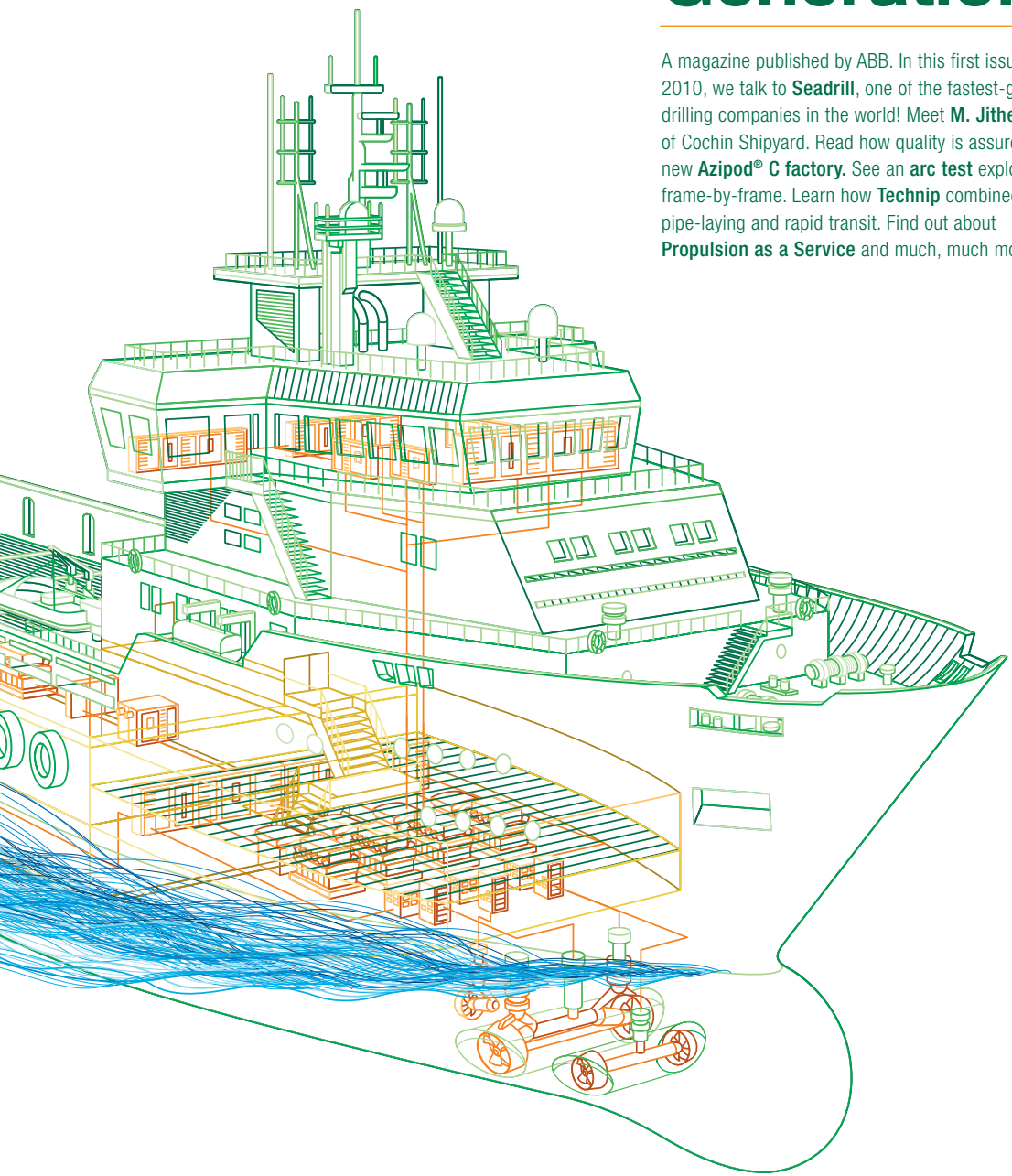
Generations

A magazine published by ABB. In this first issue of 2010, we talk to **Seadrill**, one of the fastest-growing drilling companies in the world! Meet **M. Jithendran** of Cochin Shipyard. Read how quality is assured in a new **Azipod® C factory.** See an **arc test** explode frame-by-frame. Learn how **Technip** combined pipe-laying and rapid transit. Find out about **Propulsion as a Service** and much, much more!



Neologisms are newly invented words. Here are some that may apply to your business.

Know thyself. The Greek injunction applies well to **customer service**. How do you know if you're delivering good service?

We asked a researcher to list up core reading for those interested in **innovation**.

We watch an arc test explode in front of our eyes.

Follow the steps taken to ensure **high-quality production** from a new factory of Azipod® C units!

Here an **Azipod® C** is dissected and analyzed.

The story of **the Brazilian oil adventure**.

India's maritime industry is expected to boom post-recession. We look at this growing market.

M. Jithendran, Chairman and Managing Director of giant Indian shipyard Cochin Shipyard, tells Generations about the growth in India's shipbuilding market

Our dream team of engineers dream up a new way to supply electrical propulsion, pay-per-thrust. They call it **Propulsion as a Service**.

In shipping's intricate relationship with **regulations**, the difference between success and failure can be timing.

News of innovations in ABB that may soon change your marine business too.

News from the world of ABB Marine – production, R&D, projects, support.

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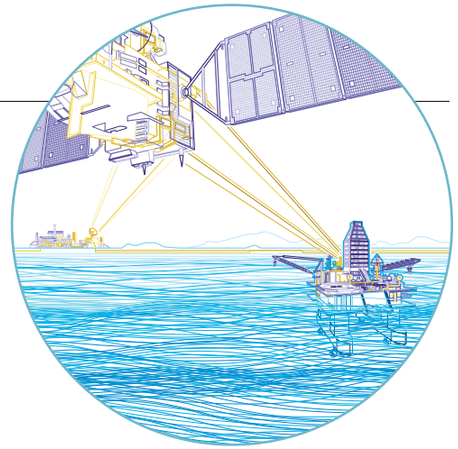
A

We take a look at the fastest-growing drilling company in the world. **Seadrill**'s VP for deepwater projects Alex Monsen talked to us.

An anchor-handler is the product of many companies, eyes and hands. We talk to the different stakeholders.

How do you combine fast transits with efficient operations in DP? **Technip** answered the paradox with Azipod® propulsion...

Here & Now



NORWAY ABB launched in May 2010 Remote Diagnostic Service (RDS). RDS gives users access to real-time data and support, via fast and automated information retrieval and the highest level of IT security. The service reduces overall maintenance costs by making expert knowledge available in the shortest possible time. BW Offshore and GasLog are already using RDS.

RUSSIA ABB is to supply electrical and propulsion systems for an arctic tanker under construction by Nordic Yard in Germany for Russian mining and metal company Norilsk Nickel. When completed in 2011, the tanker will supply fuel and lubricants to the company's northern operations and take gas condensate back to Russia. ABB's Azipod propulsion system will enable the tanker to break ice up to 1.5 meters thick, without support from ice-breaking ships. This is the 100th vessel equipped with Azipod technology.

UNITED STATES ABB's Houston office is now operational. This space supports out North American Regional Azipod Service Center. Recent activities there have included the overhaul of five Azipod C units for Transocean in Pascagoula, where they are being prepared and painted.

CHINA ABB has recently signed contracts with the China State Shipbuilding Corporation's (CSSC) Wuchang Shipyard for the supply of electrical power and propulsion systems, including two Azipod C units, to a multipurpose oceanography research vessel.

The vessel will be the first Azipod-equipped ship to engage in fishing resource exploration and oceanographic research worldwide. The ship's Marine Design & Research Institute of China (MARIC) design incorporates electrical propulsion from two 1.86 MW Compact Azipod units. The delivery also includes four generator sets and switchboards, transformers, frequency converters, a power management system, an integrated automation system and control systems.

RUSSIA Satisfied operators from two icebreaking vessels, Polar Pevek and Fesco Sakhalin, laud their Azipod propulsion systems. General Director of OOO Polarus, operator of the ice-breaking tug Polar Pevek, Helge Skarshaug said: "During four years of operation at DeKastri oil terminal as an icebreaking tug, Polar Pevek has not experienced any unscheduled docking. Azipod propulsion has proven to be the right choice".

Icebreaking supply vessel Fesco Sakhalin is operated by Far Eastern Shipping Company. Superintendent Konstantin Opolonik said: "IBSV Fesco Sakhalin has operated at Sakhalin for five years in difficult ice. During this period there has not been any off-hire time and only minor challenges with technical equipment. We have been able to solve them because of vessel's skilled crew and co-operation with ABB and its partners. Far Eastern Shipping Company is satisfied of the performance and reliability of the Azipod propulsion system."

Power provider

ABB is a global leader in power and automation technologies. New ways to create and deliver power in other industries may soon impact the marine market. Here's some of those innovations…

ABB CHARGING STATIONS FEATURED AT INTERNATIONAL MOTOR SHOW Prototypes of ABB's charging points for electric vehicles were showcased at the International Geneva Motor Show 2010. ABB's direct current (DC) fast-charging station concept was launched to the public, in association with an electric sports car prototype from Protoscar. An alternating current (AC) charging pole prototype by ABB was also featured, connected to a lightweight two-seater electric urban commuter called UC developed by Rinspeed. These prototypes are part of ABB's research into grid infrastructure technology. ABB has a broad portfolio of products and systems required to build and operate a smart grid, including intelligent power management and integration of intermittent renewable energy sources.

TRANSFORMERS WITH AMORPHOUS METAL CORE CAN REDUCE CO_2 EMISSIONS ABB's amorphous core transformers provide about 60 to 70 per cent lower no-load losses than regular electrical steel. Amorphous metal is a unique alloy whose structure of metal atoms occurs in a random pattern, as opposed to the conventional crystalline structure. The random structure has lower core losses, meaning it has a better environmental profile. Benefits of transformers with an amorphous metal core include lifetime energy and monetary savings, less heat generation and longer insulation lifetime. ABB's Amorphous Metal Distribution Transformer (AMDT) has been tested to all applicable standards and customer specifications.

LAUNCH OF SVC LIGHT WITH ENERGY STORAGE ABB introduces SVC Light® (Static Var Compensator) with Energy Storage, which enables dynamic control of active as well as reactive power in a power system, independent of each other. Effectively, the technology improves control over electrical grids, and compensates for fluctuations caused by, for example, intermittent sources like wind and solar energy. The present rated power and capacity of storage is typically in the 20 MW range for 15 to 45 minutes, but it can be scaled up to 50 MW for 60 minutes or more. This is part of ABB's global leadership in the family of Flexible Alternating Current Transmission Systems (FACTS).

CPMPLUS ENERGY MANAGER WINS AWARD Readers of Control Engineering selected the ABB energy monitoring and management software for its annual "Engineers' Choice" award. Selected by peers as best new product in the "Dashboard Software - Energy" category, cpmPlus Energy Manager helps customers in all industries to monitor, manage and optimize their energy usage for maximum efficiency and cost savings. It also includes reporting and analysis tools that evaluate the energy use patterns of all processes and pinpoints areas for improvement. Energy Manager is a core component of cpmPlus, ABB's Collaborative Production Management suite of applications.

Wait. Wait. Wait….OK, now.

How can shipping companies deal with the whims of regulators? Knowledge of the process helps. A veteran of shipping rules offers two examples: Ballast water rules and COP15.

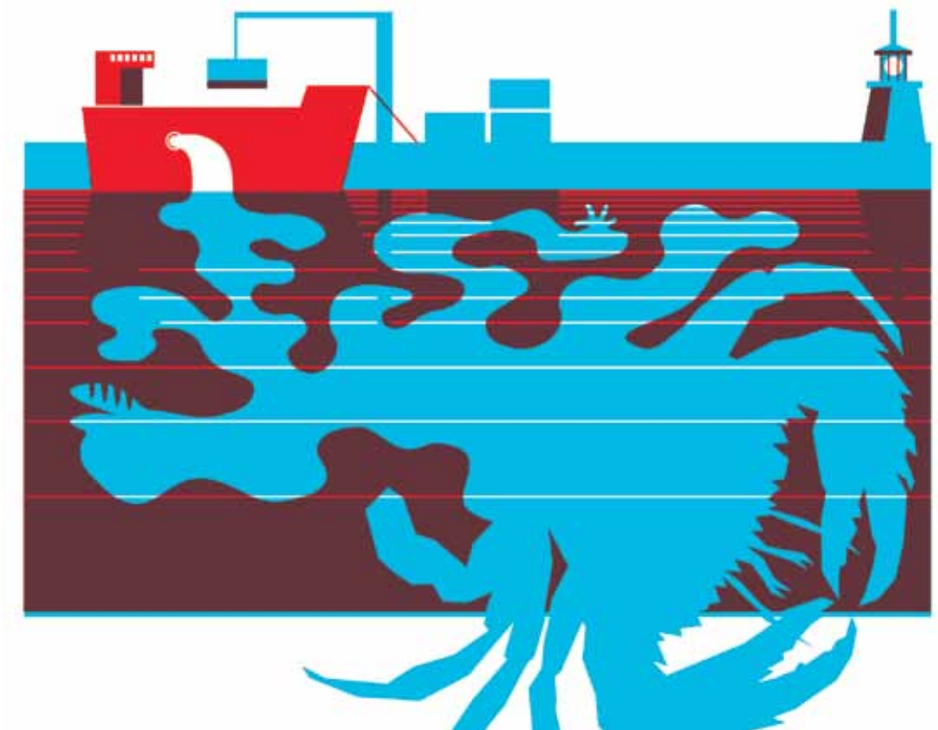
WRITER: *Ryan Skinner* || ILLUSTRATION: *Otto* || PHOTO: *Ryan Skinner*

In *War and Peace*, Leo Tolstoy said of the general who led Russian forces against Napoleon that he understood "it is impossible for one man to direct hundreds of thousands of others". One might say that the lonely shipowner is in the same situation. He aims to serve a society with an asset, but society can place any number of conditions on his asset, at any time.

This instalment of Generations' House Rules aims to provide insight to shipping companies that helps them find footing in a shifting regulatory framework. Fundamental to this must be an understanding of the political processes that drive regulations.

We spoke to a veteran of rules-making in shipping: Terje C. Gløersen, director of the Norwegian Shipowners' Association for a generation (now in the process of retiring). Specifically, what can we learn from two recent regulatory events – passage and ratification of the ballast water convention, and the pandemonium around COP15?

WHEN IS A CONVENTION A CONVENTION? The Ballast Water Convention provides as clear an example as any of the shifting calendar of shipping rules. Specifically, the people making these rules understood that, at the time they were



regulating a minimum level of performance, the technology needed to meet that minimum level was not in place.

"This convention was adopted in 2004 with a minimum performance standard that was, in effect, impossible to meet at the time. The deadline was to begin for the first category of new ships constructed in 2009, and would be retroactive in case the Convention entered into force at a later date," said Gløersen.

By locking in a future market based on a performance requirement, the IMO sought to drive technology development for handling ballast water. With invasive species in ballast water causing billions of dollars of damage to biosystems, port states were desperate to do something.

Meanwhile, the convention effectively made shipowners hostage to technology developments. Some shipowners, and some flag states, invested in ballast water system development. Others had no way to impact this uncertain future.

As the deadline for implementation approached, only two solutions had received type approval. Thanks to a review clause in the convention, the IMO pushed the timetable back until the second annual survey for the first category of new ships (but not later than the end of 2011).

"It was just too challenging to develop a compact and efficient solution for ships on time. We needed several systems to create competition, and also enough production and retrofit capacity to supply the industry," said Gløersen.

Today nine systems are type-approved and Gløersen is confident that the new timetable will stick. The convention, however, is still not in force; it needs to be ratified by 30 governments representing at least 35 per cent of the world fleet before that happens. This hurdle may be cleared by year's end. "Many countries simply have a back-up of laws to adopt," commented Gløersen.

The question remains: Were any companies caught out, making big investments based on a 2009 deadline that was postponed? Probably. "Many companies took a wait and see attitude. Now we feel confident in the revised timetable starting in 2011, even if the convention enters into force at a later time. There is no established way to mitigate this kind of political risk for the equipment makers. Seeking loan provisions that account for this risk may be one way."

WHEN IS A CONVENTION NOT A CONVENTION? Unlike the ballast water convention, which enjoyed global consensus in principle, efforts to curb carbon-dioxide emissions face a more fundamental challenge. Simply put: Many countries are not willing to agree to a regulatory scheme that cuts evenly across the globe. Producing carbon is seen as a necessary evil on the road to greater prosperity.

Unlike the ballast water convention, which essentially prescribes a fixed, one-time investment for all ships, efforts to reduce carbon output will have a deeper and longer significance to shipping operations. But starting when?

COP15 was meant to answer that question, or at least ask it. "We cannot be happy with the outcome of COP15. Much more work to cut carbon emissions remains. The IMO works along two tracks: Technical and operational requirements, and market-based instruments."

The first is enshrined in what the IMO calls an energy efficiency design index, which stipulates a reduction in carbon emissions per ton-mile over time. One might say that this index simply puts the industry's ongoing work to increase fuel efficiency into a regulatory framework. But it also adds legal teeth to chase and penalize operators to prevent them from increasing the carbon footprint of new ships.

Greater controversy swirls around the market-based instruments. These efforts to put a price on carbon face almost insurmountable hurdles. The solution may be allotment of up to 16 billion dollars such an instrument would create annually, Gløersen speculated. ›››

Terje C. Gløersen, director of the Norwegian Shipowners' Association

"Testing of the index will continue at an intersessional meeting starting 28 June," said Gløersen. "For some ship types, this index can be fast-tracked by the IMO via tacit amendment to MARPOL Annex VI and enter into force as little as 16 months after adoption (earliest, MEPC 62 in July 2011).

"Market-based instruments are highly political and global requirements are now fiercely opposed by leading developing countries. Much more information about impacts on developing countries is needed, in addition to a breakthrough in the UNFCCC negotiations."

LESSONS LEARNED Rules adoption and implementation is a question of timing. Shipping companies are best served by a stance of gaining knowledge about the regulatory changes at hand, and preparing for implementation. Given this positioning, each company can weigh the cost versus benefit of going forward on pilot projects, or waiting until change is mandatory.

For these two examples, the picture has clarified. The ballast water timetable looks set in stone; deadlines will not be pushed back any further. Likewise, carbon emissions are certain to grow more costly. The EEDI will stipulate a level of continuous improvement already in place at many shipping companies. Market-based instruments are not a prescient issue, but simply an element in the general picture of rising fuel and carbon-related costs. |||

SLANG

Neologism: a meaningless word coined by a psychotic

Sometimes we simply need a new word to describe a new phenomenon. Sometimes we just invent new words for fun. Here are some words that may fall in either category.

WRITER: *Ryan Skinner* ||| ILLUSTRATION: *Daniel Barradas*

Automagically

Actions that happen automatically, but also seem to happen magically. The word may be used when the speaker does not understand the process by which the action occurs.

Backronym

Created by finding words with first letters to accommodate a predefined, wanted acronym.

Category killer

Used in marketing or strategic management to describe a product, service, brand or company with such a distinct sustainable competitive advantage that competitors find it almost impossible to operate profitably in the same field, or category. (eBay is an example).

Chartjunk

All visual elements in charts and graphs that are not necessary to comprehend the information represented on the graph, or that distract the viewer from this information.

