	0.280
00:01:50	0.130	0.060	0.025	0.012	1.300	1.250
00:02:00	0.070	0.025	0.012	0.006	0.700	0.650
00:02:10	0.170	0.080	0.030	0.015	1.700	1.650
00:02:20	0.040	0.015	0.007	0.003	0.400	0.380
00:02:30	0.110	0.045	0.022	0.011	1.100	1.050
00:02:40	0.020	0.008	0.004	0.002	0.200	0.180
00:02:50	0.140	0.065	0.028	0.013	1.400	1.350
00:03:00	0.060	0.022	0.011	0.005	0.600	0.550
00:03:10	0.160	0.075	0.027	0.013	1.600	1.550
00:03:20	0.030	0.012	0.006	0.003	0.300	0.280
00:03:30	0.090	0.035	0.017	0.008	0.900	0.850
00:03:40	0.010	0.004	0.002	0.001	0.100	0.090
00:03:50	0.120	0.050	0.020	0.010	1.200	1.150
00:04:00	0.040	0.015	0.007	0.003	0.400	0.380
00:04:10	0.100	0.040	0.020	0.010	1.000	0.950
00:04:20	0.020	0.008	0.004	0.002	0.200	0.180
00:04:30	0.080	0.030	0.015	0.007	0.800	0.750
00:04:40	0.010	0.004	0.002	0.001	0.100	0.090
00:04:50	0.110	0.045	0.020	0.010	1.100	1.050
00:05:00	0.030	0.012	0.006	0.003	0.300	0.280
00:05:10	0.070	0.025	0.012	0.006	0.700	0.650
00:05:20	0.010	0.004	0.002	0.001	0.100	0.090
00:05:30	0.090	0.035	0.017	0.008	0.900	0.850
00:05:40	0.020	0.008	0.004	0.002	0.200	0.180
00:05:50	0.100	0.040	0.020	0.010	1.000	0.950
00:06:00	0.040	0.015	0.007	0.003	0.400	0.380
00:06:10	0.080	0.030	0.015	0.007	0.800	0.750
00:06:20	0.010	0.004	0.002	0.001	0.100	0.090
00:06:30	0.090	0.035	0.017	0.008	0.900	0.850
00:06:40	0.020	0.008	0.004	0.002	0.200	0.180
00:06:50	0.100	0.040	0.020	0.010	1.000	0.950
00:07:00	0.040	0.015	0.007	0.003	0.400	0.380
00:07:10	0.080	0.030	0.015	0.007	0.800	0.750
00:07:20	0.010	0.004	0.002	0.001	0.100	0.090
00:07:30	0.090	0.035	0.017	0.008	0.900	0.850
00:07:40	0.020	0.008	0.004	0.002	0.200	0.180
00:07:50	0.100	0.040	0.020	0.010	1.000	0.950
00:08:00	0.040	0.015	0.007	0.003	0.400	0.380
00:08:10	0.080	0.030	0.015	0.007	0.800	0.750
00:08:20	0.010	0.004	0.002	0.001	0.100	0.090
00:08:30	0.090	0.035	0.017	0.008	0.900	0.850
00:08:40	0.020	0.008	0.004	0.002	0.200	0.180
00:08:50	0.100	0.040	0.020	0.010	1.000	0.950
00:09:00	0.040	0.015	0.007	0.003	0.400	0.380
00:09:10	0.080	0.030	0.015	0.007	0.800	0.750
00:09:20	0.010	0.004	0.002	0.001	0.100	0.090
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00:09:50	0.100	0.040	0.020	0.010	1.000	0.950
00:10:00	0.040	0.015	0.007	0.003	0.400	0.380

# Analyzing DP incidents

**IAN GIDDINGS – This article outlines how the International Marine Contractors Association (IMCA) Dynamic Positioning Station Keeping reporting scheme operates and how published reports can be used by various interested parties involved in dynamic positioning such as vessel owners and operators.**

The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies. It was formed in 1995 through the merger of two existing organizations – the Dynamic Positioning Vessel Owners Association (DPVOA) and the International Association of Diving Contractors (AODC).

IMCA's aims are to:

- strive for the highest possible standards with a balance of risk and cost in health and safety, technology, quality and efficiency, and environmental awareness and protection
- achieve and sustain effective self-regulation in the industry
- ease the free movement of equipment and personnel globally
- achieve equitable contracting regimes
- provide a framework for training, certification, competence and recruitment to support and sustain the industry globally
- resolve industry issues
- promote cooperation across the industry

To achieve these aims, the IMCA undertakes a number of functions, including the provision of guidance, built upon best practices from its members and others. Cooperation across the industry is also promoted through the IMCA Dynamic Positioning Station Keeping reporting scheme. Under this scheme, members and others submit reports of DP incidents and from these an annual report is developed with the intention of sharing the lessons learned from these incidents.

## History of IMCA DP incident reporting

The process of gathering and analyzing DP incidents was first carried out as a project for the then UK Department of Energy, which resulted in the production of the document Dynamic Positioning Station Keeping Incidents – An Incident Databank 1980 – 1988 for Dynamically Positioned Vessels used for Diving Support. This document looked at the collected DP incidents from vessels within the diving support sector of the industry. Now with 21 volumes of DP incidents produced over the years, this system has changed into one in which DP incidents from all vessel types are accepted, analyzed and published.

It is interesting to note that the first incidents, of which there were 38, were categorized as incidents while diving, incidents without divers and DP related incidents and the causes as operator error, thruster/electrical and reference/computers. In analyzing these incidents certain principles, which have been adhered to ever since, were established. These were:

- Incident tree, comments, main and secondary cause
- Names of individual vessels, owners and their clients kept confidential
- Information in publication does not enable identification of vessel, owner or client
- Publication made available to all those participating in provision of data

Initial classifications for the incidents were major loss of position, minor loss of position and lost time incidents. However, as the first two were subjective and difficult to develop any definitive criteria for, these

have now been merged within the reports under the heading DP incident. In recent years the IMCA has accepted incident reports from both member and non-member companies and on company reporting forms as well as on the IMCA reporting form, which had been previously developed and used.

The definition of an incident has been amended over the years. In some ways the early definition of “anything that takes the operator by surprise” was more effective in encouraging reporting. The use of deviation distances – or red and yellow DP alert settings as initiators for incident reporting – has proven difficult to use for various reasons. For example, a drilling vessel has a greater acceptable physical deviation than a dive support vessel; thus, a single numerical value for this deviation cannot be developed. However, the Activity Specific Operating Guidelines, as set out in the Marine Technology Society’s DP Operations Guidance, are currently being considered for use as a possible trigger to report.

### Incident analysis process

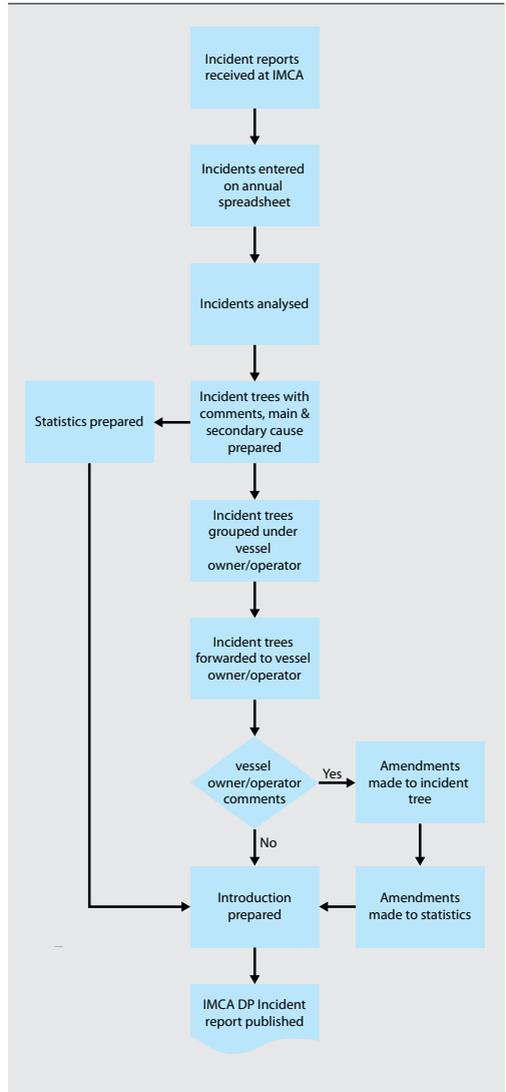
Once the incidents have been collected for a year – varying between roughly 50 to 100 reports each year – they are analyzed in-house to produce an incident tree and to determine the main cause, if possible and if it is not given in the report. Essential features of the incident tree, in addition to the outline of events, are the details of the setup of vessel, namely what generators, thrusters, position reference systems and sensors were being used at the time of the incident.

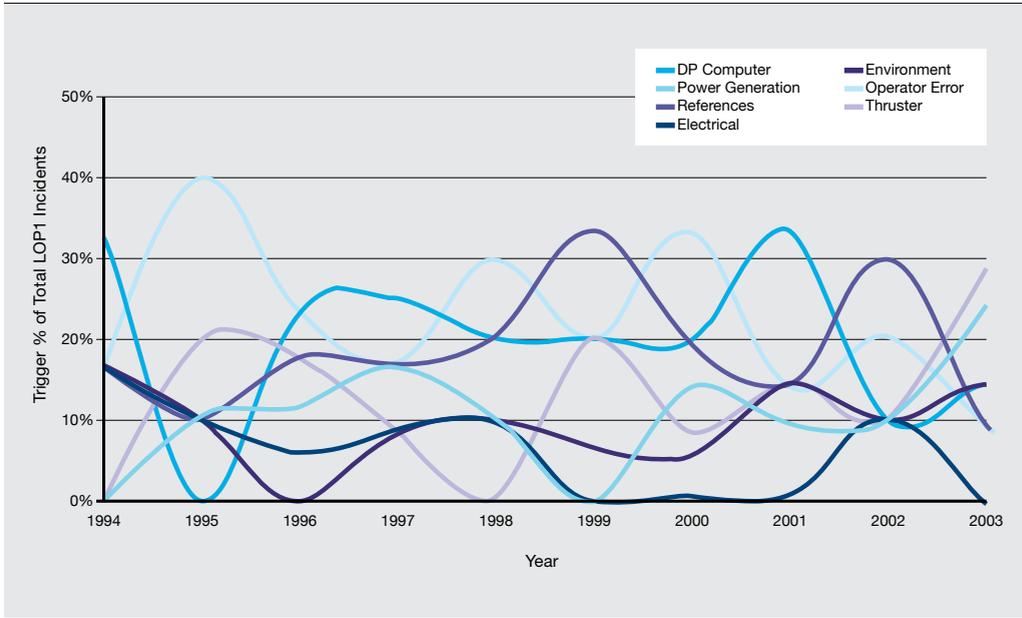
Based on this analysis, if possible, the trigger or initiating event and the main and, if appropriate, secondary cause of the incident are established. Although this may produce the root causes of the incident, this is not always possible, principally because the analysis being carried out is significantly removed from the incident. On occasion, not only the incident report may be received but also supporting material that may include root-cause analysis in which case this can be taken into consideration.

An essential part of the process is the review of the final report by the owner or operator of the vessel to ensure that the incident and its causes have been correctly interpreted. This is illustrated in figure 1.

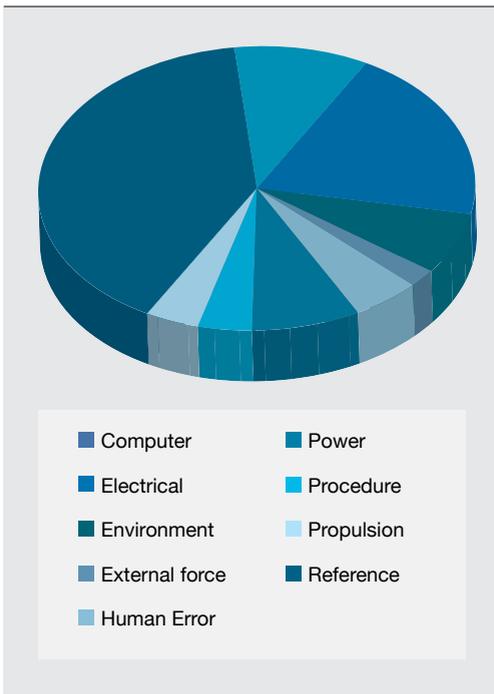
### Statistical analysis

Once the initial inhouse analysis and approval from the submitter have been completed, the statistical analysis can also be completed. This is another area





3 Main causes for the incidents received and analyzed during 2010



that has changed over the years. As outlined above, initially there were three categories of incident cause, whereas now there are nine categories, or 10 if you include undetermined. These are computer, electrical, environment, external force, human error, power, procedure, propulsion and reference.

Over the years, we have also attempted to categorize incidents additionally as DP downtime, near miss and hazard observation. These classes may not have led to an incident but do provide useful lessons. For example, on board a shuttle tanker it was noted that a position reference system being used external to the DP system did not agree with those being used by the DP itself, thus identifying a potential problem.

Although it is not possible to derive some of the more usual statistical information, such as mean time between failures, from the incident analysis, it is possible to look at what appear to be the main causes of DP incidents and at their trends. In addition, a 10-year study has been carried out resulting in the publication of the document Analysis of Station Keeping Incident Data 1994 – 2003, from which the diagram in figure 2 is reproduced.

While this shows the trends, no one area stands out above the others. In this diagram it should be noted

that these incidents were classified as loss of position 1 (LOP 1) or major loss of position. For comparison, the main causes for the incidents received and analyzed during 2010 are in figure 3. Here it can be seen that the largest main cause of incidents are the references, which have contributed significantly to incidents over the years. The aim is to repeat the 10-year exercise for the years 2004 to 2013 in due course, taking into account the changes that have been made in the intervening period.

Furthermore, as this is a voluntary incident reporting scheme, difficulties occur in trying to extrapolate the findings across all DP vessels. It is thought that, for whatever reason, more incidents are occurring than are being reported.

### Computers

In recent years it has been noticed that, as human error as a main cause appears to be reducing as a main cause of incidents, computers are playing a greater role as causes of DP incidents as shown in the incidents outlined below:

	Main causes
2008	Software bug (3 incidents)
	Incorrect current model
	Draught defaulting to zero after confirmation
	Vessel moved ahead of DP model prediction
2009	System software
	Software issue
	Software function error for lamp test & button test
2010	Erroneous set heading parameter in software
	Poor quality control on software
	Software bug
	Virus infecting operator stations
	Software not properly installed

It can of course be argued that most incidents come down to human error, as for example in the incidents where computer software has been determined as the main cause they could be further attributed to the human error in the development and testing of the software. Indeed an incident in which a software virus is introduced into the system through an infected USB device is categorized as a computer main cause as that is where the incident is stemming from. However, the human factors within this incident indicate that human error plays a significant part when a person introduces the USB device into the

loop. Unfortunately, the incident report does not indicate if the process of transfer was normal or indeed sanctioned. So the significant thing at this point is to draw out the lesson, namely not to allow the use of USB devices within the DP system. This is an area DP system manufacturers are investigating for effective solutions to the problem of unintended virus transfer. Furthermore, it seems that software is a cause for concern here and that this is being addressed by the software developers within DP system manufacturers and those offering hardware-in-the-loop (HiL) and similar testing for these systems.

### The future

This brings us neatly to the future. In addition to the further 10-year study being proposed, the scheme is being looked at both in the terms of how the data is collected and how the information is presented. It is hoped that by refreshing the scheme it will encourage more vessel owners/operators to report. As mentioned elsewhere in this article, one issue being looked at is when to report and we hope to bring some clarity to this. Secondly, the output has traditionally been focused on the incident tree. However it is felt that more dialogue, probably before the incident tree, may aid understanding of the incident and the lessons learned.

Finally, there is the question of what to do with the annual reports. IMCA supplies one copy for each of its member's vessels as well as a copy for all who submit incident reports but are not members. It is hoped that the reports do not just end up on bookshelves either on board a vessel or in an office on shore. An example of what can be done can be seen in the approach of one of IMCA's members who reviews the annual incident summary in a comparison process between the incidents and their vessels to determine if any of the incidents are feasible for the vessel. If it is determined that the fault, failure or error is a possibility a recommendation addressing this possibility is produced.

These improvements, it is hoped, will produce more meaningful incident reports and share the lessons learned for the benefit of the sector and the wider industry.

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# Blackout prevention and restoration

**FRANK WENDT – The philosophy of availability by design that underlies new notations and class rules for dynamically positioned vessels applies to other vessel types where safety and availability are essential design criteria, in particular ships with electric propulsion. This article looks at the new rules and how a solution may be designed to meet their requirements.**

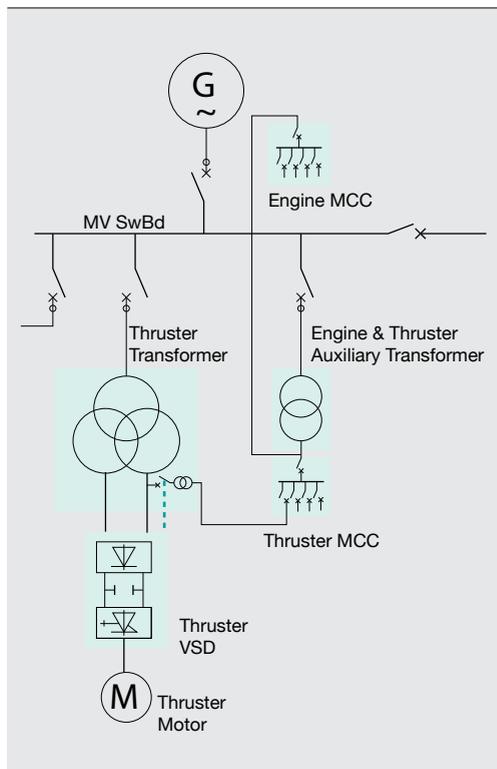
The marine industry continuously strives to increase the level of safety and availability and, at the same time, improve energy efficiency. As a result of this, classification societies are reviewing their rules and regulations to give owners and operators a new technical certification framework. Consequently, new notations and class rules have been issued for dynamic position systems. New system solutions are also being sought within power generation and distribution, particularly for thrusters, and for generator control and protection to allow for more flexible and efficient operation of the power and thruster plant. Solutions might be based on the availability of new technology or on well-proven technologies rearranged and combined to achieve the required performance and functionality.