Complification

The process of making something more complicated or more complex.

Freemium

A business model that works by offering basic services or products for free, while charging for advanced or special features (often used in an online setting).

Hand-waving

The act of trying to get past a difficult situation or problem by ignoring it (also known, in the entertainment industry, as "jazz hands").

Hypotenize

To take a shortcut, specifically, by traversing a hypotenuse of two paths at right angles.

Marchitecture

Any form of electronic architecture perceived to have been produced purely for marketing reasons. Used by a vendor to place itself in such a way to promote all their strongest abilities whilst masking their weaknesses.

Retro-Tech

Technology that intentionally employs older legacy solutions or appearance.

PROFESSIONAL ENDEAVOUR

Customer Service: Knowing how you're doing

A recent survey indicated that 56 per cent of corporate executives felt their company was "extremely customer-centric". Only 12 per cent of clients agreed. How are companies like ABB striving to close the gap between the service they think they're offering and the customers' perceived experience?

WRITER: *Ryan Skinner* ||| ILLUSTRATION: *Otto*

STEP ONE in the classic manager's "recession playbook" is to re-invest in existing customer relationships. With markets across the world reeling from the financial crisis and trade and shipping feeling the impact especially acutely, marine industrial outfits need to focus rigorously on customer satisfaction.

Combine this trend with technological developments that mean customers, users and potential critics are available constantly, online. Web 2.0 tools mean that there are countless new ways to engage customers. And customers, happy or no, can more easily influence one another.

With a bit of melodrama, one might say these forces create a perfect storm for customer service and customer relationship management. I spoke with a manager at ABB who works in customer service about how they are addressing customer service issues. And I look into a number of tools and strategies that aim to raise companies' customer service effectiveness.

COMMUNICATION'S THE KEY J.P. Hellgren is today operations manager for ABB's marine business. He's supporting ABB's vast cruise business worldwide and a number of marine service centres all over the world. Further, Hellgren's spent almost a decade posted around the world working in technical service and support in ABB. If anyone knows the tricky in's and out's of customer contact, it's him.

So, how does Hellgren know when he's doing things right? "If I have happy customers, a happy team and a happy network, then I'm doing this right." But how does he know if these groups are all happy? "There's a couple of ways, but face-time is the first and foremost, then email and also systematic polling systems."

The last element, systematic polling systems, is called eCROL at ABB. eCROL stands for electronic Customer Relationship OnLine, and it is essentially a questionnaire that goes out to ABB customers regularly, and particularly after a major job.

"We can compare our own feelings about how we provided customer service to the customer's opinion. Where there are significant discrepancies, we follow up and find out where we've misunderstood and where we can improve," said Hellgren.

In order to manage the expectations of the customer, Hellgren sticks to a strategy of openness and honesty. "I don't have a problem sending a less experienced service technician on a job, but then I make an extra point to inform the customer of the situation. I'll tell them that this is the resource I have right now; that way, we have the same starting point to address the situation," said Hellgren.

ABB service technicians can often be dropped in to stressful situations, such as for example when a malfunction puts a drilling rig worth half a million dollars a day out of action. In these cases, the customer can be upset, and it is critical for technical service to keep its cool. In these cases, one strategy is to ask questions around the problem, and try to think outside of the box and, as Hellgren puts it, "see more than the broken component."

SERVICE EVOLUTION The nature of the customer service job is evolving. Both market forces and technological developments mean that the job of supporting ABB components is changing.

On the market side, shipyards are generally speeding up schedules. Where ABB requests eight weeks for a specific job, the shipyard may allocate only six weeks. This puts a stress on the coordination capabilities of the service technicians. Further, budgets for maintenance from cash-strapped owners are getting leaner.

"People are definitely doing what needs to be done, but if it can be delayed then many are choosing to delay a job. We recommend the scope of jobs, so we are in a situation where we need to explain what needs to be done and what will happen if a job is not done," said Hellgren. "Oftentimes, we can help a customer

New Customer Service Tools

New technology, and specifically web 2.0-based applications and social media tools, allow companies to reinvent how they talk to customers, where they meet them and how they support them. Here are a few examples.

E2E – Texas Instruments set up in 2008 an external community where its own engineers and external contacts could meet and "help each other solve problems faster". They called it E2E, and it "changed the nature of requests the customer support department receives, since engineers were able to access help for deeply technical issues from the community."

@comcastcares – A classic case of social media use for corporate benefit is the story of how a customer service engineer at American cable company Comcast began using twitter to address problems and issues with Comcast's service. His ambition to take customer service where customers are has since spread to other platforms, and Comcast has earned a reputation for service excellence.

eCROL – ABB's own tool for gathering and assessing customer feedback has had great results for the company. This online customer relationship analysis tool gives ABB managers a better perspective on how their own service perceptions match up to customers' own feedback. This reaches across business areas, geographical areas and customer segments.

identify where savings can be made."

The nature of the communication with clients often depends on the nature of the customer contact's position. Hellgren describes how the subject of conversations will differ significantly when talking to a procurement officer versus an electrical engineer. "Where technical staff want to dive into the details of what needs to be done, the purchasers are often more concerned with the scope of the work and defining a specification."

On the technology side, a major change that will impact the job of service personnel is remote diagnostics. ABB is currently developing remote diagnostics systems for its propeller and drilling drives. With these in place, components will be able to communicate key performance data on the fly to engineers on the ship or rig, and this same data can be sent to ABB for analysis.

"Ideally, this will make troubleshooting happen much faster. When we can see what they are seeing, we can provide advice and propose corrective actions without making a site visit. These systems are logging information continuously, as well, so we can study long-term trends and advise customers on ways to fine-tune the components and achieve greater efficiency or up-time," said Hellgren.

CONCLUSION Service organizations today combine the robust, soft knowledge and experience of managers like Hellgren with objective metrics developed by tools like ABB's eCROL tool. The combination of these two allows ABB to improve the quality, quantity and verifiability of their customer service efforts. The objective interface of these polling tools enable customers to assess performance across disciplines like purchasing, engineering and management.

"No matter the quality of the polling results, though, we believe that they need to be followed up in person, in order to qualify the responses and give them more context," concludes Hellgren.

JP Hellgren

JP Hellgren is today an operations manager for ABB's marine business in Helsinki. He's supporting ABB's vast cruise business worldwide, including state-of-the-art vessels like Oasis of the Seas and HAL's Eurodam, and the numerous ABB service centres that serve these ships. Hellgren's spent almost a decade in locations all over the world, working in technical service and support. When it comes to customer support, he's seen it all.

New Customer Service Models

There are almost as many ways to approach customer service as there are customer service practitioners. Experts in the field, however, may have a little more theoretical ballast to their practical advice. Here's how some leaders think customer service.

Peter Merholz – Founding Partner of Adaptive Path, Inc. Merholz describes how, in interactions with clients, he finds that many organizations organize customer relationships from the inside out. They follow five steps he's devised, starting with systems, to procedures, touch points, interactions and experiences. He urges companies to turn this order and prioritization on its head.

Convergys – A 2009 report from this leader in relationship management urges companies to improve customer service with a grassroots approach: "companies may need to recast processes, rules and structures to give agents the authority necessary to understand and meet the individual customers' needs and provide a good experience."

Kate Dickens – An author and thought leader on customer service, Dickens has published a list of six principles of service excellence. The first of these is surprisingly simple, but critical: "The philosophical framework of the company (its vision, mission and values) should be phrased so that employees can understand them, relate to them, and aspire to them."

FIELDBOOK

Reading on innovation

We have all heard that the future is for the innovative. Innovation is not simply about creating new ideas, but the ability of people or organizations to commercialize their ideas and create technological, social and organizational change. We asked Nie Jing, a researcher of innovation and management at BI Norwegian School of Management, to recommend books to understand and manage innovation better in a company.

The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation
– Nonaka, I. & Takeuchi, H.
(1995) Oxford University Press

Provides an inside look at how Japanese companies create new knowledge organizationally, especially how to convert tacit into explicit knowledge. This has enabled Japanese firms to become world leaders in the automotive and electronics industries.

Open Innovation: The New Imperative for Creating and Profiting from Technology
– Chesbrough, H.W.
(2003) Harvard Business School Press

Offers a new vision of the innovation process, differentiating open innovation from closed innovation, with illustrations. This new vision seeks external knowledge and ideas, even as it nurtures internal ones. By utilizing valuable ideas from any source and sharing, companies can renew current business and generate new business.

The Innovator's Solution: Creating and Sustaining Successful Growth
– Christensen, C.M. & Raynor, M.E.
(2003) Harvard Business School Press

Guides managers who need to grow new business with predictable success - to become the disruptors rather than the disruptees. Read about nine of the most important decisions that managers must make to create growth.

Managing Innovation: Integrating Technological, Market and Organizational Change
–Tidd, J., Bessant, J. & Pavitt, K.
(2005) 3rd ed, John Wiley & Sons Ltd.

Offers the knowledge to understand, and the skills to manage, innovation at the operational and strategic levels. Specifically, it aims to integrate the management of market, technological and organizational change to improve the competitiveness of firms.

Product Innovation: Leading Change through Integrated Product Development
– Rainey, D.
(2005) Cambridge University Press

Defines and discusses a comprehensive framework for managing product innovation and the related new-product development (NPD) process, since product innovation is an essential strategic approach for creating competitive advantages in a dynamic and challenging business environment.

Boom! Arc Test!

These sizzling pictures illustrate what can happen when electricity goes awry. More knowledge will mean more safety!

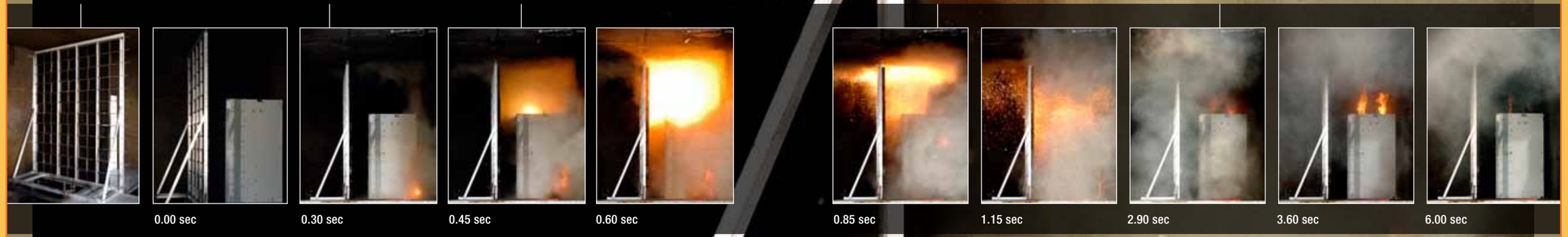
WRITER: *Ryan Skinner* ||| PHOTOS: *Nancy Bundt*

ABB REGULARLY TESTS their products to understand how they respond to failures. One of those tests is the arc test. For those who haven't seen an arc first hand, it is an undesired discharge from an electrical system leading to fire or even explosion.

These pictures were taken at ABB's NEFI High Power Laboratory in Skien, Norway. Here, an internal arcing test is performed as a development test on a medium voltage switchgear.

Flame indicators according to the relevant standard have been placed in front of the switchgear in order to detect the effect that the hot gases and flames have on persons standing next to the switchgear. An arc test can often look disastrous, even when the success criteria of the standard are fulfilled.

Interested in products with high safety level when it comes to arc faults? Check out two articles in this magazine's Chapter B about arc-proof medium-voltage switchboards! |||



Cotton flame indicators are put in front of the switchgear

0.00 sec

An arc is deliberately ignited inside the switchgear

0.30 sec

Arc temperatures between 3000-5000 Kelvin, or even higher, results in a rapid pressure rise

0.45 sec

0.60 sec

The impact is measured horizontal and verticaly (low ceiling)

0.85 sec

1.15 sec

In this case, the arc burns for less than a second and then the switchgear burns for a while

2.90 sec

3.60 sec

6.00 sec

Translating Finnish quality to Chinese

ABB has proudly announced that it will begin producing Azipod® C units from a brand new factory in China. The guy responsible for making this a success, ABB's Jaakko Aho, talked to Generations about the steps they're taking to ensure high-quality production from the new location.

WRITER: *Ryan Skinner* || PHOTOS: *ABB*

FIRST, LET IT BE SAID that ABB has been producing components in China for decades. After setting up a permanent office in China in 1979, the company has initiated manufacturing of transformers, switchgears, electrical drives and motors and industrial robotic products in China. With a $4.5 billion order intake in China in 2008, it officially became ABB's biggest market.

Even if ABB has established a track record for manufacturing excellence in China, every greenfield manufacturing project raises important questions – among them, questions related to quality. How do you ensure that you have the suppliers, processes, employees, infrastructure and management in place to deliver the expected level of quality, when the site is new?

Jaakko Aho, who is the man charged with establishing Azipod C production in China, is wary but calm. "We have a number of pillars to rely on. First of all, we have a very strong and competent organization here in China. This means that much of our supplier network will be familiar names, many of them within ABB. Secondly, we have a strong quality system at our existing production site in Finland. This will remain intact in our Chinese manufacturing operation, as we add more explicit instructions and protocols.

"Finally, the principles of our production process, which are well established, will remain intact. Only minor localization adjustments are made to make the production process reliable and efficient for local circumstances. In essence, the process and components will be identical. If we were introducing new elements or processes, this would be much more challenging. In this case, we have a very strong template to work from," he said.

Aho goes through a number of checkpoints that are critical for the quality of this greenfield manufacturing investment. If he can nail each of these points, he can be certain that the compact Azipod units that roll out of the new production facility in Shanghai bear the same professional quality for which Azipod has won a strong brand name worldwide.

QUALITY SYSTEM ABB has an established quality system that it developed for production of its Azipod C units in Finland. This system lays down a number of processes, milestones and audits that act as a kind of gate for quality; if anything does not live up to the expected level of quality, it goes no further, until it is addressed and a remedy found.

"This quality system impacts a number of phases. The first and perhaps most significant phases include assessment of suppliers, and component supply, as well as the initial production. We will place an extremely high level of scrutiny on the first materials received from suppliers, and from our own manufacturing facility," said Aho.

In addition, with production at two locations, ABB will benefit from an expanded pool of lessons learned. The Chinese production site will benefit from experiences in Finland, and vice-versa. And both benefit from the feedback from ABB's Azipod service centres around the world.

Azipod C production in China
ABB announced in 2009 that it would begin to produce Azipod C units from a new ABB production facility in the Shanghai area. Previously, ABB has supplied Azipod C units to several ferries and other vessels constructed and operating in China. Construction of the new production facility began in March 2010, and the first new Azipod C units are planned to go out the door in the second quarter of 2011.

SOURCING AND SUPPLIER NETWORK ABB uses a matrix organisation in its sourcing. Thus a dedicated sourcing organisation will lead the process of qualifying suppliers, with assistance from the Azipod global sourcing organisation in Finland and ABB's sourcing organisation within China. The Finnish unit has been working with Azipod component suppliers for years. And the Chinese unit can consolidate the Azipod C production into volume orders and share its knowledge base of suppliers in China across business units.

Potential suppliers to ABB's Azipod C production in China have to go through a rigorous series of tests and audits before they're chosen. Given ABB's history in the market, Aho and his team have a list of pre-qualified suppliers for many components.

From this list, the final suppliers will be put through a supplier qualification process, or SQP. This assesses a supplier from many perspectives – financial, technical, quality history, manpower, etc.

"Before we choose a supplier, we ask them to produce a sample of a critical component. This component is then put through a very detailed inspection. We have a very long protocol for this. 3D cameras will measure dimensions and tolerances. Destructive testing will assess the material quality," said Aho.

One key component, the heavy electrical motor of the Azipod C, will come from an ABB sub-supplier only a stone's throw away. "This proximity to the producers of such a critical element definitely adds to our quality assurance," said Aho.

FINDING COMPETENT PEOPLE Two fundamental properties will ensure that ABB has the right people working at the new factory at every stage of its development. First of all, before full production begins and well into initial manufacturing, ABB will use experienced hands from its Finnish operations. Secondly, it can rely on a powerful and experienced human resources department in China to assure the quality of its new hires. »»

"In the ramp-up phase, we will have a staff of experienced expatriates in critical positions. These will train their local counterparts, and, after a year, we plan to run the organisation mainly with local resources," said Aho.

"We have no doubt that we will find the right people here. ABB already employs 15,000 people in China, and has been ranked among the top 10 employers by students and engineers several times," said Aho. "The level of talent here is phenomenal, and we'll get them for the Azipod C production."

FACTORY, INFRASTRUCTURE AND LOGISTICS The factory will be located in the Lingang district of Shanghai – a purpose-built district for modern industrial development. Further, the site is only 30 kilometres (or roughly one hour by truck) from Yang-Sun, China's biggest container terminal.

"This district is optimized for our kind of operations in terms of logistics and infrastructure. The municipal authorities have focused on power stability, and other basic services required by heavy industry. For example, utilities and logistics here are really optimized," said Aho.

The factory itself will be an example of modern, state-of-the-art manufacturing. In terms of climate control and modern equipment, the production hall will be the peer of any facility in the world. "In terms of ergonomics, atmosphere and energy efficiency, we used the highest standards, well above those applied normally in China," said Aho.

PROCESS INTEGRITY ABB has undertaken numerous product and production transfer projects all around the world, and experiences gained in some of these projects will be applied to this project. For example, the neighboring ABB electrical machines factory has a very similar operations model, with an R&D and production knowledge base in Finland with a local production unit in China.

"What's most important for us is to retain the kind of integrity we've established in Finland. Our staff is being trained in different locations to get broader experience, and we've put a tremendous focus on our planning," said Aho.

In fact, one of the only ways in which the process will change is in terms of the information and documentation. Obviously, documents and instructions will be translated to Chinese, but they will also be made more specific. Any room for misinterpretation will be closed.

MANAGEMENT Lastly, there is the crucial aspect of management, leadership. Said Aho: "For the ramp-up phase, we will have a heavy investment of experienced professionals from Finland here. Management and leadership are such cultural issues, and we're adjusting these according to local circumstances. The same level of quality in every level of the organisation, and every part of the process, will be maintained here at the same level as a Finnish factory, for example.

The new factory is getting tremendous attention from the highest echelons in ABB. Both Heikki Soljama, head of ABB's global marine and cranes business unit, and Tobias Becker, head of ABB's process automation division for North Asia and China, have followed the project closely.

"The state-of-the-art assembly, along with a high-technology product, will benefit not only ABB, but also the whole maritime industry cluster in China, and specifically here in the Shanghai area," said Soljama. Becker added: "ABB will keep on introducing new automation technologies to China. We extend our production in China, for domestic consumption and export to the rest of the world, with ABB's global quality standard."

Aho concludes: "If anything, I believe that we are taking the precaution and steps to make this production facility a new standard for quality in the group." |||

Poised for growth in India

India's shipping, shipbuilding and offshore industries are all expected to boom post-recession. The combination of a large population, high technology and a low-cost workforce are key drivers. Read on to learn about ABB's work in this market, and a whole slew of key India facts and indicators.

WRITER: *Radhika Rani* ||| MAPS AND GRAPHICS: *Daniel Barradas*

"THE SHIPBUILDING AND SHIPPING industries in India started to boom in 2008. We expected to see the yards in India really take off. Then the financial crisis struck and everything came to a stop," says Mithilesh Pandey, head of sales for ABB's marine business in India. "But the underlying strength of this market, combined with some state support, will drive growth in coming years."

ABB established a dedicated sales office in 2008 on the back of orders for European or Asian vessels due to be built at Indian yards. Pandey took over the reins of this effort in December 2008. Last year was a trial, as the crashing market put a full stop to order intake across the country.

Things have changed. "The fundamentals are strong here. Labour is cheap, and the capabilities of the yards are increasing. The government has seen the value of shipping and shipbuilding and has instituted subsidies to bolster these industries," says Pandey. The Indian Government had a 30 per cent subsidy on ships meant for export until 2007, and a similar boost is expected in the future

As a result of the market's changing fortunes and governmental support, eight to ten new shipyards that were planned for construction in 2008, but put on ice, are expected to be on track soon. The Gujarat region alone may see as many as five new shipyards, and plans are moving forward in Kerala, Chennai and Orissa.

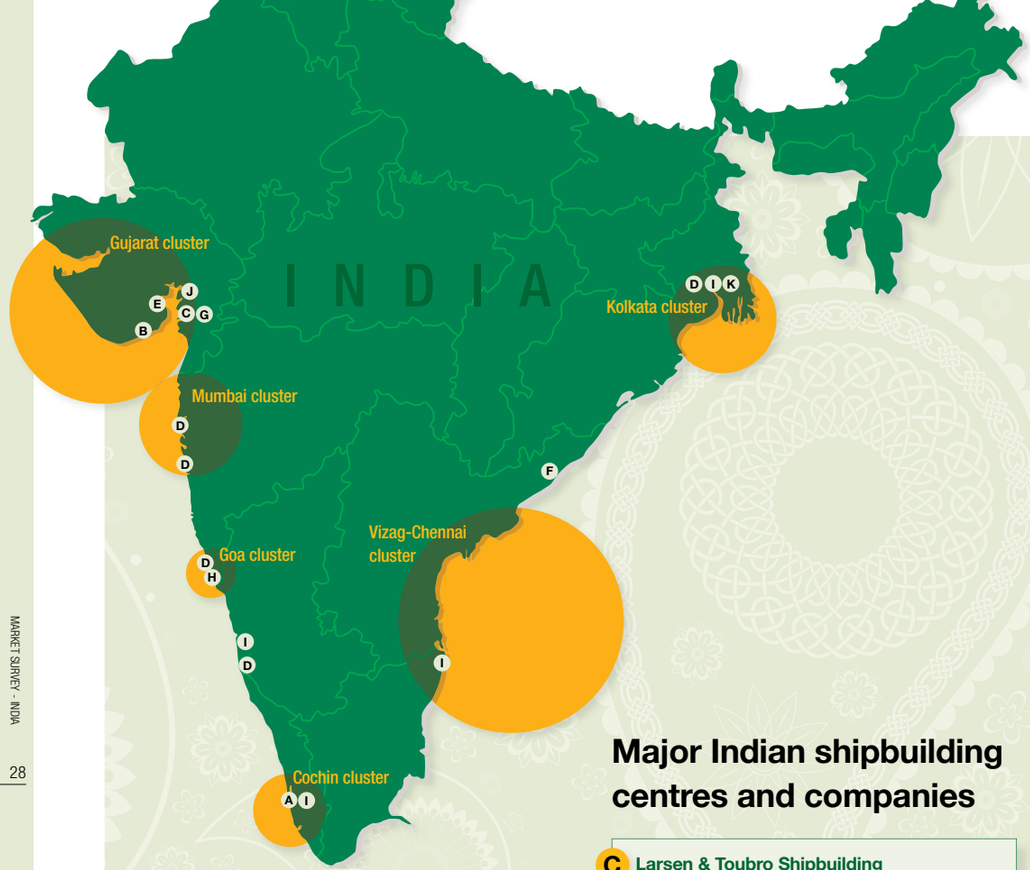
Interest for diesel-electric propulsion is growing at Indian yards, even if their experience with such technology is so far limited. "I've been talking to a number of owners and yards, and many have begun to look more seriously at diesel-electric propulsion. There is concern about the one-time cost, but buyers' increasing interest in the technology is pulling it to the yards," says Pandey.

Pandey has a small team dedicated to sales of marine propulsion packages that is set to grow. In 2010, he plans to pull in as much as USD 7 million in new orders and increase the company's after-sales support team in India. Even if ABB faces stiff competition in India, Pandey believes that the strength of ABB's products and the strength of ABB's reputation in the Indian market are assets that set his offer apart.

"It's going to be a struggle, but we're making offers at over a dozen yards. We have strong arguments, and I feel certain we'll succeed to build a strong market share here in India," concludes Pandey. |||

Commodity	Projected traffic for major ports by 2013-14 (million tonnes)	Overall capacity requirement by 2013-14 (million tonnes)	Additional capacity to be created by 2013-14 (million tonnes)
POL	191.20	248.56	93.71
Container	181.20	235.56	186.01
(TEUs)	(15.10)	(19.63)	(15.5)
Iron Ore	97.50	126.75	75.75
Coal	109.90	142.87	98.67
Other Cargo	126.04	163.85	73.95
Total	**705.84**	**917.59**	**528.09**

Leading names, faces and personalities in Indian shipping world



Major Indian shipbuilding centres and companies

A Cochin Shipyard, Cochin

Location: Kochi, Kerala

Ownership: Ministry of Shipping, Government of India

Can build vessels (tankers, bulk carriers, port crafts, passenger vessels) up to 1.1 million DWT per year.

Order book: 20 (17 platform supply vessels, 2 anchor handling tug supply vessels and 1 indigenous aircraft carrier)

http://www.cochinshipyard.com

B Pipavav Shipyard

Location: Near Port of Pipavav, Gujarat

Ownership: Private (Nikhil Gandhi, Bhavesh Gandhi, Atul Punj)

(Started commercial operations on April 1, 2009)

Order book: A $1.2 billion order book for 26 Panamax bulk carriers with the capacity of 74,500 DWT each for delivery from 2009 to 2012.

www.pipavavshipyard.com

C Larsen & Toubro Shipbuilding

Location: Hazira in Gujarat, Ennore Port in Tamil Nadu

Ownership: Private (A M Naik, chairman & MD)

Builds niche vessels - specialised heavy lift cargo vessels, CNG carriers, chemical tankers, defence & para military vessels.

Orderbook: A order for eight ships. Is eyeing for a major defence sector deal.

www.larsentoubro.com

D Bharati Shipyard

Location: In clusters: Ratnagiri; Ghodbunder, Thane, near Mumbai; Zorinto, Goa; Kolkata; Dabhol, Gujarat; Mangalore, Karnataka

Ownership: Private (by P C Kapoor and Vijay Kumar)

(holds 45.88% stake in Great Offshore Ltd)

Builds offshore support vessels for oil exploration, dredgers, power-packed ocean going tractor tugs, cargo/container ships and tankers.

Order book: 41 vessels (AHTSVs, OSVs and rigs)

www.bharatishipyard.com

E Alcock Ashdown Co. Ltd., Gujarat

Location: Bhavnagar, Gujarat

Ownership: Govt of Gujarat

Is into multipurpose cargo and passenger vessels up-to 20000dwt, PSVs, defence production ships, tugs, barges, deck loading pontoons, fishing trawlers, FRP boats & products, inland gas and liquid vessels, pollution control vessels, research vessels and fire floats.

Order book: 11 vessels (one 400 passenger cum 50T cargo vessel, 2 No. 3000 DWT product carrier, 2 No. 4000 BHP work boat cum supply vessels and 6 catamarans)

www.alcockshipyard.com

F Hindustan Shipyard Ltd., Visakhapatnam

Location: Visakhapatnam, Andhra Pradesh

Ownership: Ministry of Shipping, Government of India

(Note: It is taken over by the Ministry of Defence to build nuclear submarines. The present order book for commercial vessels is likely to be completed by March 2011.)

Is into design, construction,conversion and repairs of merchant ships, naval vessels and oil rigs up to 80,000 DWT. Can also build drill ships, offshore platform and support vessels for the oil sector.

Order book: 13 vessels (6 No. of 53,000 DWT bulkers, 1 oil recovery & pollution control vessel, 5 inshore patrol vessels and one 32-tonne Bollard pull tug)

http://hsl.nic.in

G ABG Shipyard

Location: Hazira-Dahej cluster, Gujarat

Ownership: Private (by Rishi Agarwal and Saket Agarwal)

(holds 15% stake in Great Offshore Ltd.)

Constructed 115 vessels so far, including specialised vessels like interceptor boats, self-loading & discharging bulk cement carriers, floating cranes, articouple tugs & flotilla, split barges, bulk carriers, newsprint carriers, offshore supply vessels, dynamic positioning ships, anchor handling tug supply vessels, multi-purpose support vessel and diving support vessels

Order book: 50% bulk carriers, 30-35% for oil and gas service vessels like anchor handling tug supply vessels and platform supply vessels, 10-15% short sea trade and coast guard ships

www.abgindia.com

H Chowgule's Shipbuilding

Location: Goa

Ownership: Private (D N Chowgule & Sons)

Constructed over 100 vessels comprising of iron ore barges, passenger vessels, deep sea refrigerated fishing trawlers, grab and cutter suction dredgers, tugs, twin-hull catamarans and floating restaurants.

Order book: 12 multipurpose vessels

www.chowgule.co.in

I Tebma Shipyard

Location: Facilities at Chengalpattu near Chennai, Malpe near Udupi in Karnataka, Kochi (through JV with Cochin Shipyard) and a leased facility in Kolkata.

Ownership: Private (P K Balan – chairman, Ajay Dhagat - CEO & managing director)

Constructed and delivered over 114 vessels in offshore segment like PSVs, MPSVs and AHTS.

Orderbook: 17 vessels (6 MPSVs, 2 multipurpose offshore vessels, 3 multipurpose supply vessels, 4 AHTS and 2 tugs)

www.tebma.com

J Shoft

Location: Bharuch, Gujarat

Ownership: Private (Sahay Raj, the main promoter, and Arindam Ganguli)

Built 75 vessels: tugs, supply vessels, bulk carriers, cement carriers, tankers, product carriers, dredgers, hopper barges, trawlers, cargo vessels, pontoons and naval patrol vessels.

Order book: A submarine project and 10 vessels (A 275 Men DP2 accommodation barge, an offshore supply vessel, 3 No. of 12T Bollard Pull harbour tugs, 2 No. of advanced offshore patrol vessels, 1 naval offshore patrol vessel and 2 barges)

www.shoft.in

K Hooghly Dock and Port Engineers Ltd.

Location: Kolkata, West Bengal

Ownership: Ministry of Shipping, Government of India

Builds tugs, crafts, dredgers, floating dry docks, fire float, mooring launches, fishing trawlers, pontoons. Sophisticated vessels like offshore platform, supply-support vessels, multipurpose harbour vessels, grab hopper dredger, lighthouse tender vessels, oil pollution control vessels.

Order book: 14 vessels (a floating dry dock, a hydraulic surface dredger, 2 self-loading cargo vessels, 6 work boats and 4 No. of 1000-tonne fuel barges)

http://hooghlydock.gov.in

7 largest Indian ship chartering companies

1. Samsara Shipping
Deals in liquid bulk, dry bulk & general cargo.
www.samsarashipping.com

2. Shreyas Shipping
Operates containerised coastal shipping and feedering services.
www.shreyas.co.in

3. J M Baxi & Co.
Handles dry and liquid cargoes of government and private commercial vessels.
www.jmbaxi.com

4. Arcadia Shipping
Manages bulk carriers, general cargo and container ships.
www.arcadiashipping.com

5. Parekh Group
Handles bulk, dry bulk & tankers.
www.parekhgroup.in

6. Seaways Shipping
Deals in dry cargo / reefers / DG / OOG and special cargoes.
www.seawaysline.com
(group site www.seawaysindia.com)

7. Five Star Shipping
Manages bulk carriers, tankers, liner ships, mini bulk carriers and self-unloaders.
www.fivestarship.com

Maritime organizations

INSA
The Indian National Shipowners' Association. The INSA promotes the development of the shipping industry and works towards enhancing the interests of Indian shipping companies and the national shipping industry.
www.insa.org.in

FEDSAI
Federation of Ship Agents Association of India. This association works in close coordination with the government to bring in legislative reforms in the Indian shipping industry.
www.fedsai.com

FFFAI
Federation of Freight Forwarders Association of India. FFFAI promotes the interests and coordinates activities of custom house agents' associations and their members.
www.fffai.org

AMTOI
Association of Multimodal Transporters of India. This organisation works for the protection and promotion of the interests of multimodal transporters.
www.amtoi.org

FIEO
Federation of Indian Export Organisations. Set up jointly by the Ministry of Commerce, the Government of India and the trade and industry, FIEO represents the Indian entrepreneurs' spirit of enterprise in the global market.
http://fieo.org

NUSI
National Union of Seafarers of India. NUSI works for the collective goals of seafarers – social justice, better working conditions and dispute settlement.
www.nusi.org.in

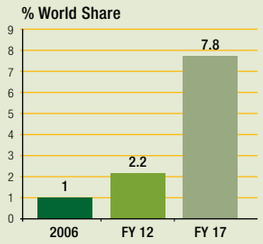
MANSA
Mumbai And Nhava Sheva Ship Agents Association. This group addresses problems faced by ship agents and owners by interacting with port authorities, the ministries and departments concerned, chambers of commerce and trade bodies.
www.mansaship.com

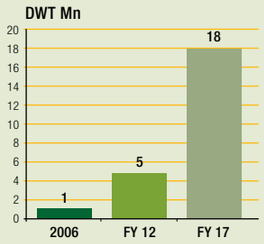
BCHAA
Bombay Custom House Agents' Association. Comprising customs brokers & freight forwarders and air cargo agents as members, it promotes the freight forwarding industry.
www.bchaa.com

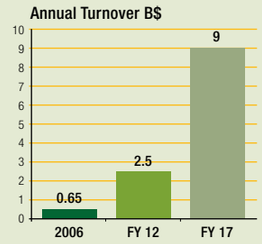
NISAA
Northern India Steamer Agents Association. Works in the interest of ship agents.
No website (Note: Its president Capt. Ram Ramchandran can be contacted at ram@redeaglegroup.com)

India's overseas trade:

General cargo: 3.34 million tonnes (5.9 per cent of the total trade)
Dry bulk cargo: 7.8 million tonnes (7.6 per cent)
Liquid bulk cargo: 35.16 million tonnes (30.9 per cent)
Total: 46.30 million tonnes (16.9 per cent)







Source: Ministry of shipping

Companies and DWT

1.	**Shipping Corporation of India**	5 million DWT	www.shipindia.com
2.	**Great Eastern Shipping Corporation**	2.89 million DWT	www.greatship.com
3.	**Mercator Lines**	2.45 million DWT	www.mllindia.com
4.	**Essar Shipping**	1.40 million DWT	www.essar.com
5.	**Chowgule Steamships**	1.2 million DWT	www.chowgulesteamships.com
6.	**Varun Shipping**	0.64 million DWT	www.varunship.com
7.	**Pratibha Shipping**	0.46 million DWT	www.pscl.org
8.	**India Steamship**	0.29 million DWT	www.indiasteamship.com
9.	**Apeejay Shipping**	0.25 million DWT	www.apeejayshipping.com
10.	**SKS Logistics**	0.1 million DWT	www.shahilogistics.com

Projected Order Book Turnover	2006-07	2007-12	2012-17
Order Book (Mn DWT)	1.3	5.00	18.00
Global Order Book (Mn DWT)	231.2	231.2	231.2
India's Share of Global Order Book	0.4%	2.2%	7.8%
Delivery (mn DWT)	0.65	2.50	9.00
Turnover (US$ Bn)	0.65	2.50	9.00
Shipbuilding Industry % of GDP	0.04%	0.16%	0.27%
Total employment	12,000	78,000	252,000

Q & A

M. Jithendran

Generations met with Cmde M. Jithendran, Chairman & Managing Director, Cochin Shipyard Ltd. to hear his opinion on the development of India's shipping and shipbuilding industries. In a word, he was bullish.

WRITER: *Radhika Rani* || ILLUSTRATION: *Kathryn Rathke*

NESTLED IN THE PICTURESQUE SHORELINE of the south Indian state of Kerala, Cochin – the Queen of the Arabian Sea – has roots as a vibrant trading city, exporting spices since the 14th century. Now called Kochi, this lush green southwest Indian city is the commercial hub of the state and one of the fastest growing metropolitan areas in the country and boasts of a leading sea port, shipping industries, information technology and of course tourism.

It is here, adjacent to the Port of Cochin, that a world-renowned shipyard, India's largest, covers 170 acres of land. Cochin Shipyard Limited (CSL), with a capacity of 110,000 DWT, has international clientele and a brimming orderbook, including an aircraft carrier. The shipyard has recently completed its second major ship conversion project undertaken for the National Institute of Oceanography of Goa, which involved converting a fisheries vessel into an oceanographic research vessel. It will soon begin construction of 15 platform supply vessels for foreign owners.

A new dry dock is also on the cards. The expansion, to cost nearly USD 10 billion, will help CSL build and repair vessels of up to 200,000 DWT. "The proposal is being discussed with the government," says Commodore M Jithendran, chairman and managing director of CSL, a public sector undertaking. Spearheading a large workforce, Jithendran believes the expertise of his team and its efficiency to deliver vessels in time sets CSL apart from the others. It is for this reason that, despite competition from the Far East and Southeast Asia for commercial shipping, Cochin Shipyard has been growing and driving volumes year after year in the shipbuilding market, he argues.

"One who wants to rule the world must first rule the seas," is how Jithendran sums up the contribution of the shipping industry to the national economy. Here he shares his perspectives and plans:

How do you see the Indian maritime industry developing, as a whole?

The Indian maritime industry went through an unprecedented boom until 2008, when it faced a sharp downturn due to the global

economic crisis. Though the industry is going through a difficult phase in the short term, a lot of positive factors such as the country's economic growth, increase in international trade and commerce are expected to support the Indian maritime industry in the long run. With the augmentation of infrastructure in logistics, port and shipbuilding by the government of India, the industry can grow to much higher levels.

Do you see this same trend in your own business?

Yes. The shipbuilding industry has faced the same trend as the other sectors of the maritime industry. Globally, shipyards have faced newbuilding cancellations to a large extent. However, diversification, innovation and a broad base to our product profile are the current strategy.

What signs have you seen that the shipping world's attention is coming to India?

India is one of the fastest growing economies in the world. As such, tremendous interest is being shown by various sectors of the maritime industry to invest in India. Indian shipyards used to focus on domestic and naval shipbuilding alone until a few years back. However, there is a change in this scenario, with yards building mostly for foreign owners. Cochin Shipyard started building for international clientele from 2001 onwards and now has orders worth about INR 30 billion (EUR 500 million) for exports.

Do you see more suppliers / partners / contractors establishing themselves in India?

With the shipbuilding industry in India picking up pace, there is definitely considerable interest shown by suppliers / contractors to establish themselves in the country. A number of leading suppliers and equipment manufacturers have expressed an interest in business partnership in this respect.