## Generator and thruster auxiliary power distribution

Generator and thrusters and their auxiliaries should be as independent as practically possible. As a design philosophy, the split in the auxiliary power system should follow the split of the main power distribution switchboard.

The separation of auxiliary distribution systems between the individual generator and thruster sets makes the power plant and thruster system more fault tolerant with respect to single failures. A failure within an individual auxiliary distribution should not propagate to other independent systems. For separation, the individual systems have to be supplied by their own dedicated auxiliary distribution transformers. The configuration improves the system with respect to the requirement for autonomous auxiliary systems for thrusters and generators and increases the robustness of these critical systems.

1 Principle of dedicated generator and thruster auxiliary transformer



A generator and thruster set that is connected to the same main switchboard section can share one transformer since they belong to the same redundancy group. For a drilling vessel or semi-submersible drilling unit, such engine and thruster auxiliary distribution transformers will typically be in a range of 500 – 750kVA.

A relatively small transformer offers several advantages. The fault current in the system is lower. The transformer can remain connected to the main switchboard during blackout, making auxiliary power to the engine and thruster immediately available after power on the switchboard has recovered. This is due to the low inrush current of a smaller transformer, which results in negligible network disturbance.

With the immediately available power, the auxiliary distribution transformer can be used as a pre-magnetizing power source for large transformers like the thruster supply transformers. Pre-magnetizing of thruster supply transformers enables fast restart of the thruster system. Such configuration also enables better service and maintenance for the thruster VSD system as thruster auxiliary and thruster VSD can be energized independently; eg, the thruster auxiliary can be operated without energizing the thruster frequency converter and transformer. In addition, the generator and thruster systems can be tested individually.

### Autonomous thruster control

Enhanced power systems require independent and autonomous thruster systems. Independence is not only related to independent auxiliary provisions but also for independent protection and decentralized control functions of the main and auxiliary systems. In the decentralized and autonomous control architecture, the thruster drives are capable of making themselves ready for operation with all the necessary services available on request from a remote control system or as an auto-restart after power blackout.

The thruster drives controller directly controls the associated auxiliaries. With individual auxiliaries, application controller and protection for each thruster is independent of the other thrusters as well as the centralized control systems. A failure within the auxiliary system or control will only affect the associated thruster. Such systems are considered to be more robust and fault tolerant.

Autonomous control is based on ABB's common marine type approved automation architecture for distributed control system. Each thruster is controlled by an individual application controller that is equipped with all necessary IO modules and communication modules as a process interface to the main and auxiliary equipment. An interface is provided to other higher-level vessel control systems for remote and manual controls as well as monitoring. The application controller contains all software for protection and autonomous control of

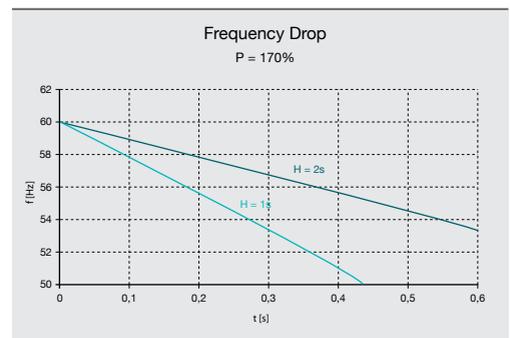
the main and auxiliary system including functions for blackout prevention and fast blackout restart.

Within an ABB vessel automation system, the thruster application controller can be seamlessly integrated through a communication network to other vessel control systems and operator stations. For integration into a third-party centralized controller system and operator station, various standard fieldbus systems are available.

### Fast-load reduction

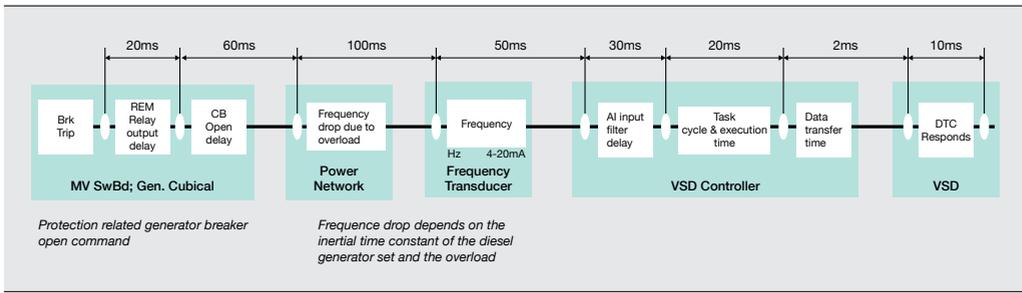
One basic design requirement for the power systems is that no single failure causes total blackout. In vessel operation modes with closed bus-ties configuration between the main distribution switchboards, a sudden loss of one or more generator sets is a typical single failure scenario where the remaining generator sets in the power plant will be exposed to high and fast load steps and possibly overload. A diesel engine has a limited capability to instant load steps, which is in the range of 33 percent of nominal load and overload. The limited power output response is a result of delays in turbocharger, fuel supply valves and automatic control and, as a consequence, causes the diesel machine speed to slow down. The slow-down impacts the network frequency and voltage, causing both to drop. The slope of the speed and frequency drop is mainly determined by the inertial time constant of the rotating parts of the diesel-generator set and actual load of the diesel engines.

2 Frequency drop for gen-set with inertial time constant  $H=1s$ ,  $H=2s$  and 170% load

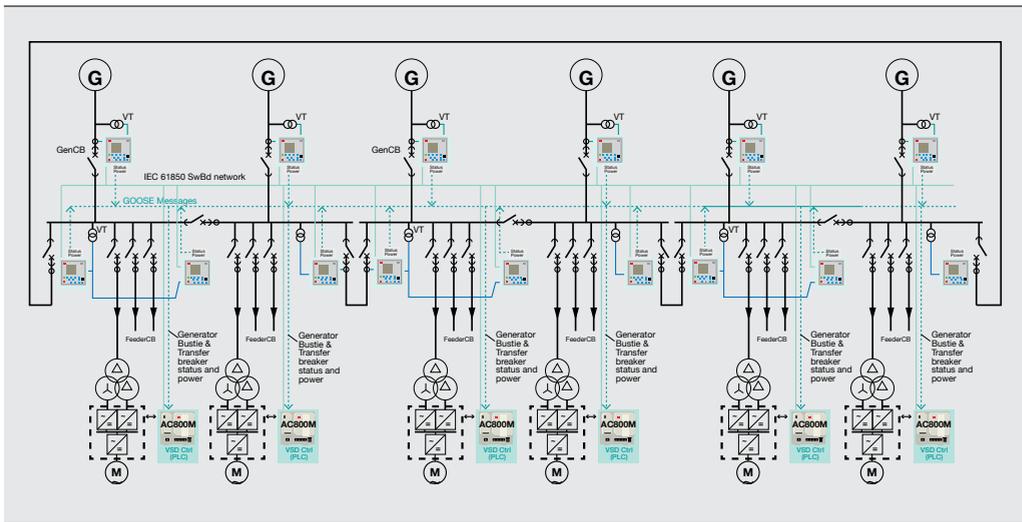


Without fast corrective action, the speed and output frequency of the remaining generator sets could drop below the under-frequency trip limit causing the failure to escalate from a single component failure to a complete system failure with total blackout. A corrective action is to implement a fast-load reduction

### 3 Time responds of the frequency based load reduction scheme



### 4 Example communication connection and signal transfer between MV switchboard and thruster VSD control



scheme in the loads, in order to reduce the load step and potential overload of the generator sets.

Load shedding of non-essential consumers that is initiated by the power management is considered to be too slow to prevent potential escalation in case of high overload. In practice for today's vessels, the amount of such sheddable power is not enough to prevent escalation of the failure.

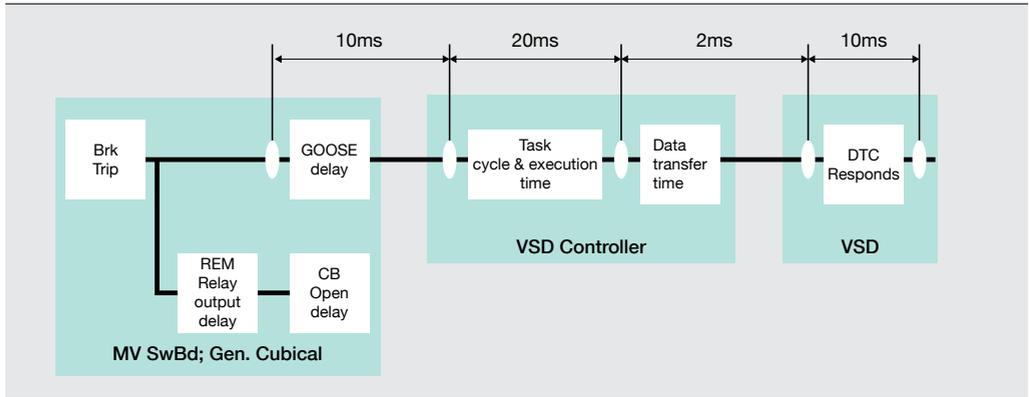
In the past, the network frequency was used as an indicator of generator overloading status. Fast load reduction was achieved by constantly monitoring the net frequency directly in the thruster and drilling variable speed drive (VSD) control systems with immediate power limitation in case the net frequency dropped below a defined threshold. The thruster and drilling VSDs are the largest power consumers in the power plant with the ability for fast and large load

reduction. The disadvantage of this method is that the thruster and drilling VSD load reduction function only gets activated after the network frequency has dropped and the condition has deteriorated; meaning that the protection lags behind the failure event.

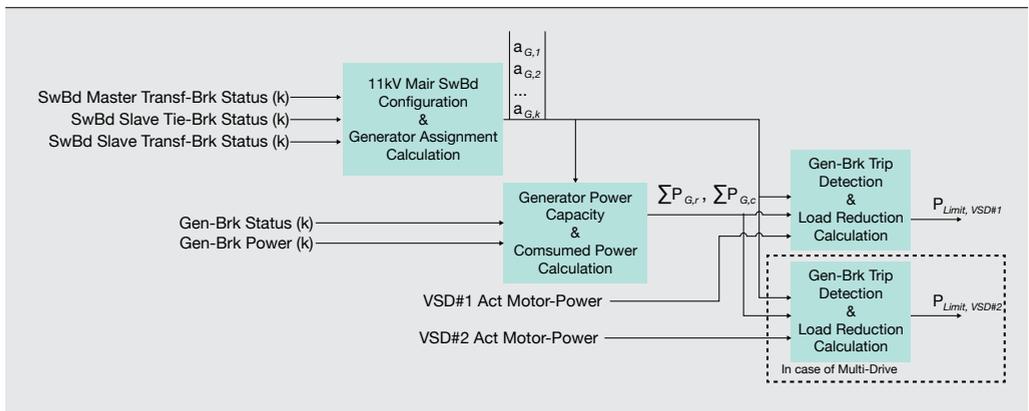
The alternative and faster solution is to use an event-based load reduction scheme. An event-based fast load reduction (EBFLR) function is decentralized and installed into each VSD application controller. Each VSD application controller directly receives the transfer and bus-tie breaker status information from all main switchboards as well as all generator breaker status and active power information.

With fast peer-to-peer IEC 61850's GOOSE communication interface between the main switchboard system and all VSD application controllers, fast program execution, fast communication between

## 5 Time responds and latency of the event based fast load reduction scheme



## 6 EBFLR principle load reduction algorithm



application controller and VSD and VSD DTC motor control with fast torque responds, the load reduction reaction time is reduced significantly.

In case of a sudden generator trip, the same trip signal that opens the generator breaker is transmitted to each VSD application controller through a GOOSE message. The generator trip event is received simultaneously by all VSD application controllers. Based on the transfer and bus-tie breaker status, the application controller calculates whether the tripping generator contributed to the VSD power supply and if so, it triggers the load reduction response.

The application controller calculates the amount of power to be reduced in the VSD to avoid generator power plant overload. A torque limiting signal that correlates to the required power reduction is sent to the frequency controller via a fast communication

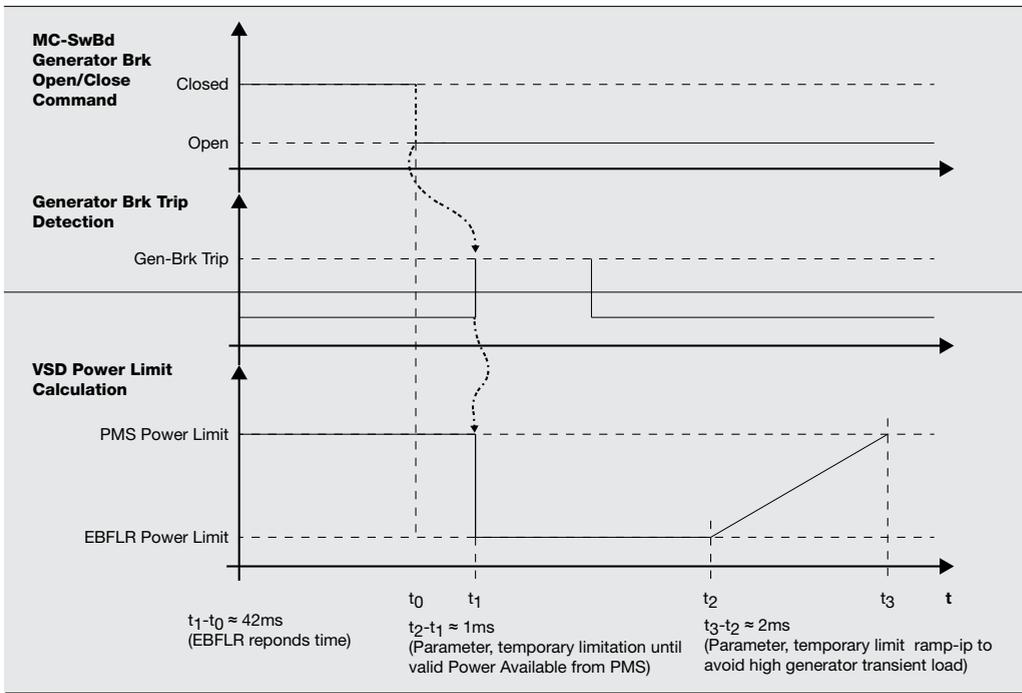
link. The fast direct torque control (DTC) motor control software reduces the motor torque and consequently the consumed motor power. The applied load reduction is dynamic and kept active until the centralized PMS system updates the power limit signal to the VSD controller. The PMS VSD power limit update time is considered to be in the range of 0.5 to 1 second. In order to avoid generator load transient, the VSD power limit is ramped up in a controlled manner.

With EBFLR, the load reduction reaction time in the VSD is pushed to a time limit that corresponds to the generator circuit breaker opening time. At the moment the generator is disconnected from the main switchboard, the load in power network is reduced.

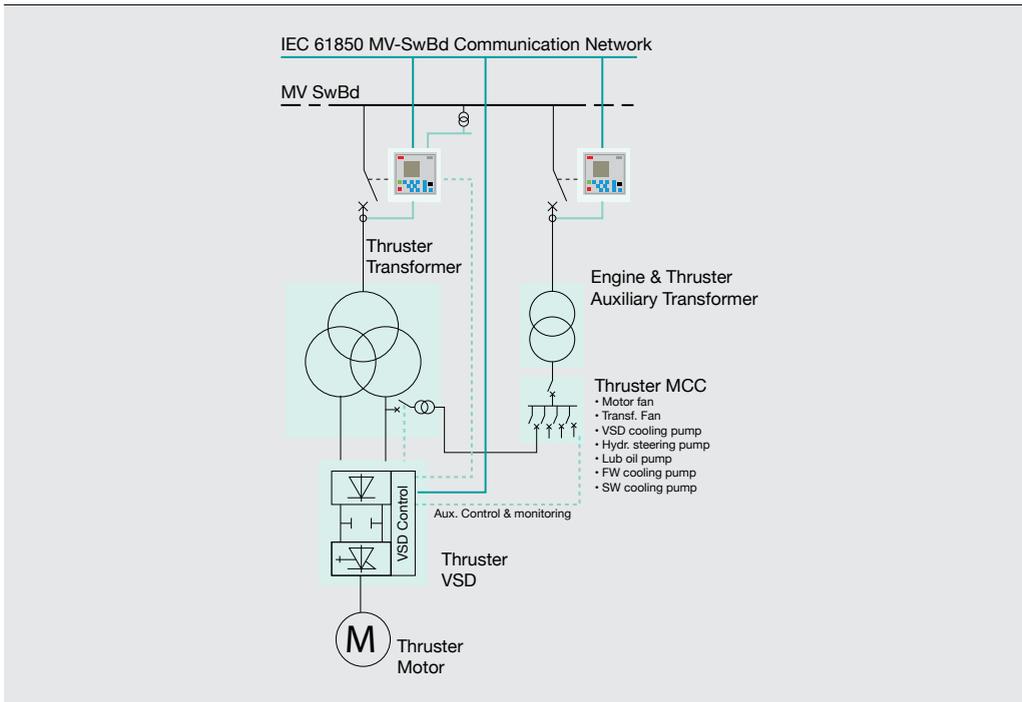
### Thruster blackout restart

In a partial or total blackout situation, the generator and thruster system will be capable of automatic full

7 EBFLR load reduction



8 Autonomous thruster system



recovery and thrusters will be ready for DP within 45 seconds of a blackout (requirement given by DNV in DYNPOS-ER class notation, ABS EHS-P notation 60s). The blackout recovery sequence can be divided into three main sequential steps:

1. Blackout detection and generator restart
2. Reestablish of the power to the distribution network
3. Thruster VSD and thruster auxiliary restart

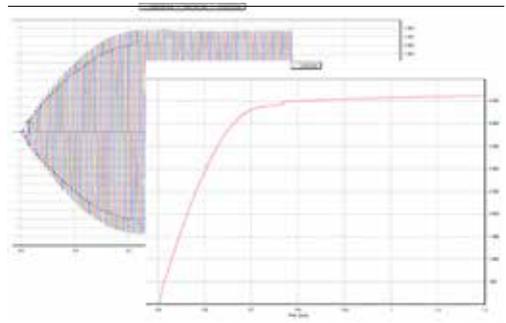
When a blackout occurs, all generators, large thruster and drilling VSD supply and distribution transformers will be disconnected from the main switchboard. The transfer circuit breaker between main switchboards will also open. The dedicated diesel and thruster auxiliary distribution transformers remain connected to the main switchboard.