What are some of the strengths of the Indian market for shipping / shipbuilding?

A number of factors provide an advantage to the Indian market. India is a fast growing economy and is slated to record very high growth in international trade. The growth in the Indian consumer market has been phenomenal, thus making the country a very attractive destination for business. Besides, the availability of local engineering skills, highly qualified technicians and good academic background of employees is a contributing factor. As for shipbuilding and repair, the expertise built up over the past decades and availability of local contractors of desired quality is also an added strength.

How has the Indian government's support of the shipbuilding industry impacted your business?

The Government of India has been very supportive of the Cochin Shipyard. We were granted the Miniratna status in July 2008, which gave the company a considerable amount of autonomy in decision-making. The Government has also been positive about the company's expansion programmes, including the one for a new dry dock.

What goals do you have for your shipyard in the next five years?

In the next five years, our main aim would be to set up the additional drydock, which would enable the company to take up the repairs / upgrades of large ships and oil rigs. With the commissioning of this facility, CSL's turnover can reach the level of INR 30 billion (EUR 500 million).

What steps have been taken to assure foreign shipowners that safety and quality are secure in Indian shipbuilding?

Cochin Shipyard has adopted an integrated management system complying with the quality management system ISO 9001-2008, Environment Management system ISO 14001-2004 and OHSAS 18001-2007. Besides, there is a very effective quality and safety department to ensure that international standards are applied in our shipbuilding processes.

What ship segments do you expect to perform most **strongly in the coming years for Indian shipbuilding?**

I feel like naval vessels will be a very good prospect for Indian shipbuilding in the near future. Aside from this, demand for offshore support vessels is also slated to grow, due to an increased level of exploration activities.

Does your yard produce offshore oil and gas-related ships or infrastructure?

The yard has undertaken major upgrades of offshore oil rigs and has also done installation of structures in the Bombay High region. The yard is currently building 16 offshore support vessels, which include four anchor-handling tug supply vessels. This is besides the 14 ships already exported in this sector in the last two years.

Cochin Shipyards

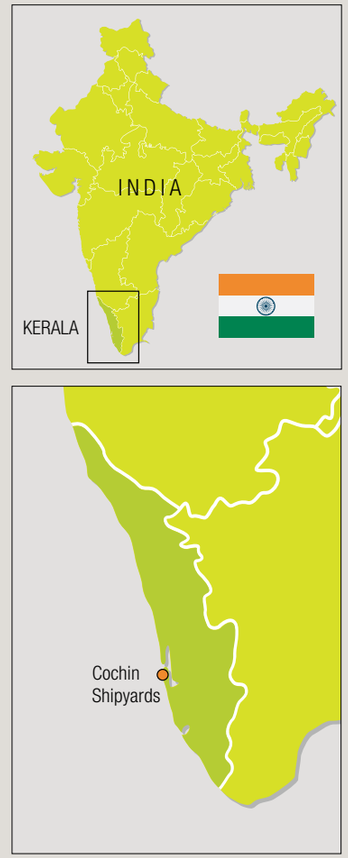
Shipbuilding
- Only Shipyard in India which can build up to 110,000 DWT
- Has built various types of vessels including tankers, bulk carriers, port crafts and passenger vessels
- Currently building platform supply vessels for export and an aircraft carrier for the Indian Navy

Ship Repair
- Only shipyard in India which can repair ships up to 125,000 DWT
- The only yard which can repair an air defense ship
- Can undertake complex and sophisticated repairs to oil rigs and naval, Coast Guard & Merchant Navy ships
- Secured three major projects from India's leading energy company for repair of two mobile offshore drilling units and one jack-up rig in 2005-06

Offshore
- Has undertaken a variety of complex and sophisticated offshore upgrades

Other
- Conducts marine engineering training, basic & advanced fire-fighting courses
- ISO 9001-2000 certified for
- Design and manufacture of small & medium crafts up to 900 GRT
- Construction of ships up to 110,000 DWT
- Repair of ships up to 125,000 DWT
- Training of Marine Engineers & Conducting of fire-fighting courses
- Laboratory for destructive and non-destructive testing of material, chemical analysis, oil-fuel testing, ultrasonic thickness gauging and other activities
- Complies with ISPS certification.

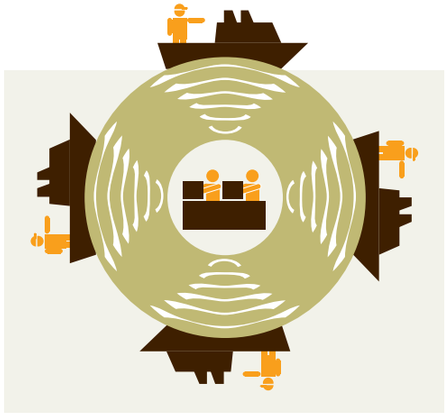
Source: Cochin Shipyard



Propulsion as a Service, or PaaS

In each issue of Generations, we launch a thought experiment. A small group of ABB's creative engineers, a writer and an illustrator combine their diverse skills to present ideas about a possible future. What new technologies might emerge to solve problems facing us today?

WRITER: *John Ensby* ||| PHOTOS & ILLUSTRATIONS: *Daniel Barradas*



WHAT IF YOU COULD DESIGN a new generation of propulsion systems for the world's biggest fleet? This is the thought experiment we brought to the 'brains trust' in this issue of Generations. Meeting in Shanghai with Sami Kanerva, Amy-LiFen Huang and Maggie-XuFen Ling, we have a brains trust team that represents the value chain from A to Z –from the broad concepts and big pieces of Sami via the sales support of Amy to Maggie's detailed documentation.

Daily, the members of this brains trust team face the challenge of coming up with solutions that decrease lifetime costs, improve capacity and cut noise and vibrations, all in a steadily smaller package onboard the vessel. Every delivery must also maintain the reliability that matches the reputation of ABB as a quality brand.

As engineers face one project after the other, the nature of the work is very much to fit a piece into an existing puzzle. Proven components make up the systems that need to fit with all other parts of the vessel. Standards and conventions keep risk at a manageable level. Bringing a new vessel to its sea trial and through 20-30 years of continuous operation is a challenge with little room for experimentation. That is why today's systems are pretty much the same as their forebears.

THE SCENARIO We want to shake up the preference for conventional solutions with a dramatic scenario. According to this scenario, ABB has decided to launch a radical business model that combines financing and technology. Instead of serving up propulsion systems to the requirements of shipowners and design offices one at a time, a new unit is being established: ABB PaaS, Propulsion as a Service. Like Software as a Service (SaaS), ABB's PaaS will offer the functionality without the worries of owning and maintaining the machinery. The marketing message is this: Never mind the machinery; tell us how far and how fast you want go and we will provide the thrust that brings you there for a fixed price per mile.

We imagine ABB PaaS powering and propelling hundreds, maybe a couple of thousand, vessels on long-term contracts. The shipowners have left the decision of exactly how to provide torque to the propeller to ABB PaaS. This, in turn, allows ABB to engage in long-term planning and investment in R&D for a new generation of solution for maritime power and propulsion. This is the opportunity we want our engineering team to start off with: Designing the next generation of systems for an order of hundreds of vessels.

INNOVATION "Today's alternating current systems (AC) build on a more than 100-year-old innovation. We should look for the opportunity to bring this century's innovation to the market," our team tells us. Systems that are ideal on land are not necessarily ideal onboard a ship. A ship is a small system – an island of its own with a set of requirements different from systems on the power grid ashore.

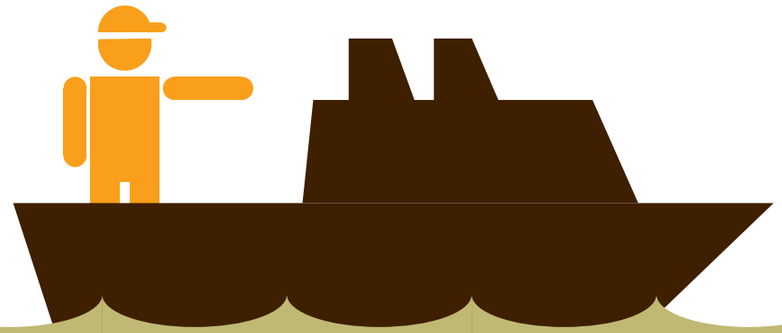
DC (direct current) is already being used in some navy vessels, and even OSV/PSVs (offshore/platform supply vessels). Our team's first choice in engineering for ABB PaaS is to provide a DC grid.

"In this economy, anything could be the next winning solution. No one knows what will happen," Sami Kanerva says. "Discussions on energy efficiency have been going on for ten years now. This could be the time when we see the birth of a new generation of solutions."

FEWER COMPONENTS AND MORE FLEXIBILITY With fewer components comes higher availability and less maintenance, two criteria already at the top of our list, but even more so if ABB is directly responsible for 30 years of operation. With the opportwunity to make a big leap to new technology, we should not make the same mistake as our predecessors. Those systems were designed with the idea that they would be fixed for the lifetime of the vessel. The probability for new environmental taxes, and the incorporation of new technology, should be an integral part of our design. If the goal is to develop components specially suited for maritime applications, they should fit together in various configurations, serving as many vessel types as possible.

EXPECT THE UNKNOWN – NEW ENERGY SOURCES The fuel bill and environmental regulations are our focus areas, in terms of cost. Innovative solutions for our century need to allow for a replacement of the energy source itself. For short-sea shipping, batteries can be charged at an onshore power site. In other vessel types, fuel cells may replace the diesel engine. The fact that we cannot predict the development 20 years ahead means that our design must be open to new and innovative components.

HARDWARE, SOFTWARE AND SERVICES The prospect of being in charge of power and propulsion for hundreds of vessels with standardized and state



The team

Our brains trust team this time bring together experience from across three main processes: R&D, sales and systems design.

Amy-LiFen Huang

Project Engineer

Based in Shanghai, was at the time of this workshop in sales support. She has since then joined a project engineering team. As an engineer in sales support, her goal is the best solution for each project, finding the optimal match between the needs of the customer and ABB's various options in system design.

Sami Kanerva

Senior Systems Specialist

Working in Finland, he has over five years in ABB R&D behind him, the last year in Marine as an expert in machines and drives as well condition monitoring. In 2010 is working with new propulsion concepts and product development.

Maggie-XuFen Ling

Project Engineer

Also located in Shanghai, works in systems design. Her responsibilities involve power plant design and detailed specifications to make sure that every component of a proposed design fits in and together make up a reliable system. Both normal operation and all possible short circuit situations are analysed before a system design is completed.

of the art equipment commands innovation in operations too. The obvious monitoring and control facility consists of a centralised mission control ashore. A team of experts remotely monitor the performance of all systems. Data gathered for statistical analysis triggers alerts and identifies best practices. Components with built-in sensors for temperature, vibration, tension and particles in fluids would give early warnings about wear and tear. Preventive maintenance is planned in due time, and spare parts stockpiled in the next port of call.

THE VOYAGE RECORDER BLACK BOX Not all data can be sent ashore for analysis. The data feeds from thousands of sensors need to meet intelligent filtering as close to the point of origin as possible. When something goes wrong, we need a complete data-set for trouble-shooting. When blackouts occur, the system is often re-set, and the detailed data log is then lost. Our new solution will always preserve the full data log from all sensors during the crucial seconds prior to a blackout.

THE PPE ONBOARD Even with the performance monitoring sensors and the centralized control centre and experts available ashore, our service solution would not be complete without a person on-board. This new profession, the Power and Propulsion Engineer, is a career opportunity for people with a talent for dealing with both equipment and a demanding captain. Social skills and an eye for the big picture would also be required, as the PPE responds quickly and intuitively to customer feedback. Gone are the days when service personnel are dispatched in a hurry from a remote location to trouble-shoot a system failure. That's too late and too expensive for our new solution. Our PPE onboard will be "Mr. Proactive", working steadily on his preventive maintenance plan, and present best practice on voyage planning and fuel economy from the onshore control centre to officers onboard.

At the on-shore control centre a full team of experts would support the vessel in proactive maintenance and best practice voyage planning.

MEASURING AND BILLING PROPULSION AS A SERVICE

"Our on-shore control centre analyzes voyage optimization like no fleet management service before," our team suggests, "meaning that we could select routes and optimal speed to cut cost where the potential is greatest: the fuel bill."

A growing database on optimal operation and voyage planning serves as budgeting tool and benchmarking between similar vessels. Deviation from the base line results from factors ranging from navigational decisions to the operational state of the machinery. Factors under ABB control – like maintenance – do not affect the shipowner's bill, while the captain's decisions do. They key to a win-win deal is to add value by sharing best practice across the ABB PaaS fleet. |||

The executive summary

What if the ship owner was offered the functionality without the worries of owning and maintaining the power and propulsion machinery?

As long as the performance was guaranteed, the decision on exactly what system to install would, in our scenario, be taken by ABB PaaS (Propulsion as a Service).

Given ABB's market share, a change to this model would create opportunities for the development of specialized components for the marine sector. An overdue switch to new technology would suddenly be realistic and systems, software, and expertise would help a new generation of vessels meet the environmental challenge.

Intelligent diagnostics and performance measurement sensors in every component would continuously add new information to a central database. And at the on-shore control centre a full team of experts would support the onboard PPE (Power and propulsion engineer) in proactive maintenance and voyage planning.

The value created would be come from a reduction in the fuel bill, future emission taxation included. In this win-win deal ABB's share is extracted on the bases of more efficient technology, fewer components, and better sharing of both work and knowledge.

PROBLEM SOLVED

Speed and control for Deep Energy

The specifications of vessels in the pipelaying industry are changing as operators seek to make the most of the globalisation of the oil and gas sector. Technip's latest ship – with the help of ABB - is a case in point.

WRITER: *Richie MacTaggart* ||| PHOTOS: *Craig Dempster, Technip*

AS OFFSHORE OIL AND GAS PRODUCTION continues to grow, the development of the pipelaying industry has worked hard to keep pace. One of the companies at the forefront of pipelaying operations is Technip. The company operates one of the best-in-class fleets of subsea pipelay and subsea construction vessels. In the summer of 2006 Technip's management decided to develop plans for a new pipelay vessel to augment its fleet. The resulting owner-operated vessel will be named the Deep Energy.

From the outset, discussions on vessel design surrounded two primary criteria – that it would need to be swift and that the propulsion systems would be able to operate effectively in the event of a major engine room failure. The end result was that ABB was chosen to supply both the propulsion system and the power generation system for the ship's engine rooms.

COMPETITIVE EDGE The first requirement that Technip wanted – a pipelaying vessel that could travel swiftly between locations – meant they were looking at a ship with a transit speed capable of 20 knots, which is quick for a vessel of this type. This was seen as a competitive edge, as Mike Gibbs, Electrical & Instrumentation Engineer at Technip, explains. "Basically, the majority of time for the pipelayer is taken up travelling between locations. If one of our vessels is travelling down to New Zealand from Europe, for example, this can take up to 50 days. However the laying of a two-reel pipeline may take only two weeks. Therefore, it is the time that can be saved travelling between operational sites – when the ship is not laying pipe - that is most imperative."

The Technip team: (left to right) Andrew Manson, Naval Architect & Vessel Delivery Manager; Graham Moffatt, Marine Engineer and Mike Gibbs, Electrical & Instrumentation Engineer, are overseeing Technip's new building project.

The latest pipe-laying addition to the Technip fleet is presently undergoing construction at STX Heavy Industries' yard in Dalian, China.

However, the equation is not that simple. If Technip wished simply to bring into service a very fast vessel, it could have utilised two fixed propellers, resulting in the required speed. But, the vessel also needed to be able to operate highly efficiently once at the pipelay site – and that means using a GPS system for dynamic positioning (DP) to have the ship hold station in exactly the right place to lay the pipeline. The propulsion system contributes toward making the exact positioning feasible and two fixed props cannot achieve this efficiently.

In order to lay the pipe in the right place the ship operates using a highly complex autopilot system linked to electronic maps and GPS through an on-board computer. Following the agreed route, pipe will be fed out from the vessel at 40 meters per minute (over 1 knot). The size of the pipe – either rigid or flexible - can be anything from 10 centimetres (4 inches) up to 45 cm (18 inches). Being able to hold the vessel in exactly the right position using the combination of thrusters is imperative for the pipeline to be laid out on the right path.

AZIPOD FLEXIBILITY Graham Moffat, Marine Engineer at Technip, details the final chosen solution. "The main propulsion finally decided upon was 2x 10 Megawatt, V18 electric Azipods from ABB, along with the addition of three centre line retractable thrusters and two tunnel thrusters, for use in DP only. The Azipods provide Technip with maximum transit speed when working flat-out, and offer full manoeuvrability when restricted to four

megawatts in DP mode. This was the first time Technip had chosen this solution for any of its vessels."

ABB's Azipod is a podded propulsion system that can rotate through 360 degrees and is mounted directly on to a short propeller shaft. The electric motor drives a fixed-pitch propeller which is controlled by a frequency converter producing full nominal torque over the entire speed range. The ability of ABB's Azipods to provide high speeds for transiting and full control for DP activities perfectly suits the dual requirements of a pipelaying vessel.

Other propulsion systems were considered but rejected after careful evaluation, as Andrew Manson, Naval Architect at Technip, states. "Nozzled azimuthing thrusters are conventionally used for this kind of vessel, however are not available in the required power range to achieve the 20 knot transit speed. Fixed propulsion is inefficient when you want to use the ship in DP mode. We recognised that the Azipod system was the optimum solution to provide the speed in transit and accuracy in position keeping. In terms of savings in transit times, we expect to be able to reduce sailing times by 50% compared to existing pipelay vessels in the market."

DYNAMIC POSITIONING Whilst considered a new technology in offshore vessels, the Azipod units will be able to provide the required power rating, good transit hydrodynamics and – importantly – DP functionality.

The configuration of the engine rooms was also an important step by Technip and ABB.

Vessel specifications

The Deep Energy is a class III DP pipelay vessel capable of rigid pipelay operations up to 18 inches, flexible pipe up to 24 inches and with dynamic top tension capability up to 450 tonnes. The vessel's rigid pipe storage is on two reels, each capable of carrying 2800 tonnes of pipe.
Length overall (LOA) is 194.50 metres and a breadth of 31 metres. Dead weight is approximately 11,000 tonnes at design draft of 8.2m.
The vessel has fully air-conditioned accommodation and equipment for 140 persons. There is a well equipped galley, scullery and provisions rooms to accommodate all personnel. There is also a mess room, two day rooms, library, cinema, offices and conference rooms for clients and vessel personnel, a hospital, gymnasium and deck and machinery workshops.

The standard system for a DP vessel is to have two engine rooms to provide redundancy for powering the ship. Instead, this ship was developed with three engine rooms and two generators in each. If for any reason you lose one of the engine rooms, two are still left, meaning that the worst case failure would still leave two thrusters running up to full power at both the stern and the bow.

STX Offshore and Shipbuilding Co. Ltd of Korea is currently building the ship. The units from ABB have been produced on-time and are now at the yard and the vessel is expected to be ready and undertaking sea trials before the end of 2010.