The opened transfer circuit breakers segregate the switchboard sections during blackout. Restoration of power will be independently controlled for each switchboard section by the power management system (PMS). Immediately after blackout is detected, the PMS will start all available generators, connect them to the main switchboards and restore power in the distribution network. By using dedicated diesel and thruster auxiliary distribution transformers, auxiliary and pre-magnetizing power is immediately available after the first generator is reconnected to the main switchboard.

The autonomous thruster control detects that the main switchboard and thruster auxiliary distribution are energized and starts the thruster VSD related auxiliary simultaneously. To avoid surge current, the VSD with the dc-intermittent circuit has to be charged before the VSD can be connected to the main switchboard. By utilizing the thruster transformer pre-magnetizing circuit also for the pre-charging of the VSD dc-link as well, the charging time can be reduced dramatically to approximately 1 second. The transformer magnetizing and dc-link charging is monitored in the VSD. The fully charged dc-link indicates that the voltage at the transformer winding is built up and the transformer is pre-magnetized.

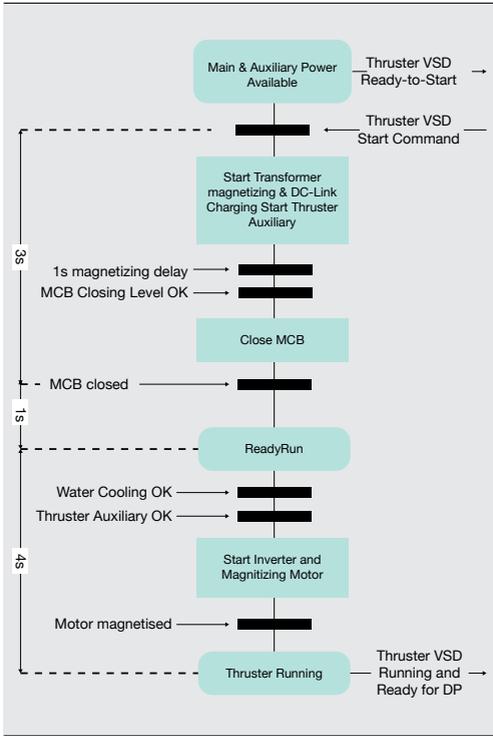
With charged dc-link, the circuit breaker to the thruster supply transformer will be closed. The VSD is energized and ready to start the thruster motor. After internal cooling and the thruster auxiliary have been confirmed, the motor will be started. The electrical motor has to be magnetized before the VSD can be released for remote control. The thruster restart

9 Transformer secondary voltage and dc-link voltage during pre-magnetizing and charging



When a blackout occurs, all generators, large thruster and drilling VSD supply and distribution transformers will be disconnected from the main switchboard.

## 10 Thruster start sequence



sequence is finished when the motor is running and ready for DP operation status.

In previous thruster VSD configuration, the thruster restart time was mainly depending on the dc-link charging time and the sequence logics handled by the centralized vessel management controller. Using the pre-magnetizing circuit for the VSD dc-link as well, the thruster charging start and restart time is shortened to a minimum and kept constant and independent from the power plant recovery timing. With approximately eight seconds restart time, the total blackout recovery time will largely depend on the diesel generator start time, and be less dependent on the centralized sequence control.

As the industry requires higher levels of safety and availability of the electric power plant, which is essential for the safe and continuous operation of the electric propulsion system or dynamic positioning, classification societies are issuing rules, regulations and guidelines that take into account the means to increase safety, not covered by previous rules. New notations are introduced that define a framework for designers, builders, owners and operators. Suppliers also receive verification by a class notation that the additional safety features meet defined criteria.

Much of the rules are focused on blackout prevention and recovery, as these are two of the most critical features for safe operation. Other rules are also made to increase awareness and quality control of software development and hardware in the loop testing.

ABB welcomes this trend in rules implementation and acceptance by the industry. In the past, much of these developments have been made in direct cooperation with designers and operators; while these evaluations are now starting to be formalized as technical rules. It is still expected, though, that as new framework is beginning to be defined, the rules will need to be revisited and requirements aligned with each other and adjusted. This will come with experience and findings from the practical use of the rules.

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# DGMS monitors more failures than basic systems

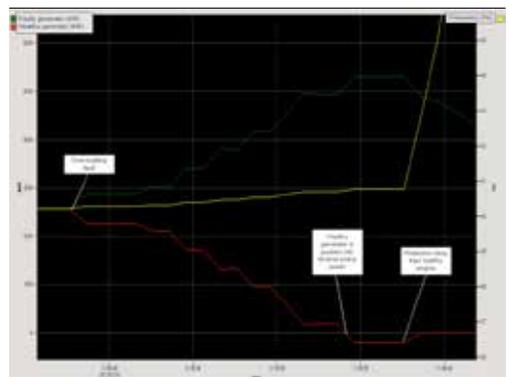
**OLA HOLTER HJUKSE – The Diesel Generator Monitoring System (DGMS) enhances the monitoring of diesel engines and generators for failures that basic protection systems do not monitor, thereby avoiding classic “black-out” situations, where healthy diesel generator sets are brought down by a faulty set. The system is also well integrated with the switchboard protection.**

Power generation is one of the most important parts of the design of diesel electric power plants for marine and offshore applications. The traditional approach of protecting against abnormal behavior and blackouts has been to split the power plant into several independent units and install dedicated protection relays for each generator.

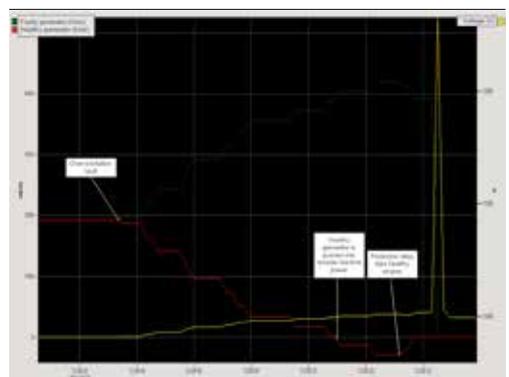
This protection scheme works well for isolated generators but for generators operating in parallel it can result in new faults not easily detected by traditional protection; typically over- and under- fuelling and excitation.

There are several reasons why such faults might occur, eg the quality of diesel, mechanical faults in the fuel rack, and AVR failures, but the result is the same: the generator delivers too little or too much active or reactive power to the power plant compared with the other generators. This might lead to a cascading fault on the generation plant as the other healthy generator sets will adjust their performance to compensate for the faulty generator. In the worst case, the faulty generator can force healthy generators into reverse active or reactive power or into delivering more power than nominal. The traditional protection will, if the point of operation exceeds protection limits, trip the healthy generators and the faulty generator will be left alone in the network. This will lead to a blackout as

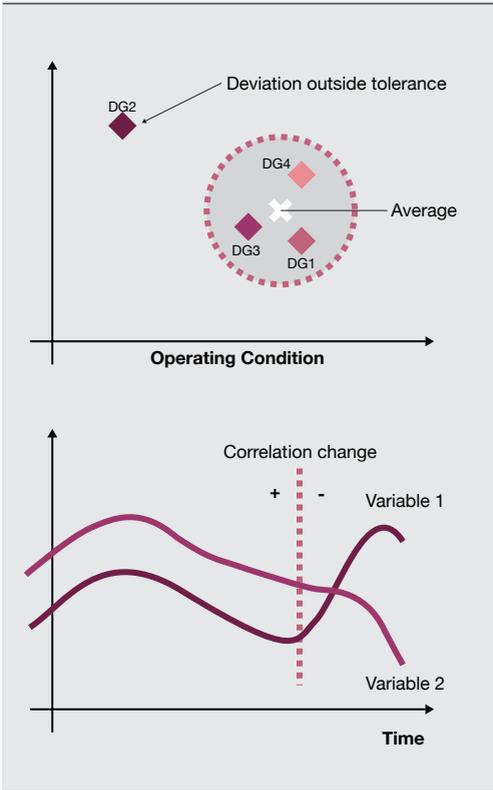
1 Trends showing over-fuelling



2 Trends showing over-excitation



### 3 Illustration of weighing and correlation functions of DGMS



this generator will be unable to control the production of active or reactive power to meet the load demand, and voltage and frequency will become uncontrolled.

#### DGMS protection

The DGMS addresses this issue by monitoring all connected generators simultaneously and comparing each individual generator performance with the expected behavior, as well as comparing it with the other generator sets connected to the same network.

These two monitoring functions may be referred to as correlation functions and voting functions (see Figure 3). A correlation function will monitor the behavior of two or more variables that are expected to behave in a certain way, triggering an alarm if they deviate from this expected correlation. The voting function needs three or more units in the same system, as it detects abnormal behavior by comparing each unit with the behavior of the other units.

To simplify, abnormality is used in active power generation as an example and the failure scenario

where the engines are exposed to a fault in their fuel feeding system.

For fuelling faults that occur when two generators are operating in droop mode, the DGMS looks at the delivered active power and frequency of the generators and compares it to the nominal frequency droop curve. If a generator moves away from the nominal frequency droop curve, it is indicated as faulty; hence correlating the frequency with the produced power.

The detection of fuelling faults on two generators operating in isochronous mode is more complicated as typically the frequency will not change enough to be an indicator of fuelling faults. The DGMS then uses the control signal from the governor to fuel-rack as an indicator instead. This signal will deviate from normal values on the faulty generator as the governor load control will try to force the fuel-rack up or down; hence correlating the command signal with the output signal.

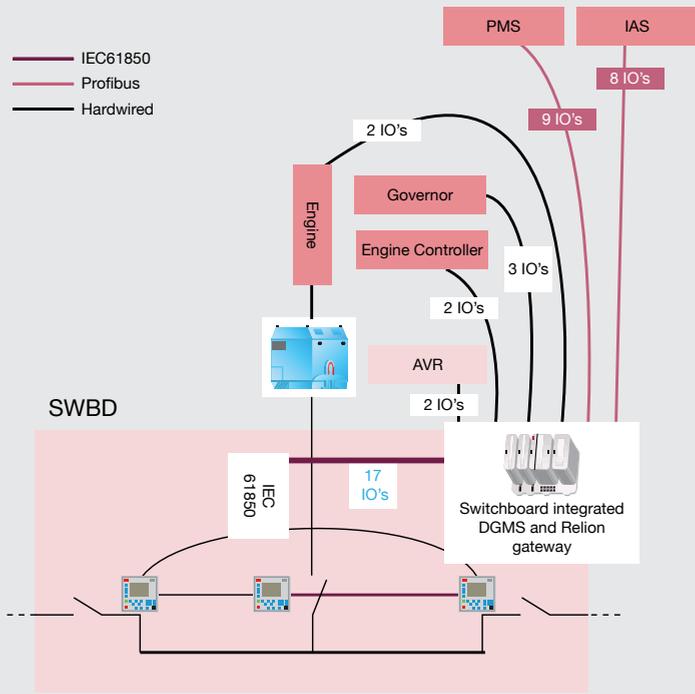
For fuelling faults that occur when generators operate with asymmetrical load sharing, the DGMS compares the load set-point to the actual delivered power. A fuelling fault is detected when the delivered power deviates from the load set-point.

When more than two generators are operating in parallel, the DGMS uses a voting algorithm to detect fuelling or excitation faults. It compares the delivered active and reactive power of all paralleled generator sets; if a generator deviates from the others, it is identified as faulty.

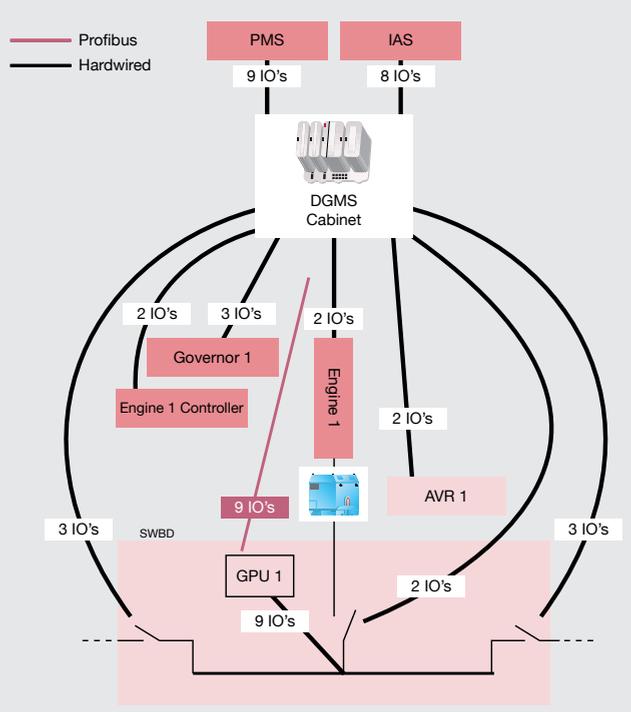
The DGMS does not trip a generator before it is absolutely necessary. An alarm will be activated and standby generator sets will be started, but a faulty generator is allowed to continue being connected to the plant if it does not cause instability of the plant or drive parallel generator sets outside of permitted boundaries.

It is important that the DGMS is able to trip the correct generator before the traditional protection trips the healthy generators. It is therefore crucial that the settings of the DGMS and the conventional power plant protection are well coordinated to avoid faulty actions.

The power plant protection system may respond to failures in the range of hundreds of milliseconds to a few seconds, depending on the failure. Hence, the

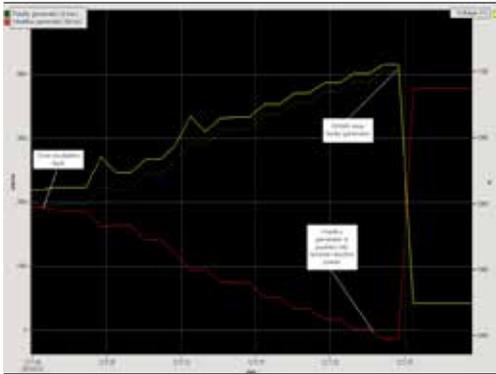


SWBD SWITCHBOARD INTEGRATED DGMS SOLUTION

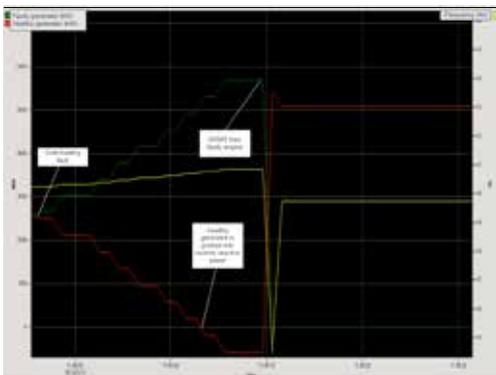


STAND ALONE DGMS SOLUTION

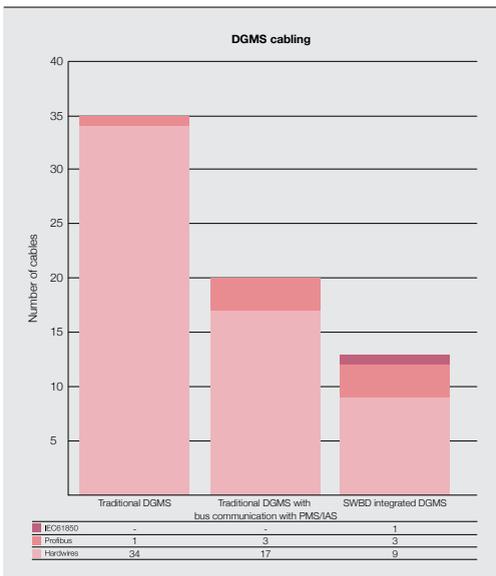
5 Trends showing over-fuelling with protection



6 Trends showing over-excitation with protection



7 Graphs of number of hardwired signals and bus signals



available time to correctly detect and act on failures is short. Time delays in measurements and the loop cycle must be minimized. Until recently, this was solved by adding hardwired signals to the basic solution, to allow fast access to critical measurements. The introduction of high-speed communication in protection relays, such as the IEC61850 and the ultra-high speed goose communication protocol has brought new opportunities to perform high-performance protection functions over communication networks.

**Switchboard integration**

ABB has introduced the IEC61850 standard Relion relays in marine power plants. These protection relays may communicate with each other, and with IEC61850 compatible control units on the same network, with communication speeds in the range of 10ms. This may even beat the time delay of hardwired signals, depending on the scanning time for the A/D conversions.

The need for hardwired signals is therefore greatly reduced along with necessary control hardware IO modules. In fact, 80 percent of the signals needed for the DGMS can now be sent over bus compared to 20 percent without Relion relays. This improves the quality of signal acquisition and reduces the response times, as well as installation costs and cabling. It also reduces the risk of hidden wiring faults.

In addition, this allows for the DGMS to be integrated into the switchboard. This saves valuable space for the installation of equipment, as well as simplifying both in-factory and on-site testing and loop checking during commissioning.

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# Drilling drives for availability and redundancy

**TOBIAS ERIKSSON – Drilling drives and their control systems are essential for the drilling system to control the drill string and auxiliaries. Drilling drives are also an integral part of the overall electric system that keeps dynamically positioned vessels on location and feeds power to essential consumers on board the vessel, allowing for safe and reliable operations.**

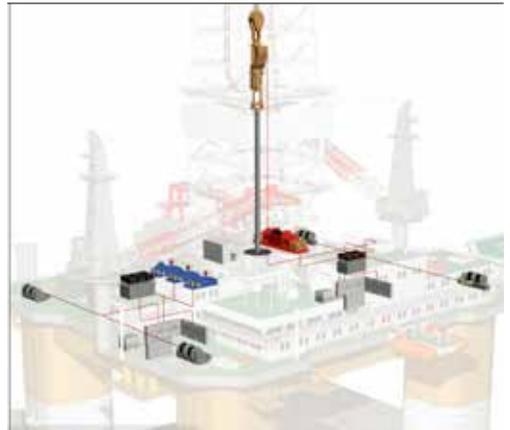
**H**igh reliability, serviceability and proper redundancy of essential functions are taken into account during system design and equipment selection. Different approaches are needed to meet stricter requirements for availability in drilling equipment. New and existing functionalities in ABB Drilling Drives System aimed at meeting these demanding requirements are described in this article.

The ABB Drilling Drives System consists of several parts: ABB ACS800 Multi-Drive Lineups, Braking Resistors, Motors, Remote I/O panels and an embedded control system.

The embedded control system, or Drilling Drives Control (DDC), controls, monitors and protects the drive lineup, including supply, DC bus and inverters for the drilling motors. It also serves as an interface for the drilling process and auxiliaries, the drilling control system, the electrical power plant and the power management system.

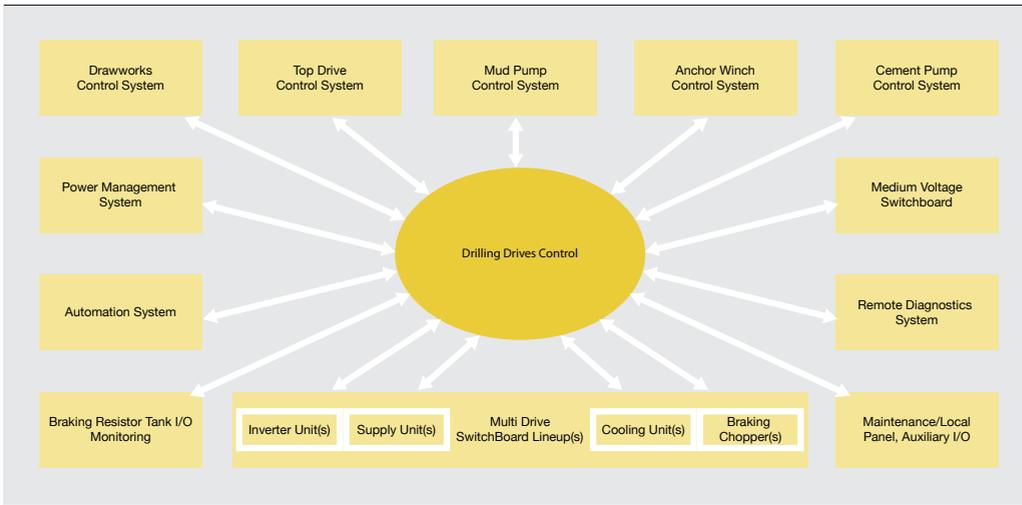
The DDC also controls switching of change-over circuits to run alternate motors, such as changing between anchor winch motors and mudpump motors if fed from the same drive inverter. If equipped with a

1 Drilling drives system overview showing the electrical connections from transformers, multi-drive switchboards to the drilling equipment drawworks, mudpumps, topdrive and anchor winches



remote diagnostics system (D4Drilling), the DDC will also be interfaced to the embedded Drilling Drives Control system.

The aim of the Drilling Drives Control is to adhere to standard architecture and tested functionalities to



In most cases it will be necessary to adapt specifically to standards to meet process and project specific requirements.

reduce engineering and commissioning and to use established interfaces with third-party suppliers. However, in most cases it will be necessary to adapt specifically to standards to meet process and project specific requirements. To ensure a high level of software quality, it is important that a quality assurance model specifies, tracks and tests such adaptations throughout engineering and commissioning.

#### Drilling Drives Control today

Depending on the project specific configuration, the DDC communicates with several different control systems. Each part of the DDC is embedded into its part of the drive system, and the overall DDC will therefore often comprise several separated sub-systems. Such varied control systems calls for highly standardized and consistent functionality, while also providing required process specific adaptabilities.

Some of the functions are identical for each application in terms of drives interfaces, such as start/stop, speed reference, torque limits, etc. Others are application specific. For example, Drawworks may require a torque up logic and handshake together with a mechanical brake. Such functionalities are implemented in the DDC software, not as a completely new customized function, but as additional layers or control blocks that can be enabled depending on the configuration. This ensures consistency in how common functionalities operate within the system through a core library of interfacing functions where blocks are commonly used regardless of application.

In addition, there is a horizontal integration of protection/interlocks/power management functionalities throughout the system.

An example is power distribution. To distribute power effectively, dynamic information from all the running drives and external commands is needed as well as fast response. Reacting quickly to disturbances in the power system is critical to prevent blackouts. Typically, the worst single failure power disturbances will require actions in the order of 200-300 ms.

Reliability is achieved through this common approach to all application software, together with a core library. First, it creates a clear and testable line of responsibility between the external system and the Drilling Drives System. Second, the external system does not require any specific drive monitoring and protection functions as such actions are handled by the DDC. The DDC also has integrated redundancy through design and built-in safety functions.

### Safety and availability

The reliability and fault tolerance of the various functions of the Drilling Drives System are critical when operating the drilling equipment, helping minimize downtime due to faults and safety actions to reduce consequences. High reliability and availability can be approached in several ways, and ABB's philosophy is founded on:

- Redundancy in terms of power and control configuration
- Specific functionality carrying out pre-emptive measures
- Design and interacting logic between the different parts of the system
- Monitoring capabilities for the overall system

The following sections present core functionalities related to each of these items.

Safety and reliability are also closely related to the processes used in software development, documentation and testing. Recently launched rules and guidelines for software development from classification societies, such as DNV ISDS and ABS ISQM, will also increase awareness on standardized, defined and tested functions.

Reliability can be improved significantly through robust testing, version control and follow-up. Not only do modules need to be tested during operations, but

every conceivable scenario must also be consistently evaluated for all functions.

### Configuration and redundancy

Different drilling applications have different redundancy requirements. Mudpumps will typically be redundant in terms of multi-motor configurations distributed on one or several drive line-ups and the mud system will be redundant by system design, which consists of redundant mud-pump configurations. There are fewer requirements for Top Drives, but the focus on safety is higher because of the potentially explosive environment.

The most stringent requirements for redundancy are for the Drawworks, particularly for Active Heave type Drawworks where total loss of operation capabilities directly impact the safety of the installation.

Redundancy must be designed and implemented with care to give a perceived high fault tolerance and availability. On the other hand, a highly complex redundancy design should be avoided. This will make it much more complicated to assess the system behavior in a fault scenario and for operators to perform the correct manual interactions if needed.

Redundancy, of course, means more components will be installed in the system, increasing the likelihood of failure. However, ABB believes it is important to achieve redundancy through simplicity in design and with a minimal increase in complexity. Redundancy should preferably use proven functionalities with necessary and adequate duplication and expansion.

To achieve the necessary level of redundancy, all systems – electrical power, control system architecture, and auxiliary configuration – must be assessed. For both main and auxiliary power supplies, different owners and designers have different approaches. Typical designs get power from segregated sub-systems of the main and auxiliary power supply, and may contain back-up assignments for drilling or winch motors, cross-feed links between drive segments, etc.

Although redundancy appears to be straightforward in designing such systems, it is important to keep in mind that perceived redundancy may be destroyed by increased complexity.

Configurations for software and hardware architecture can easily become even more complex. However, to a

certain degree they can be considered independent from power redundancy configurations.

A fundamental challenge is how each component in the control system should behave in a fault scenario where a higher-level control system cannot determine and assign what part should be doing what. For example, if a communication link breaks down between two controllers, how does each controller know whether it should keep running independently or assume the other has taken over?

For drilling applications, multi-motor configurations such as Drawworks, Top Drives and mudpumps have a common shaft. For the control system, this means it is critical that all independent drives are synchronized, regardless of their placement in the power configuration (eg, connected to different drive line-ups or power supplies). From the DDC to the drive, this is done using the ABB Drivebus protocol, a dedicated communication link to the lower-level drive controllers that provides high-speed communication for control and monitoring. While redundancy will still be achieved, this creates some constraints in how the control system should be configured.

### **Distributed redundancy**

Rather than achieving redundancy through complex software architecture, redundancy is instead achieved by expanding the existing hardware redundancy in separated control cabinets. Two redundant controllers can then be separated by long distances, while still running the same software applications and maintaining synchronized control of the drives. Each controller will connect to its own drives. This is seamlessly implemented into the application software and adds minimally to the complexity of the system (see Figure 3).

If one control cabinet fails, the complete software functionality is intact in another control cabinet because each cabinet has its own link to the drilling control system(s). Even if the overlaying application does not take advantage of dual communication lines, the application is still redundant in two physically separated controllers and still operating during, for example, a UPS control voltage failure.

This controller architecture makes multi-motor applications in different switchboard lineups, such as Drawworks, highly redundant both in terms of power and control design. This is particularly beneficial for Active Heave Drawworks applications with high redundancy requirements.

### **Multi-motor running configurations**

Traditionally, a master-follower approach is often used multi-motor applications where one of the drives controllers (the master) handles all interfaces with DDC controllers and provides the reference to the slave controllers. The slaves simply follow the master's torque output at a given point, providing load sharing. This approach is today typically used in Top Drive applications and can also be applied to Drawworks.

The greatest benefit of such a setup is that all drives run with the same reference values for the torque, with very accurate and adjustable load sharing. However, the master-follower solution has certain weak points in the redundancy that should be mitigated, such as the master-follower link itself and the fundamental issue of what action should be taken if the master fails.

New software logic makes handover from master to slave possible by intelligently looking at the existing feedback and quickly re-assigning the master with minimal interruption of control tasks. This raises the level of redundancy close to the level of a master-master configuration.

In such configurations, each motor is drooped against the other for load sharing. Its input reference from the DDC is identical and perfectly synchronized. There is no link between the drives or logic exchanged between them. As each drive is independent, this setup is very robust.

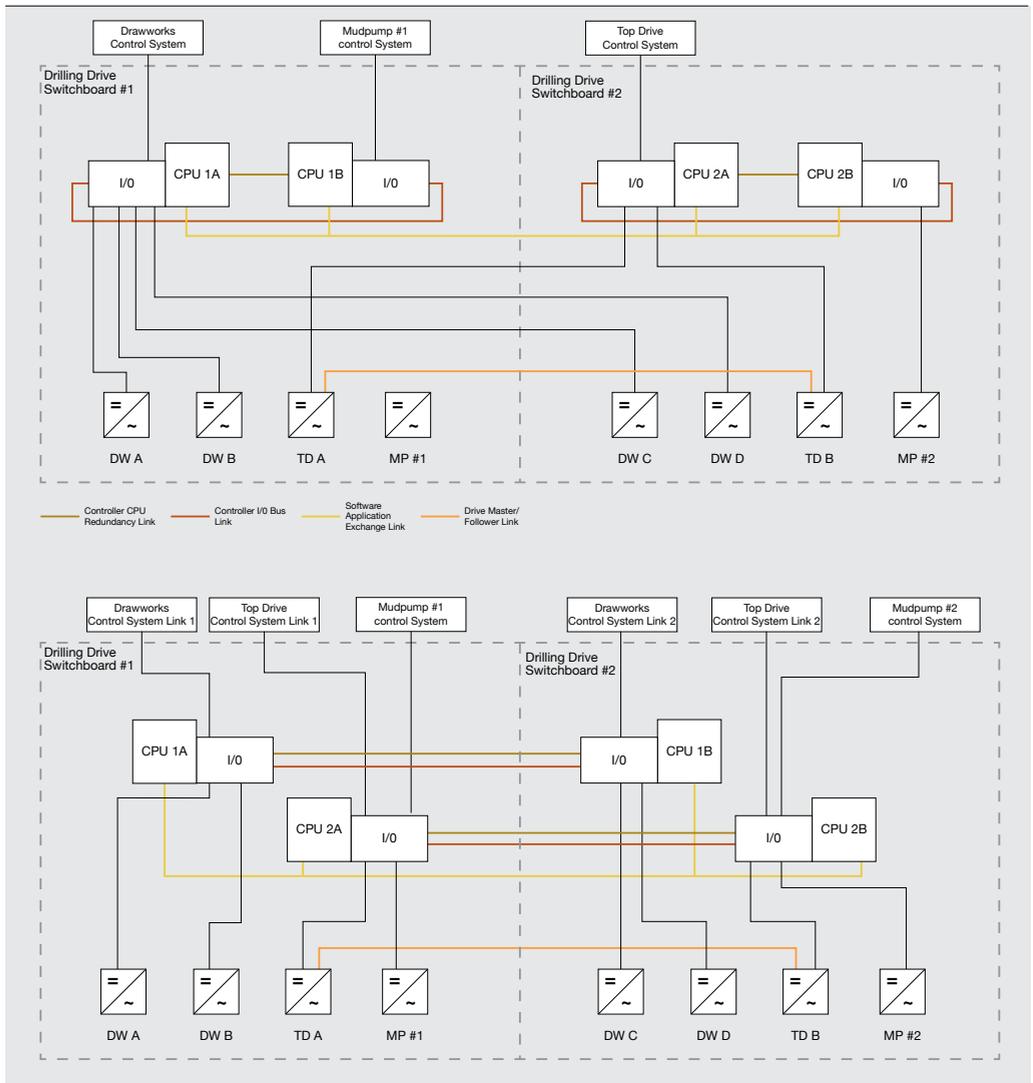
### **Power distribution and blackout prevention**

The DDC must manage the distribution and prioritization of electric power among the individual drives in order to run the most critical loads when power supplies are constrained. The dynamic nature of the drilling equipment's power consumption makes this particularly complex.

Power management can be achieved either by continuously allocating the available power, or by taking specific action if available power is exceeded. Both methods have advantages and disadvantages. In the power allocation algorithm, there are several constraints and input data also needs to be considered, such as a minimum value for each application and its priority.

Power allocation is further complicated in systems where power availability, load reduction and allocation is shared by several different control systems. Often three or more systems from different vendors

### 3 Typical control layout (top) and (below) the same layout with distributed redundancy concept



are doing parts of the calculation, requiring special attention to functional integration. A new unified power distribution module now allocates power in most configurations and interfaces. The module itself is the same, regardless of switchboard configurations. This means power limitation actions are more predictable and safer.

The main purpose of power allocation is to avoid overloading the power plant and to prevent blackouts from faults in the plant, particularly a sudden trip of a diesel engine. A classic solution is to monitor the network frequency and to use frequency deviations to initiate

power reduction along with hysteresis functions and power ramping to avoid excessive transients and to ensure smooth load changes for the prime movers.

Although frequency-initiated load reduction is robust and may be considered independent from the power management system, it is also a lagging control scheme because the failure has persisted for a while before it is detected. ABB is now implementing Event Based Fast Load Reduction (EBFLR), which works with a direct link to the Medium Voltage switchboard Relion protection relays on the new IEC61850 communication platform using the ultrafast

Goose protocol. Any event (eg, a generator trip) in the plant will trigger a limitation as quickly as possible, effectively limiting the load power before the event has disrupted the plant. This is achieved by using, for example, generator feedback signals and actively monitoring predefined events (eg, a trip). A specific limitation is continuously pre-calculated, ready to be enforced in case of an event. By using control signals in the protection relays, rather than in status signals, the power can actually be reduced even before the generator is disconnected from the switchboard.

### Monitoring

All drilling drive systems are now delivered with hardware prepared for Remote Diagnostics System (RDS) tailored for the Drilling Drives. RDS is a powerful tool for logging and monitoring. It can be used both locally on board a vessel, as well as remotely. The D4Drilling services offer support from ABB experts on shore via the RDS system in case of failures or irregular behavior, minimizing downtime and enabling pre-emptive and periodical checking of the system.