Gibbs concludes: "During the bid process ABB came across as having a highly technical team at all stages and this provided us with the confidence that their expertise would be able to meet any challenges on the project. They also seemed highly committed to what we were trying to achieve and, when combined with their track record, it meant we were comfortable in choosing ABB. I believe our choice has been well-founded. They met all the financial, operational and timing requirements and I am sure that the sea trials will further confirm our decision." |||

About Technip

Technip is a world leader in engineering, technologies and project management for the oil and gas industry, headquartered in Paris, France. The company designs and builds high-technology industrial installations, such as subsea equipment and platforms, and onshore mega-complexes for the oil, gas and petrochemical sectors. In 2009 it had a workforce of 23,000 people in 48 countries and revenues of €6.5 billion.
Technip operates in three segments of the global oil and gas market: Subsea, Offshore and Onshore.
In the Subsea segment, Technip's activities cover the design, manufacture and installation of rigid and flexible subsea pipelines and umbilicals. Technip is a key player in this market thanks to its first-class range of subsea pipe technologies and industrial and operational assets, including a constantly evolving fleet strategically deployed in the world's major offshore markets.
In the Offshore segment, the Group engineers, develops and constructs platforms for oil and gas production at sea, in shallow water and deepwater. Technip is also a leader in new applications such as Floating LNG and offshore floating wind turbine substructure.
In the Onshore segment, Technip covers the range of onshore facilities for the oil and gas chain, petrochemicals and non-oil activities. It holds many proprietary technologies and is one of the leading players worldwide in refining and petrochemical units.

History of offshore pipelaying

The history of pipelaying offshore for the oil and gas sector only stretches back about 50 years, as exploration and development offshore is a fairly young industry. The first offshore pipeline was constructed and laid by Brown & Root in 1954 in the Gulf of Mexico. It was a 10 inch, concrete coated gas pipeline, 16 kilometres long and was laid at a depth of 4 to 10 meters. The speed of laying was approximately 800 meters per day and the crew worked only during daylight.
The first purpose built pipelay barge was built in 1958. The industry's first fixed reel pipe laying barge was developed in 1961 and the development of the reel ship in 1975.
Reeling rigid pipe was developed by Santa Fe, an American company, with a horizontal reel on the Chickasaw and then a vertical reel on the Apache. This has become the standard method of operation for Technip and other leaders in the pipelaying industry.
As more oil and gas reservoirs are discovered in deep water, oil and gas exploration and development has been gradually moving farther offshore and into deeper and colder water. Nowadays, ultra deepwater production wells are being developed in water exceeding depths of 3,000 metres.
After the oil and gas fields are discovered the challenge is to move the product to onshore refining or processing facilities. Determination of pipeline routes and the locations of mooring lines for pipelines and operating barges in deeper water is challenging due to uncertainties of the sea floor. Many methods such as 2-D and now 3-D seismic surveys, satellite sensors and surface-towed sonar have mapped sea bottoms with varying degrees of resolution. Sea floor maps can show furrows, which can help locate the path of a proposed pipeline and avoid areas where the pipeline might otherwise span over ridges. New technologies are now allowing pipelines to adapt to ocean floor irregularities by snaking along the sea bottom without any restraints or anchors. Additional and better survey data over time will be vital as fields extend ever further from shore and at ever deeper depths.

A local affair

WRITER: *Scott LaHart* ||| PHOTOS: *ABB, STX Norway Electro*

NORWAY'S WEST COAST houses one of the premier maritime clusters in the world – with 12 design companies, 17 shipowners, 13 shipyards and 161 equipment suppliers staffing 21,000 people in the region. While the competence here casts a wide net, it's fair to say that the epicentre is offshore supply vessels. Indeed, approximately sixty percent of these vessel types the world over stem from Norwegian designs originating in the cluster. Quite a feat for a region housing less than a quarter of a million inhabitants.

Therefore, it's probably not a surprise to find out that when ABB – which is firmly ensconsed with an offshore supply vessel office in the region in Ulsteinvik – received a contract with STX Norway Electro for the full propulsion packages for two upcoming hybrid anchor-handling tug supply vessels, the vessels are being built by local STX shipyards from local STX ship designs for local shipowners Solstad and Rem Offshore as well.

While the relationships with the players in the cluster are important and tend to make such cooperation projects even better, it is the total package of quality, reliability, timeliness and pricing that is make or break in the end – both regarding gaining contracts and being in the picture for future ones. After all, even if local ties played a role here, the competition for contracts in the cluster alone is fierce enough…

We've spoken with both ABB Marine and STX players on the front line of the AHTS vessel project to get their viewpoints, as well as highlighted areas of note where views concur with one another, shedding light on some of the keys to the project's success.

Perspectives

1. BUILDING A HISTORY TOGETHER

A long-term relationship with partners helps lead to a shorthand – you know the other company's values and way of working, and have already invested time in maximising processes. It also brings about continuity, which helps a project sail smoother. In essence, you're removing as many of the question marks as possible, easing your way to the final goal.

2. MASTERING A GENRE – LOCALLY

For Norway's West Coast maritime cluster, it's all about offshore support vessels – from design and building to equipment manufacturing and owning. Not only have all of the maritime companies in the region built up their competence through decades of first-hand experience, but the continual sharing of information means continuous improvement, new contacts and even more contracts as well.

3. PUTTING POTENTIAL PROBLEMS TO BED

In order to be a true partner, you need to be honest when there are issues and take care of problems when they arise. And there will always be issues. While problems have the potential of creating rifts between the parties, being responsive and taking care of issues properly can lead to an even closer partnership.

4. BUILDING – AND REPLICATING – THE PERFECT VESSEL

When building a number of identical vessels, it's imperative to take lessons from the earlier vessels in the group and integrate them into the master plans of the other vessels in the series. This can be anything from procedures and ways of working to the equipment utilised itself. You can call it improvement through standardisation.

Arthur Solvag
ABB Marine vice president of sales, offshore support vessels

Oddbjørn Nygård Vik
ABB Marine project manager for Rem Offshore/Solstad AHTS vessels project

RELATIONSHIP BETWEEN ABB MARINE, REM OFFSHORE/SOLSTAD & STX EUROPE

STX Norway Electro – the company that creates these equipment packages for the shipbuilder – normally includes us in their vessel packages and design. That was the starting point – they made the request to include us for the two AHTS vessels.

Our cooperation with STX goes back to about 2004 or 2005, and we have a very solid relationship. However, we're in constant competition for the business, so we need to stay on top in performance and reasonable in price in order to be chosen.

On the shipowner side, this is one of our first projects for Solstad in recent years. However, we've provided systems for quite a few Rem Offshore vessels of late that were built at Kleven Shipyard, which is located near us in Ulsteinvik.

THE NORWEGIAN WEST COAST MARITIME CLUSTER

In fact, this project is an example of the strong maritime cluster of designers, owners, shipyards and equipment suppliers located on Norway's west coast. The proximity is a great advantage not only for carrying out projects, but also for gaining new ones and staying up to date in the industry. If we want to talk to shipowners, we don't have to pick up the phone. We go out to visit them or meet up with them at seminars in the vicinity.

There are also a number of designers in the local area. In addition to STX Design, there are also Ulstein Design, Marin Teknikk, Skipsteknisk, Havyard Design and Rolls-Royce.

ABB MARINE DELIVERIES TO THE HYBRID AHTS VESSELS ABB is providing a full propulsion package to the vessels, entailing both power generation and propulsion. While we normally provide the switchboard in such situations as well, STX is taking care of that for this project.

The equipment in this project is hybrid propulsion – a combination of mechanical and electric propulsion. This is a solution which we have promoted on the market before and have been quite successful with it. While it's not any rocket science from our side, we have a good, reliable solution.

ABB PRESENCE AT THE SHIPYARD DURING THE PROJECT We don't have a site office per se, but our office in Ulsteinvik is quite close to the STX yard in Braatvaag. It only takes about 1 ½ hours to drive to the shipyard, so we're there quite often to check on progress.

MOST CRITICAL ASPECTS OF ABB DELIVERY TO THE VESSELS While everything else has gone well, there has been some concern regarding documentation from our side and making sure that it is carried out on time. We had

some resource issues in this area for a period, but these have been taken care of now.

The software for the PTI/main propulsion drive was also a test. Due to the fact that this is a hybrid solution, we had to make sure the electrical and mechanical system worked together properly. In order to ensure that all of the aspects were covered here, we had a meeting with STX and the engine supplier before the sea trial.

The short commissioning phase – which was carried out in mid-March – was obviously another critical phase, but we're happy to report that this went well.

SUCCESS FACTORS FOR ABB VESSEL DELIVERIES

Our project execution, performance and quality attributes come to the forefront here. We always deliver on time, and with the requested quality in place. We have long experience with these types of projects, which gives us a competitive advantage. The skills and experience of our staffers also comes into play here. A key to project execution success is being open and transparent with your partners and carrying out steps in the proper order.

PROJECT TRUST There was a good amount of trust already built up with STX and Rem Offshore based on projects we've carried out with them before. One thing we note – and this is a true vote of confidence – is that when shipbuilders and shipyards use our products once, they come back for more.

ENSURING CONTINUOUS IMPROVEMENT One way we help ensure continuous improvement is by using our experience in other, similar projects and sharing notes. Not only can we call upon our experience from similar projects from the past, but it also helps to communicate with those that are carrying out a similar project at present, too. We have several similar projects currently being built at STX yards – one at STX Aukra in Norway and also a hybrid AHTS project that is currently being built at STX's Promar yard in Brazil that is almost identical to the projects we're working on in Norway.

The project management team across a number of projects has a group that meets once a month that gathers and shares various "lessons learned" from the ongoing projects. This is a good way to pick up information, learn about what has gone very well in other projects, as well as situations which haven't turned out as well and how those can be avoided in the future.

MESSAGE THE PROJECT SENDS TO THE MARKET ABOUT ABB MARINE This project is evidence that we're a reliable partner in the industry, and that we have a great deal of experience. When we get the order, we have a strong focus on performing the project according to client expectations. We deliver on time, which builds customer confidence and, as we've seen, leads to repeat orders.

While we've never been the cheapest choice on the market, our products are competitively priced, and both our quality and ability to provide tailor-made products for projects are strong selling points. Our compact design is also a differentiator from our competitors. This includes our frequency converters, which are produced in Ulsteinvik and are tailor-made for the offshore support vessel industry.

THE RELATIONSHIP BETWEEN SUBSUPPLIERS, SHIPOWNERS & SHIPYARDS AT PRESENT The general recession in the market has created a great deal of price pressure, and the extreme focus on cost by shipbuilders means that subsuppliers are struggling. It can be difficult finding that middle ground between appealing to shipowners and ship managers regarding price but also meeting the profit margins that we need while producing systems of a high standard. Everybody is going for the same projects – and both ABB and its competitors are very hungry – so it's very important that our prices are competitive.

With a focus solely on price, however, it becomes difficult to bring forward the selling points we have on the technical side, for example. We have to get better at communicating our message to shipowners and make certain that our advantages regarding life-cycle costs, fuel consumption reductions and environmental advantages are seen as more important to consider than just the initial installation and equipment costs. We have a 20-year perspective for the products and systems that we provide, and they should as well.

Henning Sandbakk

STX Norway Electro Power & Automation project manager

RELATIONSHIP BETWEEN STX NORWAY ELECTRO/STX EUROPE, ABB MARINE & REM OFFSHORE/SOLSTAD We chose the partner for the propulsion package. We carried out some rounds with different suppliers, and ABB was the best option. This was based on a combination of quality, reliability and price. We've worked together with ABB for about five years now and have had quite a few projects with them. While our cooperation has mainly consisted of offshore support vessels – PSVs and anchor handlers – we've also worked together on some ferry projects as well. Our strong cooperation definitely weighed in regarding why they were chosen this time around as well.

While we haven't worked with REM Offshore before, we have some experience with Solstad. In addition to the vessel we're working on at present at the STX Braatvaag yard, we also have two more vessels for them on order.

THE NORWEGIAN WEST COAST MARITIME CLUSTER

The construction and cooperation surrounding these vessels is a very good example of our maritime cluster, which has a great deal of history and experience specifically with offshore support vessels. In fact, I think it's fair to say that the maritime industry in this part of the country is

based on these type of vessels. So there's a lot of qualified personnel in this regard.

Being based in the same area is also an advantage regarding the working relationship – everyone knows where the other side is coming from – and from a logistics point of view.

DECIDING ON HYBRID PROPULSION The decision to go with hybrid propulsion on these vessels was more or less decided between STX and the shipowners. The owners were looking for vessels with fuel and environmental advantages, along with flexibility in its operating profile, and this was the best way to go about it. STX already had this vessel design in place, so when Solstad provided its description, this was the vessel that was proposed.

MOST CRITICAL ASPECTS OF ABB DELIVERY TO THE VESSELS Generally things went smoothly, but in every project there are a few concerns along the way, and this one is no exception. There was an issue with documentation from ABB's side in the beginning. Since we received the documentation a bit late, we had to utilise documentation from earlier vessels instead and presume that it would more or less be the same. After we had a meeting with ABB to discuss this matter, there seemed to be quite a few changes from their side. From then on, we received both the answers we needed and documentation much faster than earlier.

Given the vessel's hybrid propulsion solution, ABB and the engine supplier's system also had to be synchronised to work together in the software for the PTI/main propulsion drive. There was a meeting between ABB, the engine supplier, and STX before the sea trial to take care of any problems here. While there were a lot of discussions, there were only a few minor changes – and the software and the hybrid system in general appear to have worked very well indeed in the sea trial that just finished up a couple of days ago.

PROJECT TRUST ABB had our trust from the very beginning – and nothing took place to change that confidence we have in them.

ENSURING CONTINUOUS IMPROVEMENT While the vessel that we just sea trialled is the first of the bunch, we have contracts for about 10 offshore support ships of this type at present. From now through 2011, these vessels will be built at a number of STX yards on Norway's west coast and at our Promar yard in Brazil. Two of these vessels are for Solstad and Rem, and the remaining vessels are for other shipowners.

There are three vessels of this type being built at present – the vessel just sea trialled and her sister vessel in Braatvaag, along with another one in Aukra. Everything that we discover now will be passed along to the other vessels of this type, as the intention is to make all of these vessels similar. This goes down to the equipment deliveries as well – ABB's propulsion package is a part of STX Norway Electro's contract for all of these offshore support ships.

I'm a part of a group of three people in the organisation that have an overview over the 10 vessels in all of their various stages of development. Our role is to visit the various yards, see the progress on the projects, and make certain that all of the building teams and yards are on the same page.

THE RELATIONSHIP BETWEEN SUBSUPPLIERS, SHIPOWNERS & SHIPYARDS AT PRESENT There is definitely more of a squeeze on the various players than there was during the boom years. Shipowners squeeze the yard, and then the yard has to squeeze the subsuppliers. But I wouldn't say that this has changed the working relationship per se – it simply means that each side needs to look at how they can be more effective and consider new equipment in order to keep the prices at acceptable levels for all parties.

Seadrill: risky business, cautious execution

In six years, Seadrill has expanded rapidly with a series of high-profile acquisitions and an ambitious newbuilding programme to become the world's fastest growing deepwater drilling contractor. But behind Seadrill's high-flying reputation lies a company that takes no chances with construction and operational risk.

WRITER: *Alexander Wardwell* || PHOTOS: *Seadrill*

SEADRILL'S RAPID EMERGENCE as a leading, global deepwater drilling contractor has taken many industry analysts by surprise. Established in 2005, the company started with three jack-up rigs, two FPSOs, four newbuild jack-up rigs and two newbuild semi-submersibles. It its first year of operation, the company ordered eight more units, acquired Odfjell Invest, and increased its ownership share in Eastern Drilling and Apexindo, the largest on- and offshore drilling company in Indonesia.

The following year saw three more newbuilding orders and the acquisition of Mosvold Drilling and, after a protracted bidding contest with an established Houston-based drilling contractor Nobel Drilling, Seadrill snapped up the Norwegian oilfield services contractor Smedvig – providing the company with a cadre of proven managers with the expertise to oversee its growing portfolio of assets.

RAPID GROWTH Over the next three years, the company continued to grow rapidly, winning valuable new contracts, taking delivery of 11 units (including two drillships), while placing orders for still more rigs, jack ups and semis. By the end of next year, the company's deepwater drilling assets will consist of 10 semis, four drillships, nine jack ups and a fleet of 16 semi tender and tender rigs, representing one of the industry's most modern fleet and a strong reputation for delivering high-specification deep and ultra-deepwater harsh-environment drilling solutions.

SEIZING OPPORTUNITIES Any company with the resources, capital and nerve to commit to such an ambitious growth programme is noteworthy, especially when one considers that some of its semis and drill ships were built on spec – an unheard of risk at the time. Indeed, by some estimates, Seadrill's newbuilding programme has cost the company a staggering sum of about USD eight billion for 25 units – not bad for a company that didn't exist six years ago. Yet a closer look at the company's background and changes in the global energy and offshore markets, helps put Seadrill's expansion plans into perspective.

Over the past decade, rising global demand for energy, combined with declining production from shallow water fields has driven rising demand for subsea exploration, well construction and deep water drilling. According to a recent study produced by consultants Infield Systems and Douglas Westwood, the total number of subsea wells will balloon to more than 5,500 by the end of 2010. While some projects have or may be delayed due to financing issues related to the global economic downturn, the rapid construction of new wells is likely to continue, if not accelerate, in the years to come. Indeed, annual expenditure in the deepwater segment is estimated to reach around USD 35 billion in 2014, with a total global capital expenditure USD 167 billion between 2010 and 2014.

This remarkable growth has created challenges for energy companies and suppliers alike. Increased demand for fuel has forced

Working with class

While managing the classification of Seadrill's drilling units is the responsibility of the yards, DNV has a long track record with the company. Indeed, DNV has classed a number of units for companies acquired by Seadrill in the past, including Smedvig and Mosvold Drilling, and has played an active role in the company's newbuilding programme. According to Tomas Solli, Business Development Manager for DNV, Seadrill's emphasis on proven basic design concepts has helped expedite the process. "Seadrill's designs are consistent with industry standards and their site teams have a lot of technical expertise, so they know exactly what they want and how to get there," he says.

many energy companies to re-evaluate stranded or marginal fields and seek to develop fields in harsher environments and deeper waters. As oil majors venture into deeper waters and ever harsher and more remote environments, they have become increasingly dependent on oilfield services contractors. Indeed, the study indicated that the average water depth for subsea completions worldwide has gone down to around 1,000 meters, and most analysts agree that this trend toward deepwater development will accelerate.

In recent years, West Africa has been the most significant region for subsea growth, and the industry is expanding into remoter areas such as the Arctic and Western Australia. While 30 per cent of newly completed global subsea wells are in European waters, deepwater development in other areas, such as Brazil and the Gulf of Mexico, is expected to rise. In short, deepwater development represents an increasingly attractive growth opportunity.

GOOD TIMING Alex Monsen, Seadrill's Vice President of Deepwater Projects, says Seadrill's advantage was not just recognising this trend early, but acting on it. "Timing is everything," says Monsen. "The drilling industry tends to operate in cycles, and Seadrill entered the market when consolidation made sense and when demand for deepwater drilling was expected to rise. It is a credit to the foresight of our senior management, and their willingness to act quickly, that we have had the opportunity to capitalise on these market trends."

With a growth strategy firmly grounded in market reality, Seadrill begins to look more conservative. And despite it's relatively young age, the company has the experience to match many more established players. While Seadrill itself was not listed on any stock exchange before 2005, the company can claim a history which dates back to 1972, when Smedvig Drilling was first established and went on to build the West Venture I, the first Norwegian-owned semi-submersible drilling unit ever produced. Indeed, the company has some 7,300 highly competent employees, many with more than 30 years' experience, representing over 40 nationalities and operating in 15 countries on five continents.

MINIMISING RISK But it is perhaps how Seadrill manages operations and the newbuilding process where its true, more conservative character comes into focus. At present, the company is cycling through a seven-unit newbuilding programme, scheduled to be completed in 2011. Four remaining larger units are currently under construction: the West Gemini, a drill ship expected to be delivered in June from the Samsung yard in Korea, the West Orion and the West Capricorn, now under construction at the Jurong yard in Singapore, and the semi tender rig West Jaya, due to be delivered from the Kepple FELS yard.

Monsen says that while managing the company's ambitious newbuilding programme has been a challenge, he notes that working with the yards and suppliers on consecutive builds has helped reduce delays. "While their can be some small technical differences from one unit to the next, they are basically the same," he says. "Over time, we have identified delay risks, and applied those lessons to the construction process on the next unit." Monsen also notes that Seadrill avoids building specialised units in favour of standard engineering designs, based on proven solutions. "We select basic designs and stick to them – we don't change the concept during a build."

LONG-TERM RELATIONSHIPS Another success factor for Seadrill is its close relationship with select yards and a network of key suppliers. "By working with the same yards and suppliers over time, we can all learn to be more efficient," he says. "Semis are technically sophisticated, but we have insisted on a philosophy of simplicity which covers every aspect of the build – from workflow to installation of equipment, systems integration to commissioning."

The company has long-term relationships with a number of shipyards, including Daewoo Shipbuilding and Marine Engineering (DSME), Samsung Heavy Industries, Jurong Shipyard and Kepple FELS among others, and works with a broad range of key suppliers, including Rolls Royce (thrusters), Wartsila (propulsion), Kongsberg Maritime (dynamic positioning systems and related controls), Cameron (riser systems) and ABB Marine, which has provided a complete range of electrical systems for no less than 15 of Seadrill's drilling units. ABB is also scheduled to deliver systems to the DP semi West Venture, the drillship West Navigator, the Semi Sub West Alfa, and the Jack Up West Epsilon.

Seadrill's relationship with ABB is a good example of how the company works with suppliers to keep construction schedules on line and minimise long-term operational risk. Since 2005, ABB has supplied about half of all the global deepwater drilling rig projects. This achievement supported in part by Seadrill's current newbuild programme, which saw four semis from the Jurong Shipyard, two semis from DSME, two semis from Samsung Heavy Industries and three drillships.

A PHILOSOPHY OF SIMPLICITY According to Jorulf Nergard, ABB's Vice President – Sales (Floaters) working with Seadrill has helped ABB improve its product and service offering. "Consistent with Seadrill's approach to cost and safety, we have made a real effort to focus on simplicity," he says. "This approach not only improves on delivery times at the yard, but is an advantage in both operations and maintenance."

Nergard explains that there is an association between risk and the number of parts and complexity of systems. "The leading cause of blackouts during operations is manual operation, not technical failure, " he says. "Advanced electrical systems may offer improvements, but

Alex Monsen
Vice President,
Deepwater Projects

Alex Monsen started working for Seadrill in June 2006. He has more than 20 years of experience from the drilling industry and has held several senior positions in Stena Drilling, most recently as Project Manager for Stena Drilling's DrillMax project. He has a bachelor's degree in Naval Architecture from the University of Strathclyde and a Master's degree from Strathclyde Business School. Mr Monsen is a Norwegian citizen and resides in Singapore.

Above: The drillship West Gemini now under construction at the Samsung yard in Korea, is on schedule to be delivered in June. **Below:** The semi West Orion, at the Jurong yard in Singapore

Seadrill's ultra deepwater semi-sub drilling rig is currently serving a six year charter with Petrobras.

since Seadrill specialises in deepwater and operations in harsh environments, reliability and crew training is critical. Our job is to supply Seadrill with stable, redundant systems that reduce risk and are easy to maintain and repair."

Seadrill semis and drillships are equipped with six to eight ABB gensets with power ratings between 4.8 and 7 MW each, and six to eight azimuthing thrusters with ratings from 3.3 to 4.5 MW each with the propeller speed controlled from ABB's DTC-based AC frequency converters. Consistent with Seadrill's preference for industry-standard design, ABB's design electrical systems are relatively straightforward, but adapted to marine requirements.

REDUNDANT SYSTEMS These systems are fully redundant, configured so that only two or three thrusters out of the installed six to eight will be lost in the event of a major fault, and can maintain position in the event of a single major fault occurs. They are controlled by ABB's DTC AC Frequency converters to manage the speed of the various drilling motors, and are fed from two or more switchboard systems. These are located in two or more fireproof rooms in order to get the appropriate redundancy and will secure a continuous drilling operation.

As a further precaution, ABB designed a top to bottom solution in each of the system splits, from the generators to the motors for azimuthing thrusters, auxilliary and drilling systems. According to ABB's Senior Project Manager Tore Sundsvaag, drillships typically have two splits, while semis have four. "This splitting configuration increases the units tolerance for a complete failure of a sub-system, and ensures that that unit still has adequate power to achieve safe operation," he says. "A clean split also eases the installation and speeds class approval."

Sundsvaag, who has worked on the ABB site team for many of Seadrill's newbuilds (including the recently delivered semisub, West Eminence, now under a six year charter agreement with Petrobras in Brazil), acknowledges that the development of simple systems is a challenge, but that the process was made easier in part because Seadrill knows what they want. "Seadrill has a high degree of technical competence and because we have worked with them over time, we can learn from previous experience," he says. "For example, we significantly cut the sea trial testing period for the West Eminence by testing components prior to sea trials – saving seven days."

"Our job is to supply Seadrill with stable, redundant systems that reduce risk and are easy to maintain and repair."

Jorulf Nergard, Vice President – Sales (Floaters), ABB Marine

REDUCING DELAYS Monsen says that efforts like this have helped make ABB a preferred supplier of electrical systems. "Competitive pricing will always play a big role in choosing suppliers, but we have been satisfied with ABB's performance and how they have worked with other suppliers to achieve good results," he says. "The combined efforts of all the yards and suppliers has allowed us to reduce delays by about three months since this newbuilding programme began, which represents significant cost savings."

By building long-term relationships, relying on proven design concepts and insisting on a philosophy of simplicity, Seadrill has produced eight drilling units in 11 months – a significant achievement. At present, Seadrill has not announced plans for additional newbuildings, and while rumours of other acquisitions continue to circulate, the company has kept a low profile recently. However, for a company known for business surprises, no one is willing to bet Seadrill will stand still for long. In the meantime, the company continues to build its reputation as a leading global provider of safe, reliable deepwater drilling services. |||

Arc modeling and active protection: We reprint a classic ABB article on interal arcing, which describes designed protection.

A switchboard's worst enemy is the internal arc. How are they designed and tested to prevent this?

How was this little devil originally designed and how does the system work today?

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The integration of power management systems directly into the electric power plant, and benefits thereof

Direct Torque Control naturally protects you from overloading generators. Find out how.

Looking at how failed or failing components can be assessed and isolated remotely.

We look at one of the most crucial components of the Azipod® propulsor: the thrust bearing.

Azipod® CO
10 years of compact efficiency

Azipod C series was introduced ten years ago. This article explains how the product features were designed and how the system operates today.

AUTHOR: *Jukka Varis* – jukka.varis@fi.abb.com

Figure 1: Two Azipod® CO:s waiting for delivery at ABB factory

AFTER THE LAUNCH of Azipod in the 1990s, ABB Marine started a new development project at the end of 1999 to meet market needs for lower power ranges, mainly below 5 MW, utilizing the important features learned from the larger units such as, low emissions, high efficiency, ease of installation,, ease of use and maintainance. The Azipod CO product launch was in summer 2000 and the first pilot unit started operation in autumn 2001. Since then the family has grown both in sizes and in applications - one example being the nozzled version Azipod CZ (see Generations 1, 2009).

AZIPOD CO SERIES DEVELOPMENT The Azipod CO series is designed with a combination of innovations that are gathered into one simple, but highly sophisticated system. Several technological decisions had to be made rather soon after starting the development project. Decisions were based on the requirement specifications from interviews with shipyards and operators which were then augmented by own know-how and experience gained from the larger Azipod units.

Permanent magnet technology was selected to be one of the key drivers in the new motor design since, at the time, rare earth permanent magnet techno-logy with high flux density had reached its commercial maturity and was feasibly available. By utilizing a motor with permanent magnets with practically zero heat losses from the rotor, it was possible to cool the unit directly with

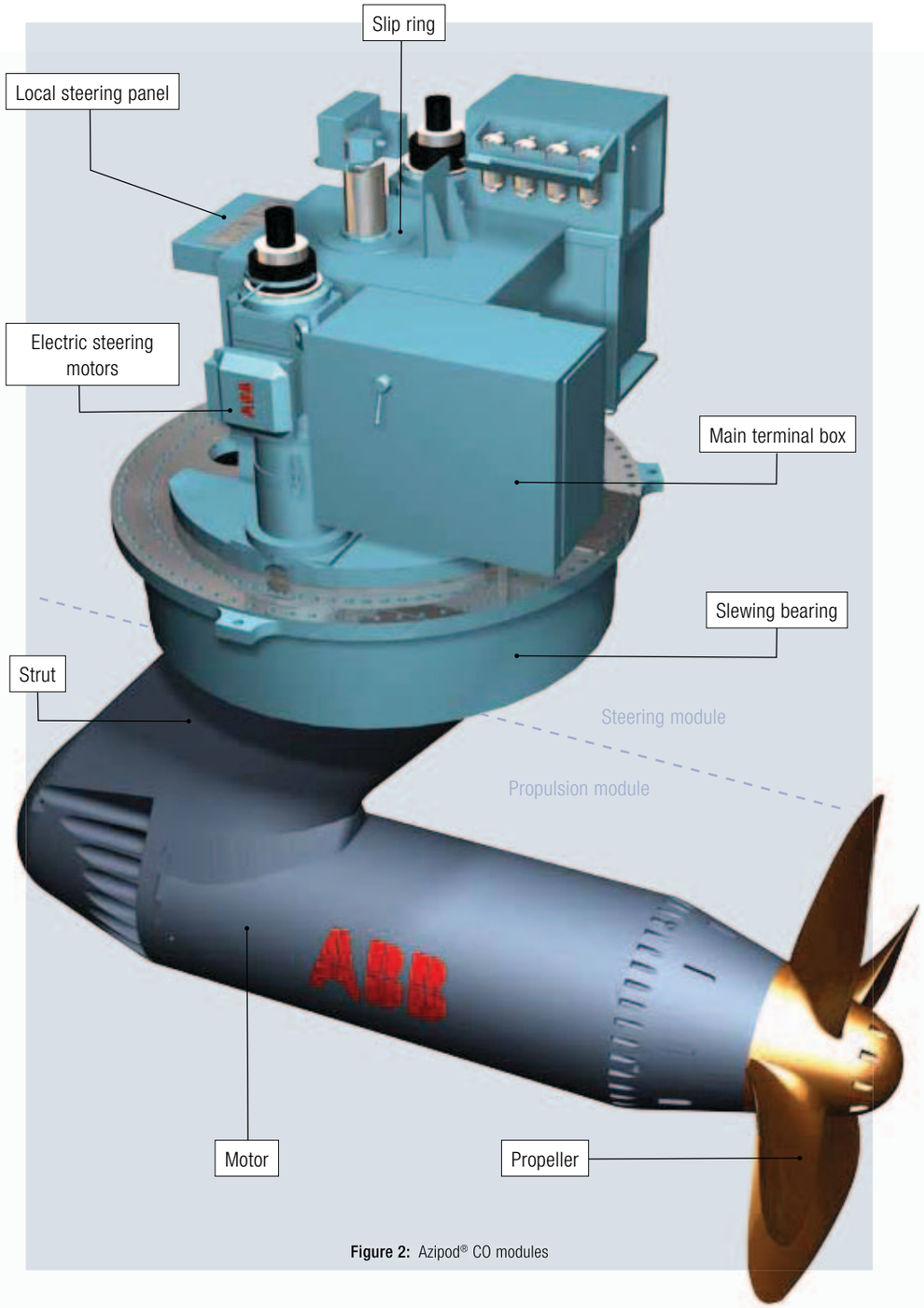

Figure 2: Azipod® CO modules

Figure 3

surrounding sea water without compromising the output power. The cooling effect was boosted by the main innovation of selecting a flange mounting motor module design, enabling the whole circumference of the motor housing to be in direct contact with water.

AZIPOD CO MODULES The manufacturing process and logistics played a leading role when the module platform was designed. Three modules, each having its own specific function were developed.

1 - Motor module, which rotates the propeller and creates the thrust force.
2 - Steering module; this combines all monitoring, supporting and steering functions and connects the unit to the vessel.
3 - Strut module, which is used as a bridge between the motor module and the steering module.

All main modules can be made separately, thus enabling a parallel manufacturing process. In different combinations, these three ensure flexibility on design, but due to constraints in manufacturing on such large components, the Azipod CO units are mainly made of pre-designed standard modules.

Main features

- Two shaft bearing systems only, in contrast to a minimum of six in a similar mechanical thruster
- No gear and minimized mechanical transmission losses
- Excellent hydrodynamic efficiency of propeller with uniform wake field
- No shaft alignment during assembly and installation, simplifying the construction and installation work
- Minimum amount of oil consumption, electrical steering
- No oil filters, pumps and oil cooling units
- No foundations needed besides thruster well
- High and accurate torque and power capability, reverse and forward rotation, improving station keeping capability and allowing for better utilization of installed power generation capacity
- Simple and rigid mechanical structure, with a minimized number of moveable parts, yielding lower maintenance
- Higher overall efficiency, reduced power and fuel consumption

The steering module is delivered as the first component to be installed at the shipyard. The motor and strut combination is typically delivered prior to the launching of the vessel. In some cases the motor can even be installed when the ship is afloat, if the ship can be trimmed enough to assemble the motor.

STEERING MODULE The steering module incorporates the sliprings for main power supply and control lines, swivel joint for grease, oil and pressurized air supplies, slewing bearing with seals and steering motors with planetary gears, the automatic greasing unit with piping, and main and auxiliary terminal boxes. All components are assembled to combine one module that can be easily installed into the vessel with one flanged bolt joint. The steering angle of the Azipod is controlled with a fully electric steering drive.

Such electric motor drives operating in a fully parallel mode is the typical application at ABB's portfolio. As

Figure 4: M/Y Ice

an example, a paper manufacturing machine may have 200 motor drives that are operating in parallel with separate, precise speed and torque control for each motor. On a steering drive the challenge is different. Alternating the turning direction combined with high inertias, big gear ratios and clearance in the gears makes it unique. The whole control needs to be done smoothly, according to the required feedback speed and without overloading the gear teeth when the backslash has been passed. To be able to meet these demands, ABB built a full size steering test bench in 2000 for initial tests to tune the steering control software. Later the unit has been used for further development and testing of the steering control software. The steering gear's maximum speed is 12 degrees per second,, which is also appropriate for dynamic positioning needs.

MAINTENANCE FRIENDLINESS It was clear from the beginning that to make the maintenance as easy as possible, it was essential to have most of the components that may need maintenance installed in the Azipod room. Only the maintenance of underwater components will require dry docking of the vessel, with planned intervals of five years. ABB Marine Service has developed service packages to support maintenance needs. ABB Marine's service stations are able to support the Azipod CO operations.

ECOLOGY AND ENERGY EFFICIENCY Azipod CO is designed for low emissions. This applies to energy efficiency, heat, noise, and vibrations as well as chemical substances. The vast majority of Azipod CO components are made of recyclable materials. One of the most noticeable aspects of the Azipod C technology is the silent operation of the Azipod propulsion motor and the steering drives, where the noise from ventilation fans in the propulsion room may exceed that from the propulsor itself. Yet the main benefit is the total efficiency of the system. Mr. Meng Guang Li, chief captain of the Chinese company Sinorail has, commented on the fuel oil consumption of Yantai-Dalian train ferries "Zhongtie bohai I, II and III" as follows: "After several years of operation and survey, these vessels show a 25% oil saving when compared with to similar Ro/Ro passenger vessel routinely operatedbetween Yantai and Dalian."

The environmental, comfort, and fuel efficient features of the Azipod CO have also resulted in deliveries to several private yachts; such as M/Y Ice, Picture 3.

We are proud after ten years since the initial idea of the Azipod C series was proposed, and over a million accumulated running hours on off-shore supply vessels, semi-submersibles, ro-pax vessels, mega-yachts, and research vessels that the system has performed well, and that the features that were considered important at the initial design stage seem to have beome accepted more as standard requirements for the marine industry. |||

Design and testing of arc-proof medium voltage marine switchboards

The marine market for air insulated, medium voltage switchboards demands high standards with respect to reliability of operation and safety. Internal arc is the most dangerous fault that can happen inside a switchboard, and the design and testing to ensure maximum safety to the user is therefore of the utmost importance.

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THE MOST SEVERE FAULT THAT CAN HAPPEN in a switchboard is an internal arc. Although the probability for an arc fault occurring is very low during the lifetime of the switchboard, the effects caused by the arc can be highly severe if the faults are not cleared quickly.

The switchboard itself can be damaged and it can cause injury to people exposed to the fault.

Even though the design of a modern switchboard is made to minimize the likelihood for internal arcs, it is not 100% possible to eliminate internal arcing.

Therefore, ABB puts a high priority on minimizing the consequences of faults by design and early fault detection, as well as thorough testing of the units in realistic arc tests.

CAUSES OF INTERNAL ARC The following points may be the cause of an internal arc occurring in a switchboard, or other electrical equipment:

- Loss of insulation properties: Dust and impurities on insulating surfaces can cause a path for currents to other potentials. Corrosion can also cause impurities but also weakens the contact between conductors, causing increased resistance. The increased resistance generates heat, which may lead to sparks causing arc faults. Heat is also generated if the equipment is operated above the nominal current level or by joints which are not aligned or which have improper torque.
- Failure of insulating materials. Voids in insulating materials can eventually cause failure of the insulating materials when stressed, e.g. over voltages.
- Over voltages: If the voltage between different conductors or ground is too high it may cause an arc strike. Over voltages may be caused by other system faults, e.g. earth fault, but also normal voltage level can cause arc strike between different potential if the insulation material is damaged or the equipment design is poor.
- Condensation can cause current paths from conductors to ground or to conductors of different potential, leading to arcs.
- Human errors: Accidental touching of live parts is known to cause arcs. Also, dropping tools on live parts or tools forgotten, e.g. during maintenance, can initiate arcs.
- Rodents and birds entering the panels and switchboard. These can lead to earth faults or short circuits and eventually cause an arc flash. The risks can be minimized by sealing all open areas preventing such animals from entering the switchboard.
- Incorrect operation/settings of protection relays and breakers. Failure could lead to prolonged exposure to arc flash

EFFECTS AND CONSEQUENCES When an arc is developed it releases an enormous amount of energy and the temperature in the arc can reach 20 000°C. This is more than twice the surface temperature of the sun. The energy discharge in the arc is directly proportional to the square if the current and time duration of the arc, i.e. energy ~ I2t. The following list shows some of the effects caused by an electric arc:

- The heat from the arc causes a pressure build up which may reach 120kPa inside the switchboard.
- Air blasts caused by the pressure build up.
- Vaporization and melting of any materials in the arc zone.
- Spreading of molten metals and emission of hot and hazardous gases.