### Summary

Operating a drilling system safely, reliably and efficiently depends on the high availability of drilling drives and their control systems. Availability and performance of the control system is achieved through redundancy in design and fault integrity of the software functions and communication.

Physical separation of redundant functions reduces the risk for common failures, and distributed control systems have a higher fault tolerance. Standardized software libraries ensure that proven and tested functions are reused, while project specific software development is kept to a minimum.

For pre-emptive measures, a new unified power distribution module is available. Combined with Event Based Fast Load reduction, this results in a reliable, predictable drilling power management system with improved power allocation and blackout prevention functions.

The use of advanced monitoring and logging of variables and events has been introduced to drilling drives and control systems. They can be connected remotely, providing access to expert support on a nearly continuous basis.

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Any event in the plant will trigger a limitation as quickly as possible effectively limiting the load power before the event has disrupted the plant.

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# Limitations of FMEA and HIL testing

**BOLSHOY BHATTACHARYA AND STEVEN CARGILL – The widespread adoption of Dynamic Positioning (DP) for various marine activities has caused operators and oil companies alike to closely scrutinize the safety and reliability of these operations. Classification society rules and guidelines from industry bodies require that a Failure Mode and Effects Analysis (FMEA) be carried out on these vessels to ensure their safety and reliability. The FMEA – a systematic approach to failure analysis – can be expanded to include criticality, creating a Failure Mode, Effects and Criticality Analysis (FMECA).**

**H**owever, the FMEA is a technique that often requires the incorporation of various other studies and tools to fully understand failures. One such tool is Hardware in the Loop (HIL) simulation or testing. HIL simulations are used to simulate real-world embedded systems by modeling the controlled system (inputs and outputs for the control system) to create a dynamic response.

This article looks at the reliance of the FMEA on received data from studies and testing as well as the limitations of this process. The flowchart below provides a high-level view of the procedures involved in creating an FMEA.

The FMEA is a tried and tested process of fault finding and is a requirement for vessels that are to be classed as IMO equipment class 2 and above. DP equipment classes define the failure modes to be considered and the effects that the vessel can withstand without losing position.

As such, the FMEA is a vital document that highlights various aspects of the vessel's DP system design, which include, but are not limited to, fault tolerance, redundancy in capacity and capability, environmental limitations and the worst single failure that the vessel can withstand without losing position and/or heading.

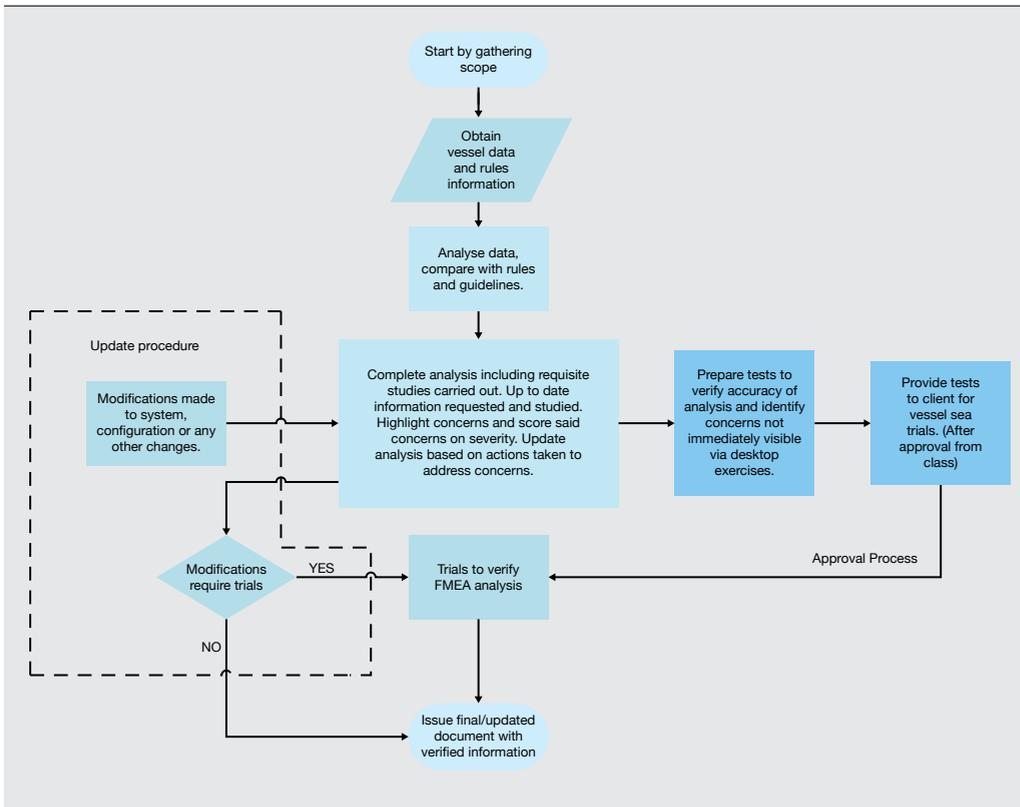
## Limitations of the FMEA process

The FMEA should relay as much information as it can about a vessel's various failure modes and effects, thus acting as a tool for the crew to enhance their knowledge about the vessel's DP systems. However, in practice, there is great disparity in the quality of vessel FMEA's depending on a variety of factors like authoring body, associated costs, personnel field of expertise and experience. As the FMEA is mostly a desktop exercise, it relies on the accuracy of other studies and testing to verify the fault tolerance of the DP system.

This aspect of the FMEA limits the quality of the FMEA in that the quality mirrors the accuracy and quantity of background study and the testing methods used to arrive at the conclusions.

This article discusses one factor that limits the FMEA process due to the sheer complexity of real-world responses – the configuration of the power plant as a closed bus.

For DP vessels, a power plant with all power generators and consumers connected on a single bus is a closed bus configuration. In such configurations, the amount of online generation can be calculated as a sum of power consumed and spinning reserve and an optimal number of generators can be connected.



Such a system has various advantages for the operator, such as:

- Efficiency – As all generators and consumers are on the same bus, a limited number of generators can be run at an optimal rate and efficiency, increasing overall productivity.
- Emission control – As the generators operate efficiently, waste generation is minimized and pollution from emissions is controlled.
- Maintenance – Equipment can be taken offline for regular maintenance to ensure the equipment has maximum availability and the power system does not have any downtime.

However, a number of concerns related to DP safety and reliability need to be highlighted:

- Fault tolerance – As the power system is in effect a closed environment, a fault on any one of the consumers or generators could have a cascading effect on the rest of the system.
- Redundancy - The capability of the power system to continue operating without losing position in the

event of loss of generation capacity due to a single point failure is a requirement for DP vessels.

- Reliability and protection – As a single point failure can cascade into multiple failures, the system has to rely on protective functions to isolate the fault and restrict the effect.

To address the limitations of the FMEA, various studies are conducted and incorporated into the FMEA document. A relay coordination study provides breaker switching information due to protective functions, a harmonics study illustrates the effect of higher order harmonics in distorting the AC wave spectrum, and a short circuit test can illustrate the voltage dip ride through capability of the consumers.

These tests may result in detrimental effects – just as a short circuit test may prove or disprove the protection features and voltage dip ride, through capability of the equipment, but may also cause the breakers to be damaged and require them to be repaired.

A primary concern of operating with a closed bus is the propagation of single failures across redundant systems due to failure of a common component group or subsystem, common cause failures affecting both redundant systems, and primary failure in one redundant system transferring to the other. Without proper protection, these failures can lead to a complete failure of power generation or thrust capacity, resulting in various unwanted situations. This means the FMEA must be detailed in its identification of all failure modes and also in its description of failure effects.

New and complex protection features now available from leading manufacturers such as ABB, AKA and Siemens maintain power plant stability and functionality even when major faults occur in a closed bus system that can potentially black out the power plant.

The application of these features increases the tasks of the FMEA practitioner who must ensure that these protective features do not introduce the potential for other failures to occur. Traditional testing methods are time consuming and may not give the needed level of confidence in these systems. Thus new tools, methods and ideologies are constantly being developed to further secure the FMEA as the de-facto method of assessing and analyzing failures.

## Hardware in the loop for DP?

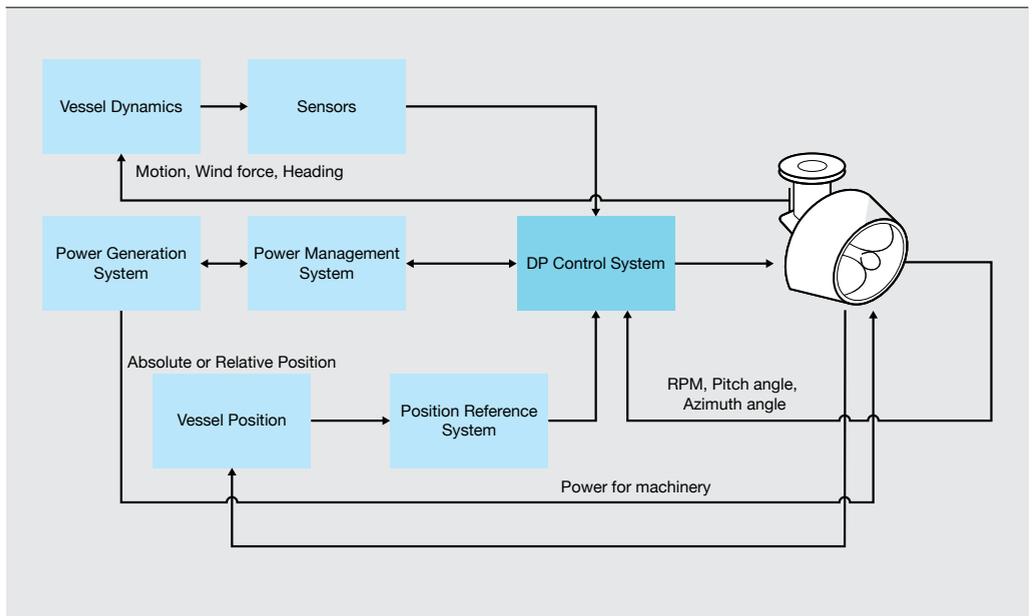
One of the tools that can assist in assessing the failure effects of a DP system is HIL testing. In the 1980s when industrial manufacturers created a product, they needed to first build a physical prototype and then write a program to control the hardware. This prototype would in turn be used to test functionality.

However, the complexity of machines – as well as the software controlling them – has grown exponentially. As the work is fragmented and segregated, it is not very cost effective to create a prototype for each phase of testing and parallel activities.

The above issues led to the development of the Hardware in the Loop process, which originated mainly in the aviation industry but has now spread to almost every complex controlled system. Unlike other methods of testing controllers, in which pre-calculated test data is inputted and controller output is measured, HIL creates a complete model for all the systems under control and all the sensors to simulate real-world behavior of the complete system.

The next figure shows the DP system of a vessel whereby all the blocks other than the DP control system are modeled using mathematical functions. This model is dynamic; it changes the vessel

2 DP system (HIL system under test)



model specifications based on the controller output, allowing the user to simulate potentially destructive failure modes safely.

This method of testing has a variety of advantages over the traditional way of testing, such as:

- Increased reliability and quality due to test repeatability and ability to perform destructive tests
- Efficient development due to shortened validation process and identification of design flaws
- Cost effectiveness as actual hardware does not need to be created or tested until the model is simulated

According to DNV Recommended Practice D102, when the power plant is intended to be operated with closed bus tie(s) between redundant power systems, the various requirements for analysis must be supported with extensive verification by FMEA testing. Especially, in the situation where the intention is to justify the 'equivalent integrity of power operations' as required by IMO MSC/Circ. 645 the extent of necessary FMEA testing may include tests that traditionally have been considered to be potentially destructive (eg, short circuits and earth failures on electrical system).

Through HIL testing, these destructive tests can first be simulated on a model and inferences can then enable tests to be conducted in a safe manner. This procedure can simplify the FMEA verification process and allow data to be collected, which was not feasible through normal studies.

However, in its current iteration, even the HIL testing ideology is not completely without restrictions. It is increasingly complex to model all attributes of the vessel design accurately, particularly for DP equipment class 3 vessels, which require very careful scrutiny of cross connections. The HIL simulation is only as good as the mathematical models used.

As the vessel model is complex, not every nuance can be catered for – it is not absolute. For example, power plant faults can develop at a rapid rate; the model has to be fairly high frequency to react to the changes a fault like crash synchronization can create. Also subtle disturbances in the environment or the system itself cannot be modeled. Thus cost and safety trade-offs need to be measured to qualify using HIL in lieu of actual testing.

### Would future FMEAs be safe, reliable and absolute?

According to DNV Recommended Practices E306, an FMEA is an excellent tool for raising awareness of concerns regarding the design of a DP system. Supplemental studies may be required to address issues raised by the FMEA. The DNV RP E306 then goes on to illustrate some studies required for closed bus operation of a power plant. As the consequences of a DP incident can be catastrophic, a full set of synthetic and practical tests should be carried out to ensure the maximum level of confidence.

Fault finding and testing methods like HIL are extremely helpful in providing information without actual testing. But the full extent of failure effects can only be confirmed by following up with actual testing. For example, a generator may not be able to provide rated capacity of power or take the step load of the largest consumer starting for a short or continuous time period. This will make the model inaccurate with respect to the actual system.

It is important to note that the FMEA is a living document that must be constantly updated to record any – and all – changes to the vessel. With advancements in modeling technology and fault-finding ideologies, the FMEA procedure will continue to grow, enabling reliable and incident-free operations for all DP vessels.

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# Laws and price drive interest in LNG as marine fuel

**HENRIQUE PESTANA – The use of LNG as a marine fuel is one of the hottest topics in shipping. This growing interest is driven by legislation and price.**

**L**imiting SOx emissions in Emission Control Areas (ECAs) to 0.1 percent from 2015 and to 0.5 per cent globally from 2020 will effectively ban the use of heavy fuel oil. That means ships will need to shift to low sulfur fuel oil, marine gasoil or LNG. At the same time, the limit on NOx emissions in ECAs (Tier III) from 2016 will force new ships to either install scrubbers or shift to LNG.

Financial factors are also helping the push to LNG. As of today, LNG is the most cost effective marine fuel that complies with the upcoming SOx limits.

## **Electrical drives**

A fixed pitch propeller's direct drive is by far the most efficient way of transmitting the power generated by an ultra-low speed, two-stroke engine to the propeller. However, this configuration is not applicable to all ship types. Ships equipped with medium-speed engines require a clutch and reduction gear, adding some losses to the system (about 2 to 6 percent). Alternatively, these ships can be fitted with electrical drives, allowing engines to act as generators. This increases propulsion losses (about 7 to 11 percent).

Nevertheless, the electrical drive of fixed pitch propellers offers benefits that in many cases outweigh the lower propulsion efficiency. An integrated electrical

power plant enables the designer and operator to better match the running engine capacity with the actual load demand under a wide range of operating conditions through the load-dependent start and stop of generator sets. This allows engines to operate more optimally and more efficiently, which may offset and exceed the higher transmission losses.

In addition to the more commonly known energy efficiency effect, electric propulsion has other benefits when it comes to availability, safety and maneuverability, which will be described in this article. While some of these benefits are evident regardless of the type of fuel used, many become more pronounced with LNG.

## **Dynamic response**

Diesel cycle engines – which include both dual fuel gas engines with pilot diesel ignition and high pressure gas injection engines – are intrinsically slow to respond to power fluctuations, which occur constantly due to variations in the propeller load driven by waves, wind and steering motions.

Electrical drives offer a much faster response to load variations. They can also precisely control the torque, power and propeller speed, minimizing the ship's speed loss due to external factors.

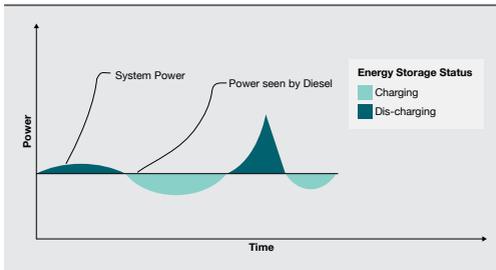
1 Load variations are kept to a minimum by keeping propeller load constant during maneuvering of a dual fuel engine LNG carrier.



2 Sea-trial recording of load reduction test by tripping, one by one, the dual-fuel engines in an electric propulsion system for LNG carriers.



3 Illustration of peak shaving through energy storage.



In a mechanical system, the engine control system responds to load variations on the propeller by adapting the fuel injection to meet the new power/speed requirements. The new equilibrium point is only achieved when the inlet air reaches the right pressure and temperature, which depends on the pressure increase of the exhaust gases. This iterative process – known as thermodynamic inertia – lies at the heart of the dynamic response of direct drive systems.

In an electrical propulsion plant, the drive can be optimized to maintain constant power and cope with load variations by adapting the torque and propeller speed. By keeping the power constant, the overall system is less exposed to the dynamic response limitations and can therefore maintain the ship's speed when faced with external factors (such as bad weather).

The logged power consumption from a single shaft LNG carrier with electric propulsion and dual fuel engines is shown in Figure 1. This clearly indicates that by controlling speed and torque simultaneously to keep the power constant, propeller load variations are not transferred to power variations in gas engines.

The dynamic response of the propulsion system is also a key element of the ship's maneuvering performance. Handling a ship in confined areas is very risky, requiring high thrust at low speed and on demand. The dynamic response of mechanical systems during maneuvering has benefited tremendously from the introduction of Controlled Pitch (CP) propellers. Nevertheless, electrical drives offer much more control compared with CP propellers. An electrical drive, for example, can provide full torque at zero speed.