- Intense light and noise.

As Figure 1 illustrates, the consequences of the fault can be significantly reduced by an early detection and interruption of the feeding currents to the faulty area.

If humans are exposed to an open arc, directly or indirectly, it may lead to severe injuries..

Typical injuries are:

- Injuries from the pressure blast or objects thrown by the blast.
- Burn damages, external an/or internal
- Ignition of clothing
- Loss of hearing

IEC STANDARD FOR ARC RESISTANT SWITCHGEAR To increase safety for operators and the public in case of an internal fault, the international standard for medium voltage switchgear includes an internal arc test as a mandatory type test where applicable. The IEC 62271-200 “AC metal-enclosed switchgear and controlgear for rated voltages above 1kV and up to and including 52kV, Annex A” was implemented for that particular reason. The Internal Arc Classification (IAC) makes allowance for internal overpressure acting on covers, doors, inspection windows, ventilation openings, etc. It also takes into consideration the thermal effects of the arc or its roots on the enclosure and of ejected hot gases and glowing particles. Metal-enclosed switchgear and controlgear is qualified as classification IAC if the following criteria are met:

- The doors of the switchboard must remain closed and no opening of the cover panels must occur.
- Any part of the switchboard which may be hazardous for personnel must not be ejected.
- No holes must appear in the external housing of the switchboard in any parts accessible to personnel.

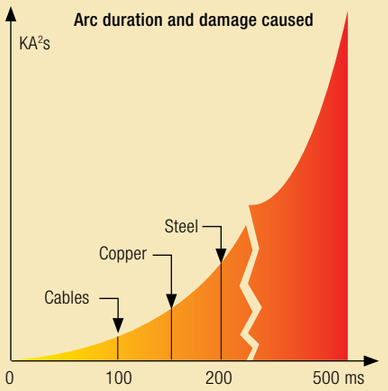

Figure 1: Energy released during arc

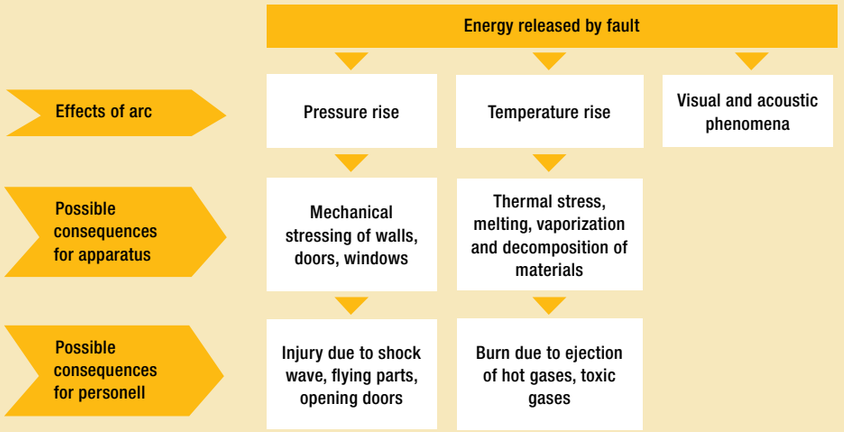

Figure 2: Effects and consequences from an arc fault

Figure 3: A rodent causing short circuit in an MV switchboard. Due to installed arc protection system, only minor damages were caused.

Figure 4: Internal arc testing of MV switchboard, from NEF1 High Power Laboratory

- The vertically and horizontally arranged fabric indicators placed outside the switchboard must not get burnt.
- All the switchboard earthing connections must remain effective.

In case where classification IAC is proven by the tests, the metal enclosed switchboard will be designated as follows:

- General: Classification IAC
- Accessibility: A, B or C (switchgear accessible to authorized personnel only (A), to all (B), not accessible due to installation (C).
- Test values: test current in kiloamperes (kA), and duration in seconds (s).

For identification purposes of the different sides of the enclosure, the following codes are used (F), front side, (L), rear side (R).

UNIGEAR SWITCHBOARD – ARC PROOF DESIGN The UniGear switchboard is always supplied for marine systems in the arc-proof version and is classified IAC AFLR. Tests have shown that the metal housing of the UniGear switchboard is able to protect personnel operating near the switchboard in the case of a fault which evolves as far as striking an internal arc. This makes the switchboard ideal for marine applications with its arc proof construction and metallic partitions between each compartment. The switchboard is tested under conditions of arcing due to internal faults by means of its structure for a time of 1.0s up to 40kA and 0.5s at 50kA.

The robust construction will contain the internal arc pressure and direct it to the gas exhaust ducts through the movable vent flaps designed for the purpose of safely venting the gases. The switchboard has the gas ducts fixed on the top of the auxiliary compartment. In marine plants, the exhaust gases cannot normally be evacuated out of the room and therefore the gas duct must always be closed on both end-sides and equipped with top flues. See figure 5 below. The low voltage compartment, which contains the protective relays, meters, devices and wiring, is located in a separate compartment and will not be damaged as a result of the arc fault. This is extremely important as the protective devices are relied on to limit the duration of the arc fault.

ARC PROTECTION Regular maintenance aimed towards reducing the exposure/risks from the causes of arc flash (as listed earlier in this document) should be the focus of all maintenance programs. In fact, many of the sources to arc fault can be prevented by sufficient maintenance. This includes infra red thermograhpy of cable connections and insulation monitoring. However, in spite of precautions taken, there will always remain a certain risk of arc failure. Older switchboards are more prone to arc faults and human error is difficult to eliminate.

For active protection against an internal arc, devices consisting of various types of sensors can be installed in the various compartments. They are designed to detect the immediate outburst of the fault and carry out selective opening of the circuit breakers. The sensors exploit the pressure or light generated by the fault.

For marine systems, the most common sensor technologies are:

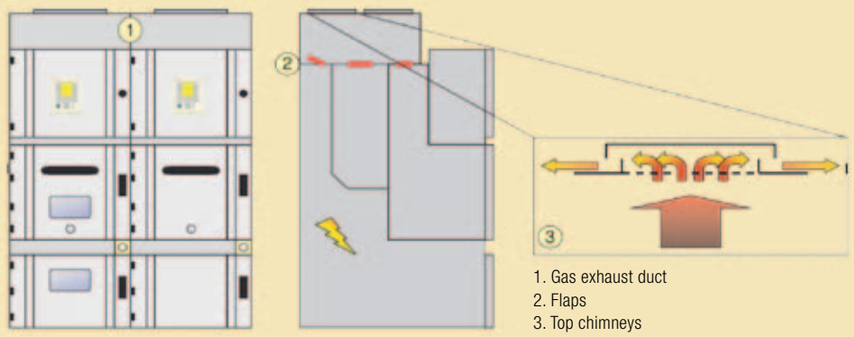

Figure 5: Arc Venting System, UniGear ZS1 MV switchboard

Ith – The sensors consist of microswitches positioned on the top of the switchgear near the gas exhaust flaps of the three power compartments. The shock wave makes the flaps open and operate the microswitches connected to shunt operating releases of the circuit breakers.

FRD – This system consists of pressure sensors located in the auxiliary compartment and connected to the three power compartments by means of small tubes. The sensors detect the rising front of the pressure wave which develops on the outburst of the arc and react by making the circuit breakers open.

TVOC – This system consists of an electronic monitoring device located in the auxiliary compartment which the optic sensors are subjected to. These are distributed in the various power compartments and are connected to the device by means of optic fibers. When a certain established light level is exceeded, the device opens the circuit breakers. To prevent the system from intervening due to light occasionally generated by external phenomena (flash of a camera, reflections of external lights, etc.), current transformers can also be connected.

Both the Ith and the FRD technologies have about 20ms activation time while the TVOC has 2-3ms activation time. Taking the opening time of the circuit breaker into account, the extinction of the fault will take place well within 100ms. This is significantly less than the settings from the protection system, which has trip settings that can be delayed by hundreds of milliseconds for selectivity reasons, within the 1000ms maximum setting time being permitted by most class societies.

These protection schemes, having fast acting protection and current interruption in case of internal arcing will not eliminate arcing itself, but will greatly reduce the consequences and damage of such faults. Safety margins for the crew increases, while the repair time of the switchboard can be much lower than would be the case without internal arc protection with fast response time. |||

REFERENCES

[1]: *Medium Voltage, Metal-Clad Arc Resistant Switchgear: Enhancing Workplace Safety*; Thomas P. McNamara, P.E.
[2]: UniGear type ZS1 Technical Catalogue; Medium voltage, arc-proof, air-insulated, metal-clad switchgear
[3]: IEC 62271-200 "AC metal-enclosed switchgear and control-gear for rated voltages above 1kV and up to and including 52kV, Annex A"
[4]: *Practical Solution Guide to Arc Flash Hazard*; Chet Davis, P.E., Conrad St. Pierre, Dave Castor, P.E., Robert Luo, Ph.D., Satish Shrestha
[5]: *Internal arc-proof switchgear: Arc modeling and active protection*, M Marchi, F Perdoncin, CIRED Birminghan, 2-5 June 1997.

Internal arc-proof switchgear: arc modeling and active protection

AUTHORS: *Mauro Marchi ||| Francesco Perdoncin*

INTRODUCTION *by Alf Kåre Ådnanes*

Internal arcing in medium voltage switchgears is rare, but the consequences of such faults can be critical to the operation of the vessel, as they can put a large part of the installation out of service until the switchboard has been repaired. Also, if not taken sufficiently into the design and installation, arcing in electric components may be a safety hazard. Therefore, ABB has made significant efforts to understand, and by active protection to reduce the effects of internal arcs in medium voltage switchboards, in order to create a safer working environment for the crew, but also to reduce the damages and enable the switchboard to return to service more quickly.

This article, by M. Marchi, and F. Perdoncin, was first published in CIRED'97, in Birmingham. Even though the design and solutions have evolved during the last decade, the article has definitely not lost its impact and technical relevance to today's solutions and the design of protection.

INTRODUCTION According to the current 298 IEC standard, internal arc tests are not mandatory but are a basic requirement for users who are aware of personnel safety needs.

Over twenty years experience in the design of arc-proof switchgear has led to a construction with little difference from non arc-proof switchgears. Therefore, a logical consequence would be internal arc-proof switchgear as the standard solution.

The additional costs of internal arc-proof solutions are due to research and development costs as numerous and expensive destructive type tests are necessary for the many different versions and service conditions.

For these reasons, it is necessary to reduce to the minimum the tests and to avoid the empirical approach which was used a few years ago for the development of this type of switchgear.

For this purpose, ABB SACE has conceived a series of calculation methods which allow foreseeing the behavior of the switchgear during internal arc conditions, starting right from the design phase.

The main characteristic of the internal arc-proof switchgear is that, in the presence of an arc, the external manifestations must be contained to the utmost extent; this can be obtained by guaranteeing structural strength and by containing the temperature of the gas which could strike the personnel.

To foresee the structural behavior of the switchgear and the thermal characteristics of the exhaust gases it is necessary to calculate the pressure developed inside the switchgear in the presence of an electric arc.

PRESSURE MODELING The pressure developed inside the switchgear is related to the arc energy and to the gas volume of the switchgear. To compute its value it is sufficient to apply the fluid mechanics equations describing the conservation of energy per unit time:

$$\eta \cdot u \cdot i = \frac{\partial}{\partial t}(\rho \cdot c_v \cdot T) + div(\rho \cdot c_v \cdot T \cdot \vec{v}) + p \cdot div(\vec{v}) \quad (1)$$

mass conservation:

$$\frac{\partial \rho}{\partial t} + div(\rho \cdot \vec{v}) = 0 \quad (2)$$

moment conservation:

$$\frac{d\vec{v}}{dt} + \frac{1}{\rho} grad(p) = 0 \quad (3)$$

and the equation of the gas status:

$$\frac{p}{\rho} = RT \quad (4)$$

The integration of these equations allows determining the change of pressure inside the switchgear.

Attention should be made to the following three items:

- evaluation of the arc voltage
- definition of escape areas
- definition of the part of the arc energy which is used to heat the gas

ARC VOLTAGE The evaluation of the arc voltage is extremely important for pressure calculation as it determines the energy developed by the arc itself.

The arc modeling is of a black-box type and it results from a combination of Cassie's model with Mayr's model.

Cassie's model [1] assumes that the arc column has a fixed temperature constant in space and time, with constant losses and an area which changes depending on current and time.

These assumptions lead to a relation of the following type:

$$\frac{dg}{dt} = \left(\frac{i^2 \cdot u}{U^2} - g \right) \frac{1}{\tau_c} \qquad (5)$$

which describes the arc in the high current area quite well.

Mayr's model [2] considers the arc as a cylinder, having a constant section in which the temperature changes both in time as well as in space in a radial direction and the energy loss per unit time is constant.

Mayr's equation is:

$$\frac{dg}{dt} = \left(\frac{i^2}{P} - g \right) \frac{1}{\tau_m} \qquad (6)$$

and describes the arc next to the current zero quite well.

The combination of these two models allows an accurate description of the arc to be established, as required..

In the compound model used for pressure calculation, the conductance values refer to the length arc per unit.

The column length is defined based on the geometry of its area of origin. When the point of the arc ignition is known, it is possible to determine the movement and the elongation of the arc by considering all the forces acting on the arc column (electrodynamics and gassdynamic forces) and the characteristics of the plasma jets at the arc roots.

DEFINITION OF ESCAPE AREAS Since the escape areas play an important role in the development of pressure inside a switchgear, they have to be determined with the utmost accuracy. There are three types of escapes: "parasitic" escapes, escapes which are due to structural deformations and escapes which are the consequences of areas with a predetermined opening.

The "parasitic" escapes are the most difficult to quantify as they are bound to the unavoidable imperfections of surface connection and therefore they relate only to non-pressure-sealed switchgear.

As the working cycles and the connection systems of structural elements are constant characteristics of the production unit, the experimental determination of these escape areas is carried out only once for each constructive type of surface connection, so as to create a data bank.

The escapes which have a consequence of structural deformations are calculated through the classical method of finite elements analysis assuming that we are considering an elastic field and that we are far from resonance conditions.

The escape areas due to the opening of valves are determined by applying dynamics laws in case of continuous opening valves or fracture mechanics laws for breaking valves.

CONVERSION COEFFICIENT: ELECTRIC ENERGY-GAS HEATING The arc energy is used partially for the vaporization of the metallic materials constituting the electrodes, partially for the vaporization of the plastic materials located in the proximity of the arc, partially for the heating of the conductors and of the enclosure, and the remaining part is used to heat the gas and consequently to raise the pressure.

This coefficient depends on the type of area where the arc is developed [3] and must be determined experimentally when it cannot be derived from an analogous situation.

APPLICATIVE EXAMPLE The application of the models and equations described above allows foreseeing the behavior of switchgear in internal-arc conditions from a structural point of view.

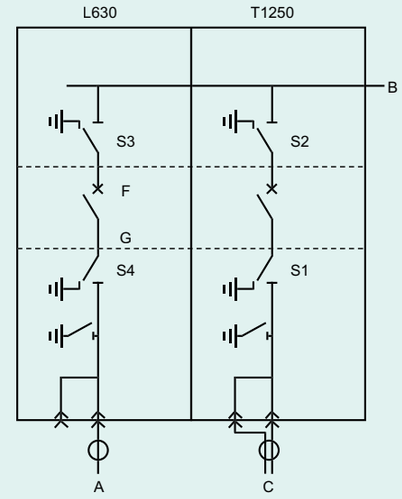

Figure 1: One-line diagram of the tested switchboard

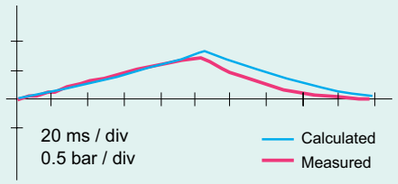

Figure 2: Pressure measured and computed pressure during internal arc test

A comparison between simulation and experimental results referring to a 24kV SF6 insulated switchboard is given below as an example.

The presence of an arc in the switch-disconnector type S3 of the bus bar compartment (Fig 1) has been simulated with the following fault values:

$$I_{cn} = 11kA \text{ at } 24\text{kV}$$

The pressure calculated through the simulation program and the pressure measured during the test is reported in Fig. 2. When the pressure is known, it is possible to compute the structure behavior and therefore to identify any weak points by using a finite element simulation program (i.e. DSTAR by SRAC).

Thus, it has been possible to prove that the maximum stress of the structure is in all ways lower than the maximum stress allowed.

This method allows the designer to optimize the dimensioning of the structure according to the short circuit levels to be obtained by reducing the number of tests to a minimum.

TEMPERATURE OF THE EMITTED GASES Once the problem of the structural strength of the switchgear has been solved, the other main point is to verify that the characteristics of the gases emitted during the tests are such as not to damage any person in the service areas.

Therefore, the determination of the diffusion modalities of the hot gases from the outlets of the switchgear into the environment and the computation of the gas temperature are essential design issues.

By setting the boundary conditions properly [4], the integrations of equations (1) to (4) yields the desired information.

The boundary conditions relevant to the space can be set by customers (e.g. when the switchgear is installed in a pre-determined environment) or can be let free (e.g. in the case of switchgear for environments without structural boundaries).

In the first case, if the physical characteristics of the hot gases affecting the service areas are such as to cause damage to people, it will be necessary to use grids, filters or canalized ducts to reduce the thermal energy level affecting the area outside the switchgear. To this purpose, it must be pointed out that the equation (1) describing the energy conservation per unit time is incomplete; it lacks the terms relevant to the radiated power, to the power lost because of viscosity phenomena and to the thermal power exchanged by conduction and by convection.

While the radiated power and the power lost because of viscosity can be neglected, the thermal power exchanged by conduction must be considered whenever it is necessary to insert structures suitable for exhaust gas cooling (e.g. cooling flaps, grids, etc.) in the escape volumes.

In this case, regarding exhaust gases which skim the surface of solid structures, the balance equation is

$$div\left(k \cdot grad(T_s)\right) = \rho \cdot c \cdot \frac{\partial T_s}{\partial t} \qquad (7)$$

With the boundary condition of interface between solid and gas:

$$-k \cdot grad(T_s) \times \vec{n} = h_f \left(T_s - T_f\right) \quad (8)$$

Where hf is the coefficient of the convective exchange and is derived – for example – from [5].

ABB SACE is implementing this simulation software which will allow it to help customers arrive at the optimum definition of structures for switchgear installation.

ACTIVE PROTECTION AGAINST INTERNAL ARC The IEC standard considers the arcing effect only outside the switchboard. Internal damage is not taken into consideration; therefore recovery time is not considered either.

Damage to the switchboard depends on the dissipated arc energy due to short-circuit duration and current value.

When a fault occurs in the installation but does not involve the switchboard, the short circuit's duration must respect selectivity times. However, when an internal fault occurs, the priority is to minimize damage to the switchboard by reducing short circuit duration to a minimum, bypassing selectivity protection.