### Fast load reduction

The engine and electrical power plant are essential to safely operate vessels, in particular ones that use dynamically positioning (DP) and maneuver near shores and harbors. Electric propulsion increases the redundancy of the plant by enabling all engines to provide power to any of the propulsors and thrusters.

Thus the loss of one engine out of, say, four, has a relative small effect on the maneuverability of the vessel. For gas or diesel electric power plants, it is important to keep in mind the risk of cascading failures of paralleled gen-sets. Traditionally, the solution has been to run the power plant in split mode when a higher safety level is required, but this limits the plant's maximum energy efficiency.

New enhanced reliability notations from classification societies allow for the use of closed bus systems also in higher DP class operations. This requires additional efforts in load control and fast protection, which can now be solved through electric propulsion (see Preventing and restoring blackouts on page 154). The effectiveness of load reduction is shown in Figure 2.

During a test run, the engines of a four-engine power plant were shut down one by one. The load reduction on the propulsion was controlled fast enough to keep the frequency variations in the network well within the permitted limits, ensuring availability of the remaining power plant – even if the 11 MW engine tripped and only the 5.5 MW engine was left to provide power.

Frequency converters used to drive electric propulsion motors are based on power electronic circuits – high-power components that are switched up to a few kHz to control the torque of the motor. Such converters may control the torque load within milliseconds. This allows for precise control of the load power of the generator sets and permits the engines to operate closer to their maximum load, which also gives the highest energy efficiency and minimum emissions.

### Energy storage

Batteries and super capacitors can further enhance the dynamic response of electrical propulsion systems. Energy storage systems can provide energy to sustain peak loads and to fill the time gap between thrust demand and energy production (see Figure 3).

Electrical drives are capable of providing full torque almost instantaneously, but will normally need to be limited as the engines can usually not provide such load variations. Energy storage systems make it possible to reduce this constraint on propeller performance by providing fast power fluctuations from, for example, the battery, while the gas or diesel engine is exposed to more stable load with slower variations.

This is particularly important for large and frequent load variations (for example, in DP) or in harsh conditions or ice-breaking operations, where the dynamic capability of the station-keeping system directly affects the vessel's performance. This also raises the average loading of the engines and allows them to operate more energy efficiently as they do not need to meet dynamic peak loads.

## LNG electrical propulsion: *Viking Grace*

Viking Line recently took delivery of *Viking Grace* – the first large ferry powered by LNG – from STX Turku Shipyard. The company decided on LNG propulsion mainly to comply with ECA SOx requirements and because of the low price of LNG compared with heavy fuel oil.

*Viking Grace*, operating the Turku-Stockholm route in the Baltic Sea, is about 218 meters long and 31.8 meters wide with a gross tonnage of 57,700. She can carry 2,800 passengers and has a service speed of 21.8 knots.

The vessel is equipped with four Wärtsilä 8L50DF engines – dual fuel engines that use about 1 percent of diesel oil as a pilot fuel to ignite the gas-air mixture. Each engine is connected to an ABB generator of 8191 kVA at 500 rpm, producing total power of 30,400 kW.

Each of the two fixed pitch propellers is driven by a 10.5 MW ABB ACS8 synchronous motor that is controlled by an ABB AC6000 frequency converter and fed by two propulsion transformers that convert electricity from 6600 V to 3300 V.

ABB also supplied two 2300 kW motors for the stern transversal thruster and one 1500 kW motor for the bow transversal thruster. Two 600 kW AC motors were also supplied by ABB as well as the four 2500 kVA converters.

The propulsion drives supplied by ABB were programmed to take into account the dynamic response of the engines to ensure that the power plant remains stable during different operational modes.



## Partial load

The specific consumption of an LNG engine at 50 percent load is about 6 to 8 percent higher than at full load. Ships that operate regularly on partial load can improve their overall fuel consumption by using an electrical propulsion plant. The generators used match the produced load demand, optimizing overall fuel consumption. Particularly for DP vessels – where redundancy requirements result in very low average engine utilization – the specific fuel oil consumption is much higher than at optimal load, which is typically 85 percent. This can be further enhanced by using DC distribution (ABB's Onboard DC Grid), which allows generators to operate at variable speed and closer to their most efficient power/speed ratio.

## Emissions

One of the biggest benefits of LNG engines over conventional fuels is lower emissions. Combusting LNG does not produce SO<sub>x</sub>, substantially reducing NO<sub>x</sub> and CO<sub>2</sub> emissions. However, these benefits can easily be wiped out by methane slip, which occurs when the gas injected into the combustion chamber is not fully burnt and escapes through the exhaust, particularly when operating in partial load.

Methane slip can be minimized by using electrical propulsion; the power management system selects the number of online generators to optimize cylinder pressure so that the gas injected into the combustion chamber is fully burnt. Onboard DC grid, where the engine speed can be varied and the cylinder pressure can be kept at a higher level, also allows for more complete combustion with less methane slip.

## Methane number

Both dual fuel (DF) and lean burn spark ignited (LBSI) engines are very sensitive to the quality of gas. The methane number is equivalent to the octane number in gas and indicates its knock resistance. A high methane number is good for the performance of the engine, while too low a number can lead to knocking and cause extensive engine damage. The methane number depends on the origin of the gas and can vary quite substantially (from 70 to 90 in an index of 100).

If the gas has a low methane number, the engine needs to be derated to prevent knocking and damage, which affects propulsion. However, an electrical propulsion plant lessens this effect because it is possible to install additional power without compromising propulsion efficiency at the design point (service speed).

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Methane slip can be minimized by using electrical propulsion.

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# Benefits of Azipod® propulsion that go beyond safety

**JUKKA VARIS – Azipod® propulsion is mainly known for its high efficiency. However, it has also other benefits related to safety and availability that are well recognized in vessels types such as cruise ships and ice breakers, but are perhaps not as well known in other market segments. This article describes these benefits and looks at improvements introduced over the history of Azipod® propulsion.**

**A**zipod® technology was first introduced in 1990 on a pilot installation for a Finnish fairway maintenance vessel and then later installed in some ice-going vessels and ice breakers. It took seven years for the technology to break through to wider markets. The first installation of Azipod® technology on a cruise vessel – the Fantasy-class vessel Elation in 1998 – showed remarkably positive results with high efficiency and excellent maneuverability. During these tests, it was also noted that Azipod® propulsion improved some important navigational safety issues: it shortened markedly the crash-stop distance and improved the ability to control the course during the crash-stop maneuver in a manner that was unheard of earlier.

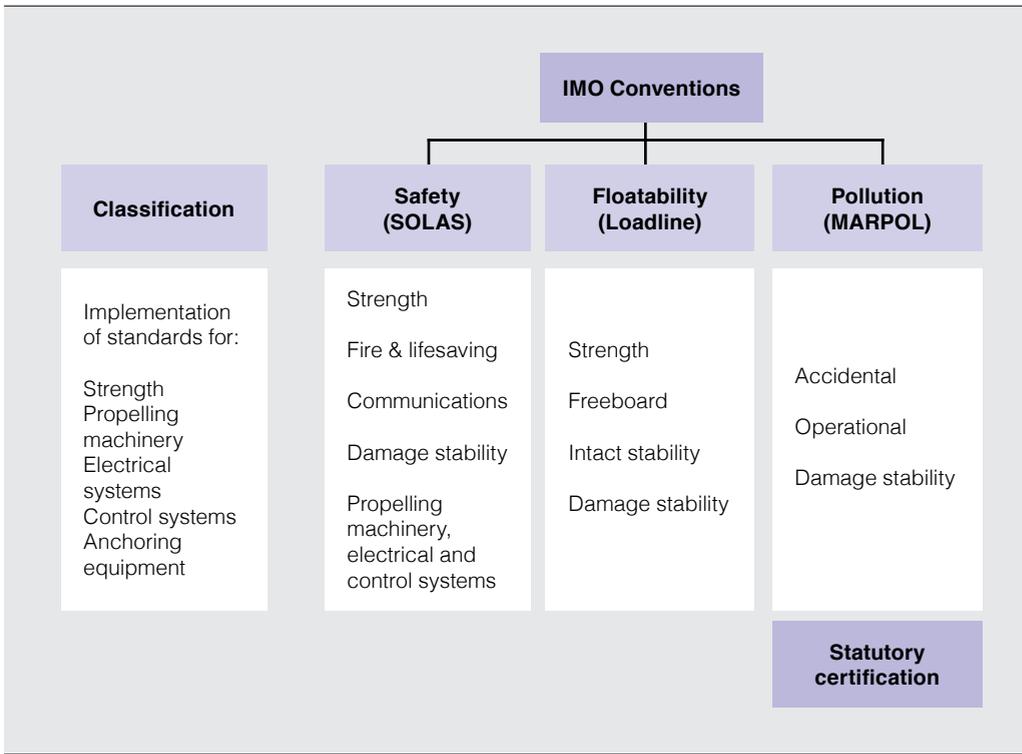
## **Global safety regulations**

Shipping is one of the most global industries in the world. Ship owners and managers span many countries and vessels operate under different jurisdictions, often far from the country where it is registered. This has given rise to a need for global standards and regulations. Maritime treaties date back to the early 19th century. The 1912 Titanic disaster led to the first

International Convention for the Safety of Life at Sea (SOLAS). The convention establishing the International Maritime Organization (IMO) was adopted in Geneva in 1948 and the IMO first met in 1959. The organization's main task has been to develop and maintain a comprehensive regulatory framework for shipping, and it has launched several recommendations and instruments to improve navigational safety since 1959. The IMO has also issued a series of resolutions and codes, including guidelines on navigation and performance standards for ship-borne navigational and radio communications equipment. While some of these are simply recommendations, their acceptance is so widespread that they effectively dictate international policy. Other recommendations are referred to by specific Conventions, giving them the same weight as these regulations.

SOLAS is the convention that has had the greatest influence on Azipod® design. This convention covers various aspects of vessel safety, including safety of navigation in different conditions. The IMO adopted a revised version of SOLAS Chapter V, incorporating new requirements that entered into force in 2002.

Figure 1 Dependencies between regulatory departments



The classification societies are responsible for making rules based on international standards and requirements and for ensuring, through reviews and inspections, that these rules are followed. Most of the regulations deal with better reliability of systems and components, thereby directly or indirectly influencing a vessel's safety.

Azipod® propulsion is designed to meet international maritime rules and regulations. However, the concept is still in its infancy and, although the functionalities of Azipod® propulsion are combined into one unit, they are traditionally installed separately and covered by separate sections of regulations. Thus additional features may need to be taken into account in some cases.

Even though there is still a lack of specific rules for podded propulsion, class societies are continuously developing rules to meet current technologies and always aim to be one step ahead in designing new features to improve safety. Some examples of safety-related issues where Azipod® propulsion exceeds current regulations are listed below.

### Navigational safety

The initial sea trials of the first Azipod® vessel showed that the vessel's steering capabilities were exceptionally better than with the conventional rudders of its previous sister ship. During turning-circle tests at full speed, the turning radius of the Azipod® vessel was about two-thirds that of its sister ship.

This difference improves safety in situations where a vessel must avoid possible collision with another vessel. It also provides faster response time when maneuvering, like during training and testing for man overboard rescue operations using the so-called Williamson turn.

Azipod® propulsion also has better operational characteristics during unwanted crash-stop situations. Originally the crash stop using Azipod® propulsion was performed in the same way as with conventional shaft-line propellers – the propeller power was set to zero and the shaft speed was reduced until the ship's speed was slow enough to reverse propeller rotation so that the propellers began actively breaking speed.

The challenge with rudders is that they have a very limited ability to control a vessel's heading, whereas with Azipod® it is possible to direct propulsion in the wanted direction and control heading.

To make crash-stop maneuvers even faster, safer and less demanding for the components of the electric power and propulsion system, the Azipod® unit can be turned around with continuous positive power acting on the propellers. This method is called the “pod way” crash stop. Here the dynamic loads to shaft bearings are lower and there is less fluctuation of propulsion power and reverse power generated by the propulsion system towards the ship's power plant. This reduces the loads on the pod units and shortens the time and distance of the crash stop. This method is recommended for performing crash stops on vessels with separate levers for PORT and STBD Azipod® units.

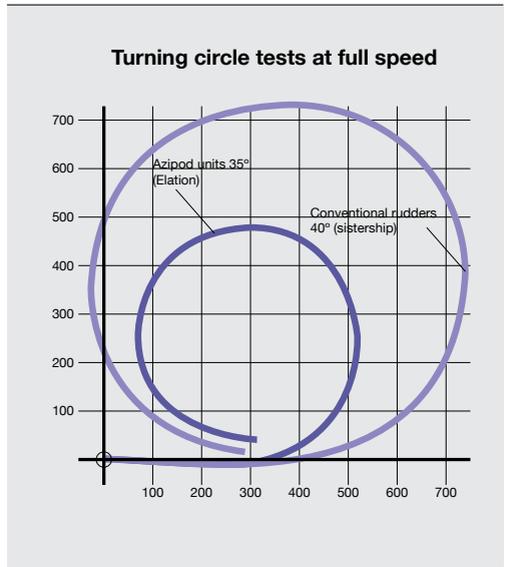
Several tests have been conducted throughout the years to compare crash-stop distances by the pod way and the conventional way. For example, crash-stop tests were conducted with a 90,000-gross-ton, 300-meter cruise vessel at 16 knots, both the conventional way (reversing propellers) and the pod way, with crash-stop distances of 0.7 nmi (1,300 meters) and 0.35 nmi (650 meters), respectively.

During a crash stop, a ship's course can be controlled by the independent levers for each pod unit. If a ship's course is to remain unchanged during the crash stop, the pods are turned simultaneously in opposite directions.

Captain Grant Thompson of the M/Y Kogo shared his operational experiences with ABB. The following excerpt from that text describes well some of these functions:

“The very first difference I noticed from a conventional shaft line yacht was the seamless transfer of power to forward propulsion. There was zero cavitation and due to the remarkably low noise and vibration readings a shift in speed hardly registers unless you are looking out of the windows or at the bridge instruments.

On sea trials, Kogo went from full ahead to a crash stop in 2 ½ times her length. Not only is this a remarkable feat but it was totally controllable and resulted in us changing the way we performed man overboard drills as we could literally just stop and back up to the victim whilst the rescue boat was being launched.

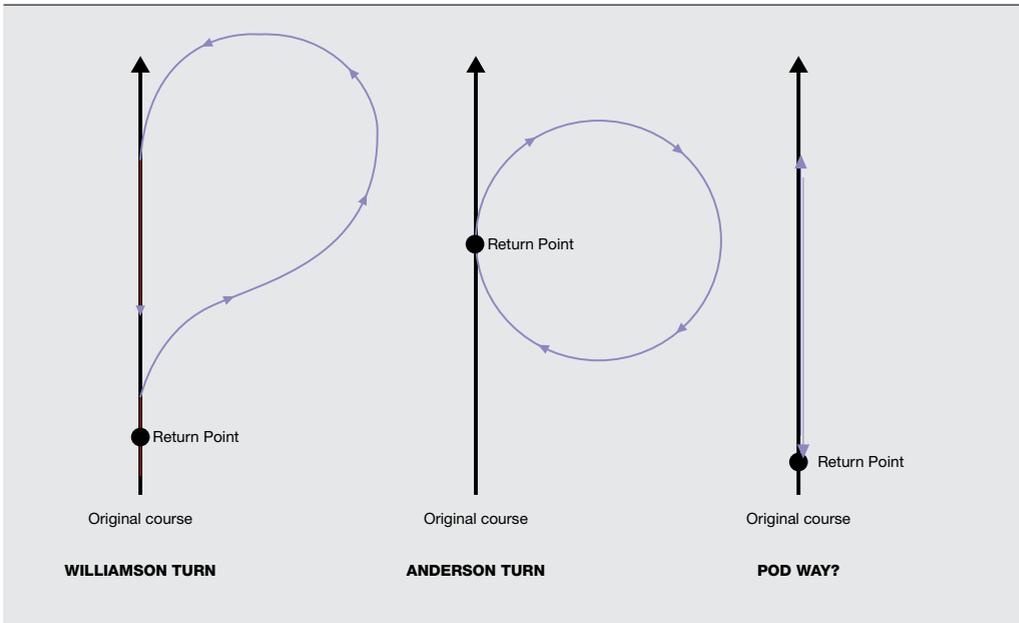


The other big difference I found to be the level of control in close quarter situations. As the pods are direct drive there is no lag in a command being executed. This resulted in very accurate slow speed docking maneuvers.”

A man overboard drill is conventionally done using one of two methods. A so-called Williamson turn, which is used to bring a ship or boat under power back to a point it previously passed through, is often used for recovering a man overboard. A Williamson turn is most effective at night, in reduced visibility, or if the return point may, or has already, gone out of sight but is still relatively close. For other situations, an Anderson turn might be more appropriate. The choice will in large part depend on prevailing wind and weather conditions.

What Captain Grant Thompson described above is applicable for vessels provided with Azipod® units and could be tested during sea trials to find out the best possible way to operate in a real situation.

Azipod® propulsion is also excellent for low-speed operation because the units can direct full thrust in any direction. This results in a better safety margin for, for example, berthing. Having high side-thrust availability with relatively short response times will provide better control against gusts or currents, reducing the risk of colliding with a pier. The following graph



illustrates the amount of thrust the different methods provide with the same power consumption, showing the superiority of Azipod® in relation to efficient-side thrust.

### Training

An important element of safety is keeping the units in good shape during operation and maintenance to reduce the risk of unexpected breakdown and to extend the lifetime of the components. How the units are operated on day-to-day basis will to a large extent determine the lifetime expectancy of the components. To achieve the most efficient way of operating and at the same time extending the lifetime of critical components, it is important to understand the behavior of Azipod® units and their interaction with the vessel hull. ABB has developed a training program that includes full-size simulator navigation. The main idea is to train bridge personnel to understand the behavior of Aizpod propulsion under different operational conditions, thereby operating the units as energy efficiently and smoothly as possible.

Another safety-related training package teaches participants the procedures for working inside an Azipod® unit. Azipod® differs from conventional machinery in that it is a confined space. That requires specific skills and procedures before entering into the

Azipod® unit. Today people who enter an Azipod® are required to have a permit – a kind of driver’s license – that they receive by passing specific training courses.

This training program is conducted with the support of Meriturva, a Finnish marine safety training center. Meriturva facilities represent a simplified construction of an Azipod®’s internal channels with the same full depth and similar spaces. The basic idea is to find out if a person is capable of working inside such as enclosed environment without becoming claustrophobic. For this reason, the mock-up drill is done in a controlled manner and the unit is provided with a safety hatch at the bottom for emergency exit.

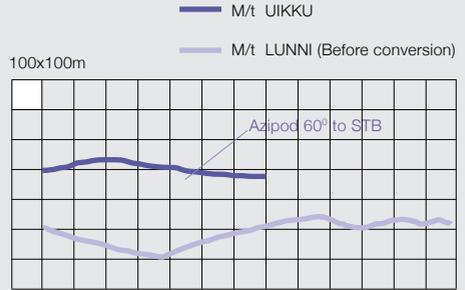
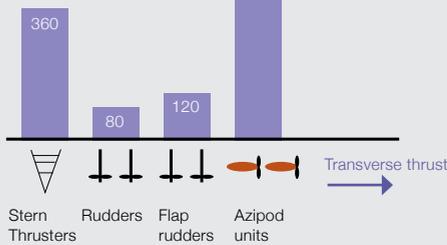
### Azipod® XO

In addition to previously mentioned navigation and training issues, ABB has improved safety through design. The latest generation Azipod® XO design process aimed to improve maintenance safety and environmental safety. The entrance to the unit was made easier, ladders with safety rails were provided, and the entrance from drive-end to non-drive end compartments were connected so that personnel could more easily move from one end to other. The new unit was designed with better efficiency, reducing fuel consumption. The shaft-seal design was made to better incorporate environmentally friendly lubricants.

- Faster manoeuvring at harbours - reduced sea voyage speed
- Less need for tug assistance
- Reduced power demand for manoeuvring
- Excellent suitability to DP operation

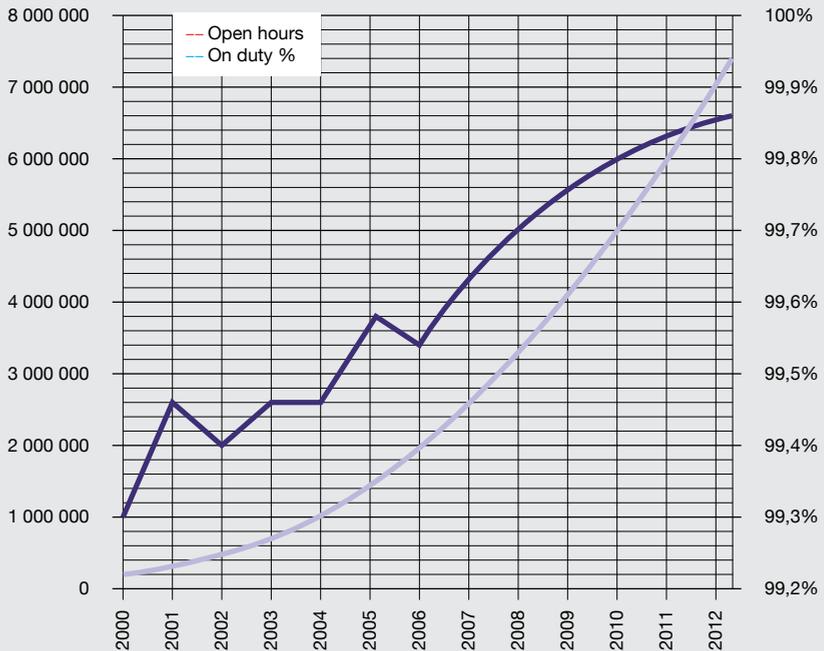
- Improved safety
- Steerability over the whole crash stop period

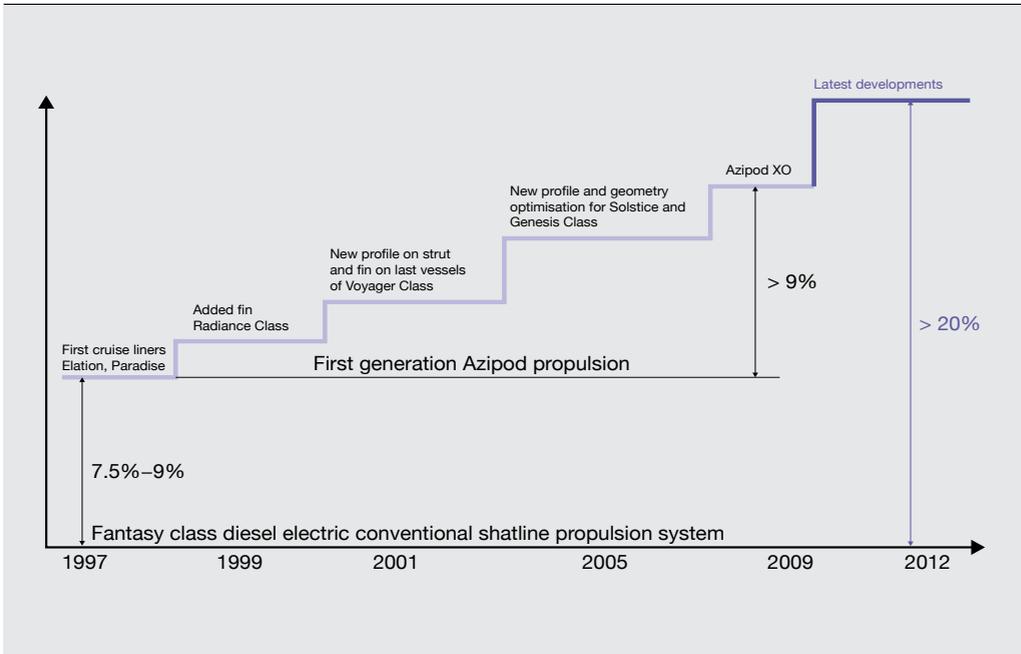
Typical transverse thrust from different alternatives produced with 3MW



Comparison between motor tanker *Uikka* (Azipod) and her sister vessel *Lunni* (shaftline). Example of a single screw vessel

### Azipod operating hours & On duty %





## Availability

The Azipod®'s availability has been monitored over the years by collecting unplanned off-hire time and comparing that figure with the total planned operational hours (see Figure 2). Off-hire time related to Azipod® units, but not due to external reasons like ground contact etc., is also included. This indicates how successful design improvements have been. Availability increased to more than 99.8 percent not only because of design and process improvements, but also as the result of improved ways of using propulsion and greater awareness of maintenance. This shows that awareness of availability can never be undervalued in the relationship and cooperation between suppliers and operators.

Maintainability of the propulsion unit has proven to be one of the more important factors in providing reliable operation of the critical components of the system – the shaft seals, shaft-line bearings, steering system, slewing seals, slewing bearings and the propulsion motor itself. The Azipod® propulsion and thruster units are now designed for five-year drydocking intervals. For some applications, a longer maintenance interval of up to 10 years can be justified. This conclusion is based on a well documented operational and maintenance history.

Today some 100 vessels use Azipod® propulsion in a wide range of operations. Ship types include cruise ships, icebreakers and ice-going cargo vessels, ferries, mega yachts, offshore supply vessels, research vessels, wind turbine installation vessels, and drilling rigs.

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# Shaft-line motors bring many advantages

**KLAUS VÄNSKÄ – In vessels where only one main engine drives propulsion, vulnerability to engine failure is obvious. But integrating an in-line (or geared) electrical motor drive train into the shaft line can improve crew safety, as well as being of benefit to the environment, the payload and the ship itself – often at no additional cost.**

In addition to adding redundancy, such shaft line motors can also complement the energy production for ship loads where the propulsion load is lower than the main engine capacity, or supplement propulsion load in booster mode. This allows the designer to specify the main engine rating not by maximum speed, but by optimizing the rating based on maximizing efficiency for the best operating conditions.

A simple single-engine propulsion system is widely used in many vessel types, such as bulk carriers, tankers and container vessels. While such systems may be seen as highly reliable because of the low number of parts and the reliability of their components, they do not provide any redundancy should the main engine or a non-redundant auxiliary system fail.

The need for an alternative means of propulsion is crucial, especially when a vessel must move through narrow straits, areas with high traffic and close to ports – or even during engine maintenance. In spite of this, alternative propulsion-drive systems are often not used due to additional installation costs. However, a system that is designed for multipurpose operations (such as multiple optimized speeds), and is also used

during normal operations, may improve fuel efficiency and increase the flexibility of a ship's design and operations – in addition to improving safety.

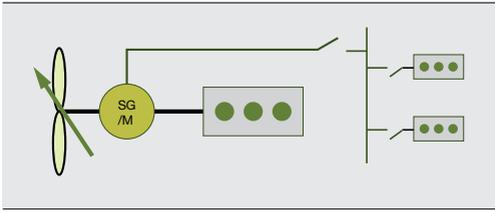
The technologies and equipment needed to build combined propulsion systems are available today, and standard products have been used in a variety of applications for years. To create a design that is both cost effective and energy efficient, it is important to understand the energy flow in the propulsion system and to optimize the design for proper operational criteria. ABB has developed tools that analyze and simulate the energy flow and evaluate the effect of different designs on operations and fuel consumption.

This article discusses the different operational conditions and aspects of ship design needed to build a propulsion system's take-home capability, which can be combined with the main engine during normal operations. This results in greater flexibility in designs that increase the optimal fuel range.

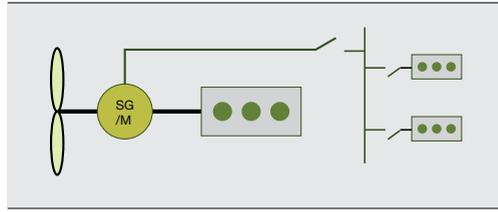
## Shaft line arrangements

Figures 1 and 2 show the two most common propulsion chain arrangements used in vessels with a single skeg. While the shaft generator is shown in both

1 Single shaft with CPP



2 Single shaft with FPP



examples, it is not installed in all vessels and is used less in vessels with fixed pitch propellers (FPP) than in those with controllable pitch propellers (CPP).

Although the difference in propeller type (CPP or FPP) is almost invisible in the diagrams, the main engines are controlled differently. For CPP, the engine speed and propeller pitch angle are controlled together by the combination curve. With FPP, the engine speed is controlled by the speed/power demand of the propeller.

Engine power with different shaft speeds can be calculated according to the following equations<sup>1</sup>. When the CPP propeller is used and a combination curve keeps the main engine's effective pressure close to constant, power is calculated as:

$$P = c \cdot n^3$$

$c = \text{constant}$   
 $n = \text{shaft speed}$

For a FPP, power is expressed according to the propeller law:

$$P = c \cdot n^3$$

In both designs, the shaft generators can supply auxiliary power, allowing the auxiliary engines to be switched off. Typically there is no frequency converter in the generator output. This means that the shaft generator can only be used if the main engine is running at a speed that corresponds to the electric network frequency. The generators are therefore only used for power take-out (PTO).

Given the power equations mentioned above, a shaft generator that uses FPP is limited to one fixed ship speed. Consequently, if a ship requires a wide power range or slow steaming, the shaft generator does not yield expected benefits. With CPP, the speed of a shaft generator can be kept at a suitable constant

range and the propulsion power is adjusted by controlling the pitch angle. This allows for wider usage of the shaft generator, but also has disadvantages. If a vessel operates far from the optimum combinatory curve, the propeller cavitation is obvious<sup>2</sup> and poor propulsion efficiency outweighs the benefits of using the shaft generator.

However, these challenges can be overcome by installing a frequency converter to the output of the shaft generator, improving the overall efficiency of the vessel. Combining a frequency converter with the shaft generator also results in other interesting features discussed in the following sections.

### Shaft generator

When a frequency converter is installed between the shaft generator output and the electric distribution system, the shaft generator can be used independently of the shaft speed, enabling a ship's operations to be optimized for each route. The frequency converter also allows for the synchronization of the shaft generator to run in parallel with the auxiliary engines.

This means that the full benefits of lower specific fuel oil consumption (SFOC) of the main engine compared with the auxiliary engine can be fully exploited. If the auxiliary engines use marine diesel oil (MDO) instead of heavy fuel oil (HFO), the difference is even greater; costs for lubrication oil and maintenance are relatively higher for the auxiliary engines than for the main engines. These costs can be also reduced by using the shaft generator system to provide more of the needed vessel loads. For newbuilds, auxiliary engine sets can be minimized by utilizing the shaft generator capability. Depending on the required auxiliary power and voltage level of the auxiliary system, the shaft generator system can be either low or medium voltage. Figure 3 shows the ABB ACS800 low-voltage shaft generator drive.

The shaft generator can be either low speed or

medium speed depending on how it is connected to the propeller shaft line. Low-speed shaft generators are typically built in-line of the main shaft, while medium-speed shaft generators are often used together with medium-speed engines, which are both connected to the same gear box. An ABB low-speed shaft generator is shown in Figure 4. In this design, the cooling unit and connection box can be located on either side or on top of the generator to better fit in with the design constraints of a vessel's shaft-line space.

### Take-home feature

The PTO function can easily be extended to a combined PTO/PTI when a frequency converter is installed between the electrical machine and the electric distribution system by allowing the machine to operate as either a motor or generator. In practice, the frequency converter controls the shaft generator/motor speed using the power generated by auxiliary engines. Therefore, the auxiliary engines can be used to rotate the main shaft should the main engine malfunction (the main engine has to be decoupled, for example, by clutch). This feature, which allows the vessel to be maneuvered if the main engine fails, adds redundancy and a higher level of safety, making it possible for the vessel to reach port or to anchor safely on its own. It may also allow for more maintenance work to be done on the main engine during loading or unloading because the vessel can move to anchorage if she is required to leave berth. The power flow during take-home running is shown in Figure 5.

### Booster for catch-up and Waste Heat Recovery System

The shaft generator/motor can also be used as a propulsion booster to supplement the main engine power and catch up top speed. This feature is still not used that often in propulsion optimization; however, it opens up for much more precise and flexible optimization and improved economical design and operation. A vessel's top speed is measured during the sea trial to verify design specifications, but rarely used later. That often means that the main engine is over dimensioned for normal operations. In other words, the value of the capital cost is not fully utilized and the vessel operates out of its most fuel efficient range.

Using one or two fewer cylinders would not only reduce the cost and size of the engine, but the other cylinders would also operate much closer to the engine's optimal design load, resulting in lower fuel consumption and reduced environmental emissions.

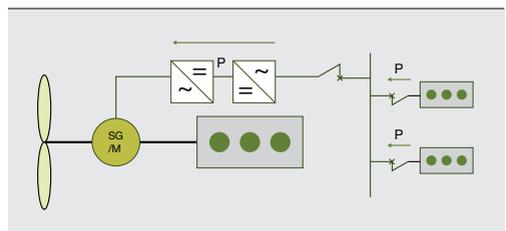
3 ABB ACS800 shaft generator drive

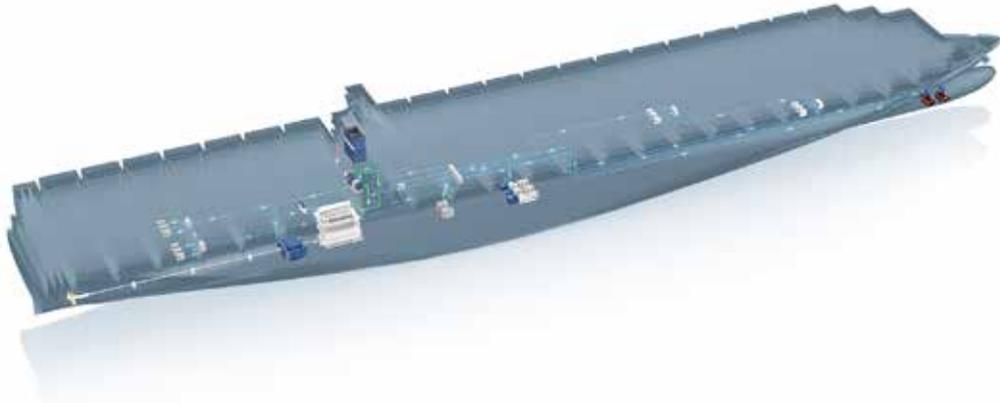


4 ABB low-speed shaft generator to be installed in-line with the main shaft



5 Auxiliary engines supplying power to the main propeller while the main engine is out of order





During top speed, additional power could be taken from the auxiliary engines and/or waste heat recovery system (WHRs) and supplied through the shaft generator/motor to the main shaft in a so-called booster mode.

When booster power is needed, the main engine is already running at maximum power. Consequently, the WHRS, if installed, generates maximum output and is therefore able to harvest about 10 percent of the main engine power from the exhaust heat. By adding some auxiliary engine power, the main engine power can be easily boosted by 20 percent, giving 20 percent less dimensioning of the main engine compared with a design where the main engine is designed to reach top speed by itself. A WHRS is not necessarily needed to boost the main engine power if this is provided by the auxiliary engines. Figure 6 shows container vessel propulsion using a WHRS and a shaft generator.

Applying this feature to design optimization can result in significant savings in investments and operational costs. Dimensioning of a combined main engine and booster shaft generator/motor propulsion system for catch-up top speed is shown in Figure 7.

### Shore connection

Port authorities and ship operators must adapt their businesses and solutions to the latest environmental regulations to minimize CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub> and particulate matter (PM) emissions. Today it is both feasible and effective to reduce ship emissions during port

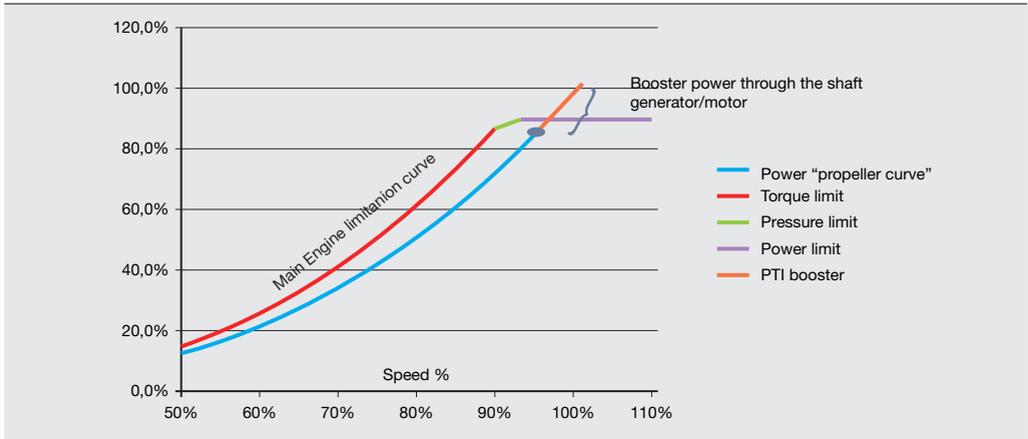
call by switching off onboard engines and connecting the vessel to an onshore power supply. However, the voltage and frequency of the onshore power supply can vary between ports. This can be solved by using the shaft generator/motor's frequency converter as an adapter to provide flexibility to connect to various voltages and frequencies that are available on shore (such as 400V to 690V for low voltage, and either 50 or 60Hz), while still providing constant voltage and frequency to the ship's systems (see Figure 8). This increases the use of available onshore power supplies in different ports around the world.

### Summary

Without having to make any excessive changes in a vessel's design, it is feasible to install systems that improve safety through redundancy and the availability of propulsion, while at the same time allowing for flexible designs that reduce the costs of the main engines and fuel costs.

This article showed how the use of shaft generator/motor configurations – in combination with an auxiliary power plant or waste heat recovery plant, or both – allows ship designers to optimize a vessel's design for various operational modes, improved safety and cost-effective construction.

The safety aspect is fulfilled merely by using the shaft generator/motor for take-home mode in addition to its primary function of providing auxiliary power in specified modes. Nonetheless, as such solutions are not required by class societies, the additional costs of



this added safety feature are often not accepted by the ship owner.

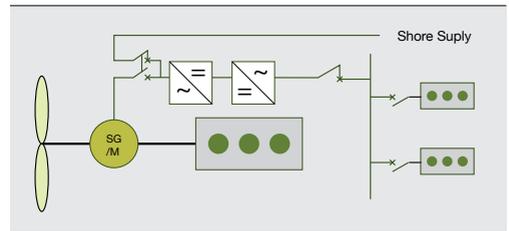
However, once the shaft generator/motor has been installed, it opens up new opportunities for reducing both the initial costs of the main engine, as well as lowering operational costs over a larger speed range.

Ultimately, if some or all of the five different features discussed in this article – take-home, shaft generator, booster for catch-up, WHRS and shore connection – are incorporated into the design, there is a good chance that this solution will be commercially viable, resulting in both a cost-effective newbuild design, as well as improved flexibility to optimize operations according to the route and freight requirements of the charter. A higher level of safety and redundancy is also achieved as a nearly free add-on to the energy optimized system.

In summary, the benefits of shaft generator/motor installation are:

- Increased safety with take-home capability
- Lower SFOC while auxiliary power is generated by main engine instead of auxiliary engine
- Reduced need for lubrication oil and lower maintenance cost for auxiliary engine
- Lower installed auxiliary engine power/amount
- Booster power for catch-up top speed, reducing the main engine size and thus lowering investment costs and SFOC during normal operations due to higher loading in remaining cylinders
- Reduced emissions

8 Shaft generator drive used for voltage and frequency conversion of shore connection



- Utilization of WHRS power to increase main engine efficiency
- More flexible solution to connect to onshore power supplies
- Redundancy in case main engine or auxiliary engine malfunction
- Independent optimization of propulsion efficiency and electricity production

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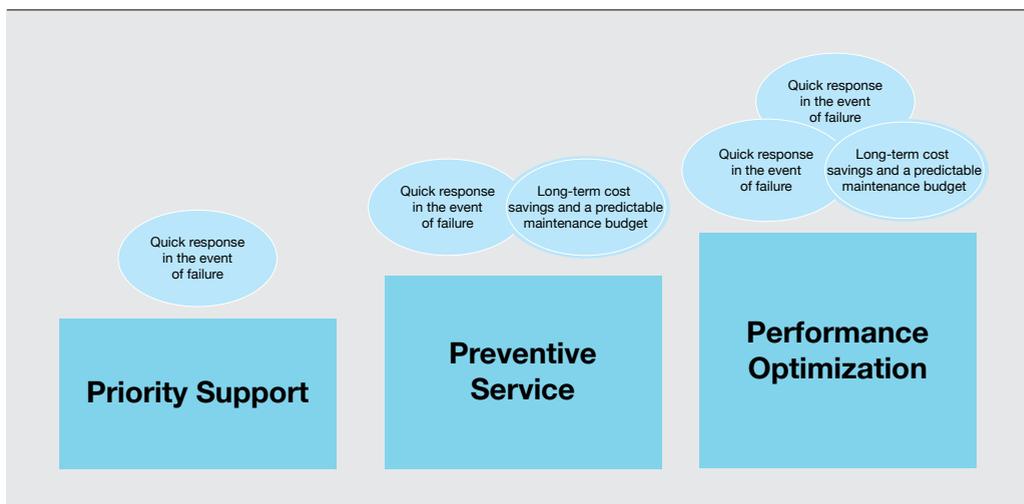
# Service agreements improve overall availability

**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 competence and operational profile. The Service Agreement should combine and optimize preventive maintenance, 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 perspective. By concentrating on performing

the right tasks in a planned sequence, the result is an improvement in equipment reliability. Systematic planning increases the efficiency and effectiveness of site visits by performing 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.

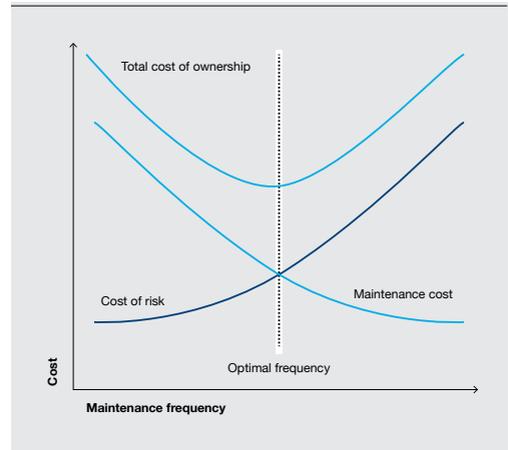
The Service Agreement concept supports an overall view of the customer's installed equipment base and long-term asset management. It enables the vessel operator to optimize asset management and operations, while offering effective communication and transparency between the owner/operator and ABB. Maintenance 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 suppliers 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 approached without proper failure statistics. However, as shown in Figure 2; it gives a good way of understanding 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 support as well as reducing unnecessary administrative costs.

Preventive maintenance and condition monitoring events are sets of standard and planned actions to be performed during a site visit. The harmonized global

## 2 The principle of optimizing cost of risk and maintenance costs



maintenance modules are developed and described in advance and the tasks can be divided between crew and service provider depending on the available competencies.

### 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 installations. 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 continuous 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 machine'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 equivalent 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

$$\begin{aligned} \text{Equivalent operating hours (Eq. h)} \\ &= \text{Actual operating hours (h)} \\ &+ \text{Number of starts (pcs)} * 20 \text{ (h)} \end{aligned}$$

### 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)
<b>Interval</b>	•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
<b>main customer preparations prior to maintenance</b>	•Disconnect the machine electrically •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 shaft couplings • Prepare for rotor removal
<b>Measurements, tools and special instruments</b>		• 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 borecope • 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
<b>Maintenance parts</b>	• 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
<b>Expected duration</b>	• 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 maintenance 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.

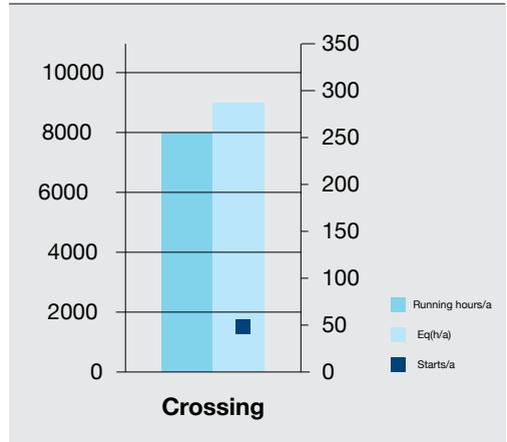
The starting and running time of machines in relation to operational needs can also affect the maintenance schedule. A reduction in the number of starts effects equivalent operating hours more than actual operating hours.

### Comparing equivalent running hours in different operational profiles

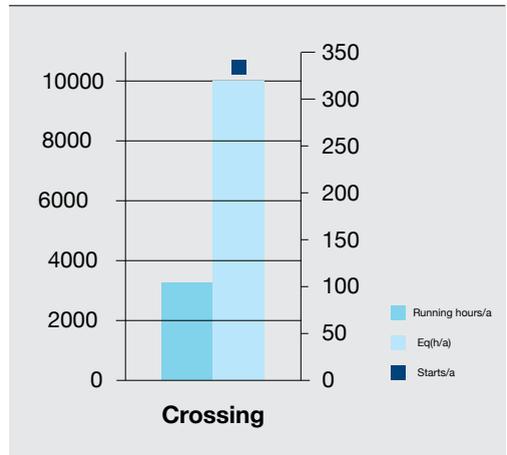
In the following example, an ocean-going vessel sailing non-stop long trips is compared to a vessel in coastal service requiring short sailing and several starts and stops. Surprisingly, Figures 3 and 4 show how different operational profiles result in the same maintenance needs. In both cases, the equivalent 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.

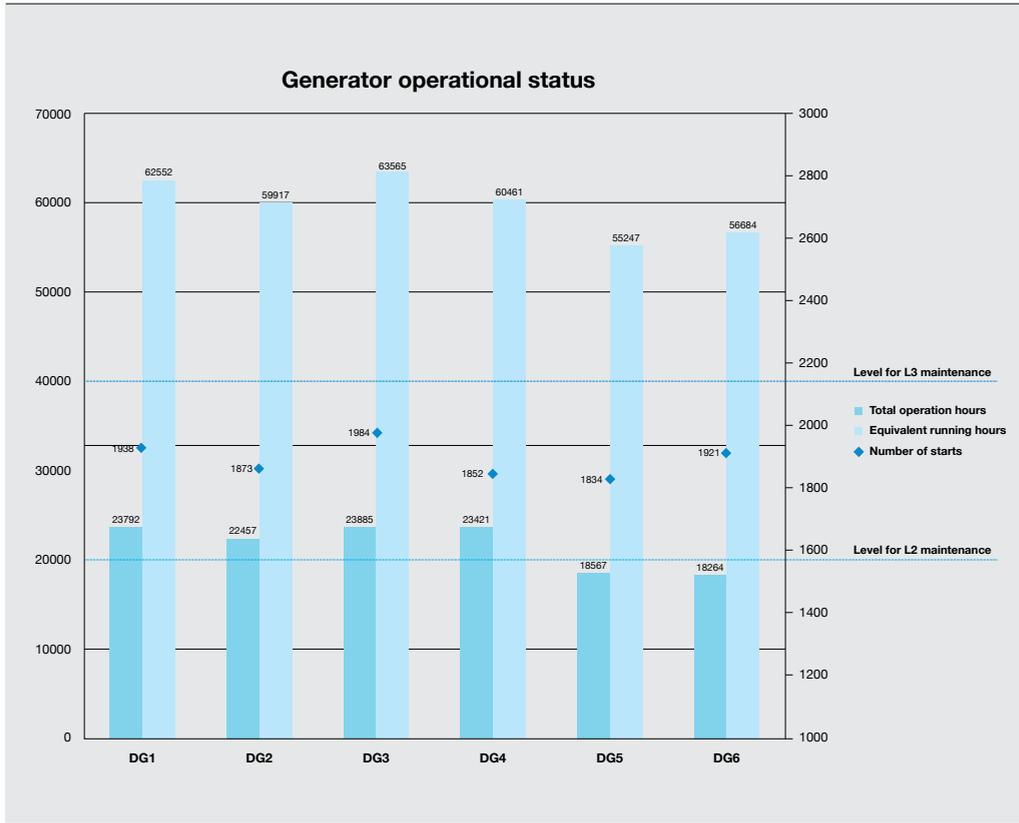
As the maintenance table indicates, the L1 maintenance is due in the both examples every year, when 10,000 equivalent hours are reached. Equally, the L2 maintenance is due every second year, when 20,000 equivalent hours are reached. If only actual running hours were followed, without considering number 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





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 reevaluate 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 engines 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 windings 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 prediction 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 action taken during planned downtime.

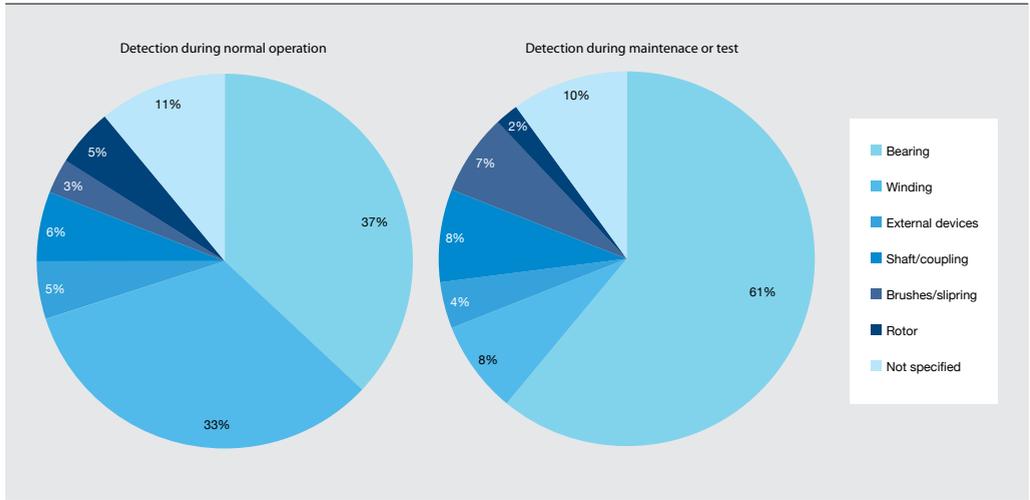


Table 2 ABB MACHsense-P measurements

Solution levels	Measurements When	Measurements What	Deliverables	Measurement Frequency
Standard	When the motor is operating at nominal load	<ul style="list-style-type: none"> <li>Vibration, voltage, current, temperature (winding, cooler and ambient) and speed</li> <li>Operation history, maintenance and failure records</li> </ul>	<ul style="list-style-type: none"> <li>Cage rotor package</li> <li>Rotor winding defects, air gap eccentricity, imbalance, looseness, static and dynamic shaft bends, internal misalignment</li> <li>Anti-friction bearing package</li> <li>Bearing defects, bearing assembly defect, lubrication interval estimates</li> <li>Installation</li> <li>Soft foot, misalignment, foundation resonance</li> <li>Power supply</li> <li>Harmonics and distortion, imbalance, over/under voltage, frequency</li> <li>Maintenance and inspection recommendations</li> </ul>	Every six months
Advanced	When the motor is operating at nominal load and with multiple loads and/or start-up	<ul style="list-style-type: none"> <li>Vibration, voltage, current, temperature (winding, cooler and ambient) and speed</li> <li>Operation history and maintenance and failures records</li> </ul>	<ul style="list-style-type: none"> <li>Same as above</li> <li>Cooler</li> <li>Fouling</li> <li>Root cause analysis</li> </ul>	When a defect is suspected either from standard measurement or from observed problems 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 developed to address reliability. In smaller machines, studies have shown that problems related to bearings, rotors and other mechanical components account for most total failures.

condition, the condition of the anti-friction bearings, the power supply and the assembly and installation of the motor.

With ABB MACHsense-P, data is collected by a specialized service engineer, who produces a report on-site. The report gives an analysis and interpretation of the test results and includes defect identification, severity, possible causes and effects on the rotor

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