A system of pressure sensors installed in the different cells of the switchboard is activated by the pressure wave which occurs during the first 20 ms of arc strike.

The sensor instantaneously trips the circuit breaker which feeds the fault; complete selective protection is therefore achieved for faults inside the switchboard. This does not, of course, interfere with the selectivity programmed for the installation.

Total duration of the short circuit current for a fault inside the switchboard can therefore be reduced to 0.1 seconds with the circuit-breakers already used for installation protection.

This pressure sensor protection system consists of a few simple and reliable components; this network of sensors can easily be checked when in service.

This selectivity only isolates the installation area directly affected by the fault, leaving the rest of the installation in service.

Repairs can be carried out quickly by replacing few components.

By reducing the short circuit duration and therefore limiting the area involved, fire risk is practically eliminated.

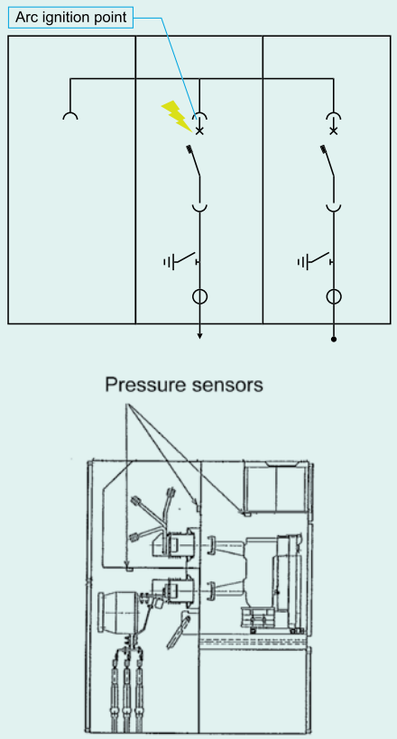

Figure 3: The arc tested 24kV switchboard

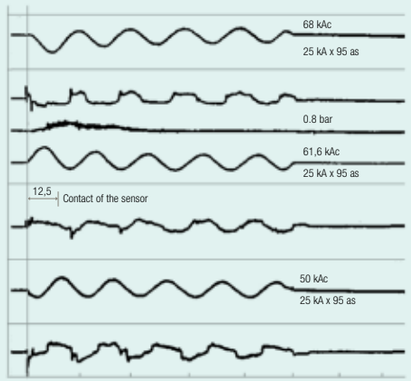

Figure 4: Recording of internal arc test at 24kV – 25kA rms.

Here is an example of the numerous tests carried out on switchboards of different types to confirm the validity of this solution.

A 24 kV switchboard made up of three units equipped with SF6 insulated circuit breakers was tested.

The pressure sensors were installed as shown in Fig. 3. The short circuit was ignited in the circuit breaker cell of the central unit. The prospective short circuit current was 25kA.

The pressure sensor in the circuit breaker cell operated in 11.5 ms, shown in the recording of Fig. 4, and tripped the incoming circuit breaker installed in the cell on the right side in 95 ms.

After these short circuit tests were carried out, the circuit breaker where the arc had ignited was removed and the cleaning of the bushing surface on the circuit breaker side only was performed, a maintenance operation which required only a few minutes.

Afterwards, dielectric tests at 50kV, 50Hz were carried out with positive results on all the cells close to the one where the arc developed to prove the switchboard suitable to remain in service.

There are other systems aimed at reducing the short circuit duration, such as quick earthing switches, which extinguish the arc and cause the upstream circuit breaker tripping: The advantage of the system described in this paper are simplicity and reliability.

With this active protection the problem of exhaust gas control is solved even when the space around the switchgear is limited, which frequently happens in urban installations and for switchgears installed in very compact, prefabricated permanent or transportable units (such as marine vessels).

CONCLUSION Simulation and mathematical modeling allow speeding up the development time of internal arc proof switchgears by reducing the number, and consequently the costs, of experimental tests.

ABB SACE can rely on proven computational means which are suitable for any topic regarding pressure calculation and the structural behavior of internal arc switchgear. It is also developing a model for the computer definition of the outlet gases in the switchgear's installation environment.

A simple pressure sensor system, which detects when an arc strikes and trips the upstream protection device, can drastically reduce the duration of the phenomenon. The advantages are increased safety and greater power supply reliability. |||

Symbol lyst

c_v	: specific heat
g	: conductance
k	: thermal conductivity
i	: arc current
p	: pressure
t	: time
u	: arc voltage
$\vec{v}$	: velocity
P	: Mayr's constant
R	: gas constant
T	: temperature
U	: Cassie's constant
η	: energy conversion factor
ρ	: density
τ_c	: Cassie's arc constant
τ_m	: Mayr's arc constant

REFERENCES

[1]: Cassie, A.M., 1992: "*Arc rupture and circuit security*", CIRGRE, Paris France, 1-4

[2]: Mayr, O., 1943: "*Beitrag zur Thorie der Statischen und der Dynamischen Lichtbogen*", Archiv fuer Electrotechnik, Berlin, Germany, 37, 588-608

[3]: Shuhmann, H., 1989: "*Untersuchungen zum Druckanstieg in Schottenraumen SF6 isolierter, eipolig metallgekapselter Hochspannungs-Schaltanlagen infolge stormstarker Stoerlichtboegen*", Thesis, Tech. Hochschule, Darmstadt

[4]: Baker, A.J. 1985: "*Finite Element Componential Fluid Mechanics*", Mc Graw Hill, 342-351

[5]: General Electric: "*Heat Transfer and Fluid Flow Data Book*", 1992

Energy savings and emission reductions in new building and retrofitting of vessels

Energy Efficiency plays the most important role in CO2 emission reductions, accounting for up to 53% of total CO2 emission reductions. In pump and fan applications onboard vessels, using Variable Speed Drives (VSD) can cut the energy consumption for these applications by as much as 60%.

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ENERGY EFFICIENCY AS A PART OF DESIGN CRITERIA

Until recently, energy efficiency in auxiliary systems was not an important factor during the design process or construction of marine vessels. Due to this reason, the systems on many ships are not energy efficient and have not been fully optimized for minimizing overall fuel consumption. Many vessels continue to be built with little emphasis on energy efficient solutions.

The onboard ship systems that are the most suitable for improving energy efficiency, are systems with large pumps and fans, which are not required to run continuously and at full capacity. When applicable, electric motors could be fitted with VSD to operate pumps and fans more efficiently in partial loads during slower sailing speeds or with reduced ventilation requirements. The electric power consumption of a pump is related to the pump volumetric flow according to affinity laws. The reduction of pump speed will affect the system pressure, Head, to the power of two and the electric power consumption to the power of three. As an example, a reduction of the pump speed with 10% will save 27% of the consumed power.

EMISSION REDUCTION

COP15 conference kept in Copenhagen at the end of 2009 aimed to get a global agreement of reducing the amount of Green House Gases (GHG) worldwide. The achievements of the conference were not what many of the participants aimed for. The parties could not agree, and most likely the different countries will only have recommendations for the reduction of GHG. All parties are in fact aware of that something needs to be done. However, it is now up to IMO to introduce global regulations on the GHG emission from vessels, a work that already is being started this year.

Flow $Q_1/Q_2 = n_1/n_2$
Head $H_1/H_2 = (n_1/n_2)^2$
Power $P_1/P_2 = (n_1/n_2)^3$

Table 1: Affinity laws – Proportion of speed (n), flow (Q), head (H) and power (P)

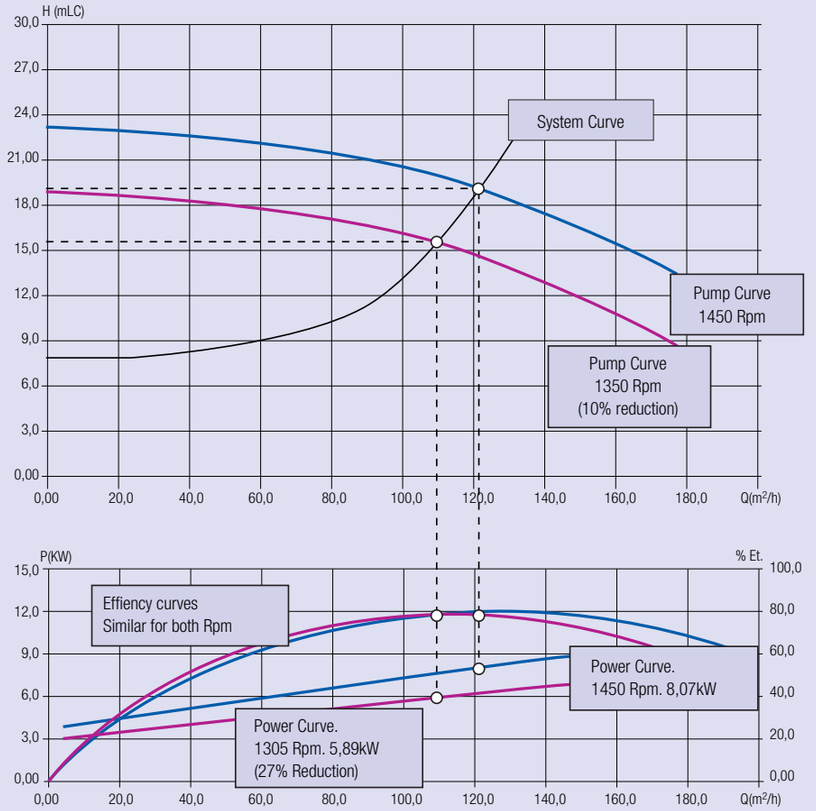
CO2 is the most common GHG and shipping industry today stands for 3-4% of total GHG emissions. It is estimated that this figure grow rapidly if the shipping industry is not doing anything to make the vessels more energy efficient. In "business as usual scenarios" IPCC estimates an increase by 150-250% to 2,5 – 3,5 billion ton of CO2 emissions from shipping towards 2050[1].

PUMPS AND FANS ARE VITAL PARTS OF THE PROCESS ONBOARD A VESSEL

PPumps and fans onboard vessels are often a vital application. If these are not working the vessel is not sailing.

Onboard a vessel there is a lot of different kind of pump applications. Sea water cooling pumps, boiler feed pumps, HVAC pumps, bilge water pumps, lubrications pumps, fire pumps, waste water pumps and many other kinds. A common thing for pump applications is that they are very often over-dimensioned to the need. This is simply because the design criteria are set to meet the extreme conditions the vessel may operate in, as an example the sea water temperature for dimensioning is generally set above normal operating conditions.

Although it is required for a ship to be able to operate in extreme cases and environments, every-day operations rarely come close to such conditions. For example maximum allowed engine load is typically 75… 90% of maximum, heat is always recovered from



Graph 1: Relation between the system curve, pump curve and needed electrical power

the system and seawater temperature only very seldom reaches design value.

A lot of energy is easily saved by letting pumps and fans be controlled by a VSD, either standalone or with a pressure or temperature sensor loop control.

Displacement pumps and Centrifugal pumps are the two most common pump types used on ships, but around 80% of all pumps onboard ships are centrifugal pumps. This kind of pump has the same duty characteristics as a fan. Fans are used for ventilation in engine room, on car deck, cargo spaces and other places where forced ventilation is needed.

When operating a centrifugal pump or a fan you can get a fairly big reduction in energy consumption by even a small reduction in rpm of the pump.

Cavitations are another important issue when talking about pumps and dimensioning of pumps. If the pump is too large, the suction capability is very poor and the risk of cavitations is very high.

Cavitations appear as a result of evaporation of the fluid, when the static pressure drops below the actual steam pressure inside the pump. Cavitations inside a pump results in severe damage to the material, especially the impeller is often badly damaged. The damage to the impeller can in some cases cause the pump to fail within couple of months.

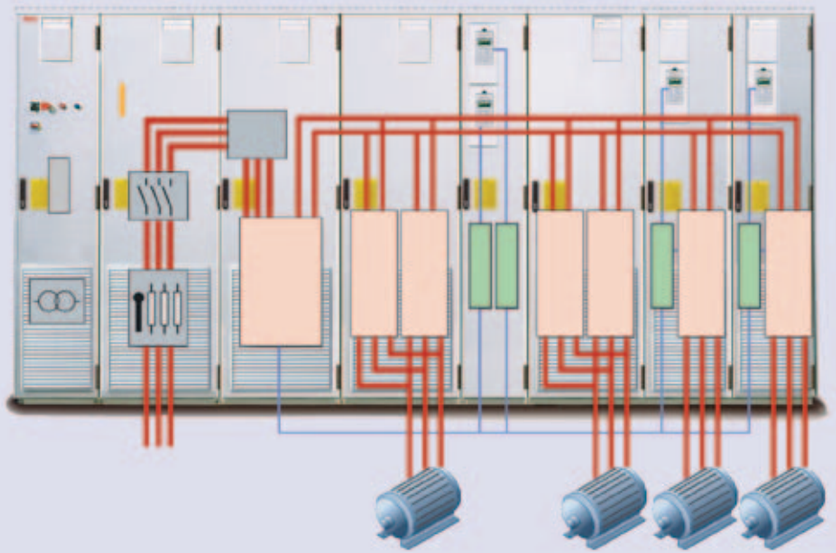


Figure 1: A typical set-up for a MultiDrive system consists of one common supply unit together with the inverter units supplied from the common DC-bar.

When using a VSD to decrease the pump speed you reduce the chance of cavitations, and the risk of damage to the pump.

By far the most commonly used flow control in pump applications is throttle control and by-pass loops to control the temperature. As a consequence pumps are running at 100% loads continuously, even though the requirement would be actually about 40% in average.

There are few large capacity pumps and fans required to run continuously at 100% that will not benefit from VSD in the respect of energy efficiency.

SYSTEM CURVE AND PUMP CURVE A fluid flow system can in general be characterized with a system curve. This curve visualizes the system head. A combination of the elevation (static head) and the friction of pipes, bends, and valves within the system. It is very difficult to change the characteristics of the system curve in an efficient way. The system curve is totally independent of the pump.

The pump curve on the other hand is a graphical description of the flow and the pressure (Head) relation for one specific pump.

The duty point of a pump in a system will always be at the intersection between the pump curve and the system curve.

On a vessel there are several ways to change the duty point of the pump. Blinds, semi closed valves and By-passes have been used for many years but these are all very inefficient. A more efficient solution is to reduce the diameter of the impeller in the pump. This solution will enhance the risk of cavitations in the pump, and there is no possibility to increase the flow or head if this should become necessary.

VSD mounted on pump is by far the most efficient way to change the duty point of a pump system, and reduce the power consumption. VSD gives a much more flexible pump control and reduce the risk of cavitations. See graph 1 for details.

Figure 2: Air cooled Drive cabinet and Module

Pump and fan applications

Pump applications suitable for VSD are:

- Sea Water Pumps
- High and Low Temperature Cooling Water Pumps
- Boiler feed pumps
- Bilge water pumps
- Waste water pumps
- Cargo pumps
- Engine Room Ventilation Fans
- Cargo Area Fans
- Air Handling Units, such as Air Conditioning Systems onboard cruise ships and passenger vessels
- Hotel Auxiliary System Pumps and Fans (mainly in passenger vessels)

REDUCING EMISSIONS DOESN'T MEAN RE-ENGINEERING YOUR EXISTING VESSEL Retrofitting existing vessels with VSD is a task demanding knowledge from the process to be modified as well as good system knowledge on VSD, motors and pumps/fans. Sometimes it is necessary to replace the existing motor with a new motor designed for VSD use. This highly depends on the voltage level and power demand of the pump. As a rule of thumb one could say that ABB Random Wound motors with a voltage level not exceeding 500V is good for VSD use as such, whilst other motors should be checked case by case for suitability.

Control method of the VSD depends on the existing Automation system. In some cases it may even be beneficial to install an independent control system for the modified processes.

ABB Marine Service has wide experience and knowledge on complete retrofit energy efficiency design packages, including ABB products together with project service and all site activities, to suit the customer needs.

In vessels built between years 1988 to 2008 and still sailing, approximate 2% of the main sea water cooling systems have VSD control. By modifying these systems, which is a fairly simply thing to do, there is a substantial amount of reduced emissions and costs to achieve. Small changes in the system, but big impact on emission reduction and fuel consumption.

ENERGY EFFICIENCY IN NEW BUILDINGS The recommendation for new buildings would be to install the VSD with a common DC bus to reduce the amount of cabling and space needed, so-called Multidrive. It offers all of the benefits of a single VSD, but unlike single VSD (which have to have their own rectifier, DC link and inverter), the Multidrive system generates the required DC voltage in a "central" unit and feeds it onto a common DC bus to which the single, independently operated inverters are connected. In a Multidrive system all the desirable features of a single VSD are still retained. In addition, the individual inverters do not all have to have the same power rating. On the contrary, a Multidrive package can consist of drives of very different sizes. See Figure 1 with a typical setup of a MultiDrive system. The number of multidrives will depend on the system redundancy requirements, as redundant parts of the installation must have separate feeding.

The Multidrive cooling method can be either with air or liquid.

Some of the benefits of a Multidrive system include:

- Reduced cabling due to the single power entry for multiple drives.
- Cost effective reduction of harmonics using an active front end supply unit or at least a 12-pulse line supply.
- Common DC bus bar
- Shared energy and motor-to-motor braking without braking chopper or regenerative supply unit
- Reduced line current
- Energy savings
- Does not require use of separate MCC
- Higher power factor for VSD controlled

Figure 3: ACS800-01 VSD

The ACS800-01 product is type tested and approved by:

- DNV (Det Norske Veritas)
- LR (Lloyd's Register of Shipping)
- ABS (American Bureau of Shipping)
- RINA (Registro Italiano Navale)
- BV (Bureau Veritas)
- GL (Germanischer Lloyd)

applications, results in better efficiency on the main generators

- Centralized engineering at the ship yard, since all the consumers are controlled from a single point.

The biggest benefit designing the new building in a more energy efficient way – is the potential of reducing size of the power plant.

MARINE TYPE APPROVED DRIVE The ACS800-01/04 product is type tested and approved for marine drive applications. The type approval test is required for essential applications onboard. Essential applications are those related to navigation, propulsion, safety of the ship and passenger, cargo and crew. Examples of essential applications are ballast pumps, bilge pumps, circulating and cooling water pumps.

Major benefits from installing a VSD:

- Soft starting – no big starting currents causing disturbance on the network
- No process disturbance due to voltage drops; no trips of other electrical devices connected to same bus
- No excessive thermal mechanical stress on the motor; longer lifetime of the motor
- Immediate start-up without warming-up delays (e.g. steam turbines)
- Controlled and smooth start-up
- Accurate process control – flow based on production need.
- Mechanical weariness of piping is minimum
- Risk of cavitations in the pump is minimum
- Passenger comfort (in air conditioning application)
- Energy efficiency
- Reliability/technical improvement
- Environmental compliancy
- Size of Energy bill

NOTES [1] DNV presentation 26.1.2010. Fuel management, Ship Performance and Energy Efficiency – London, Lloyd's Maritime Academy

Energy efficiency makes a difference – case studies

CO_2 is the most common GHG and shipping industry today stands for 3-4% of total GHG emissions. It is estimated that this figure grow rapidly if the shipping industry is not doing anything to make the vessels more energy efficient. In "business as usual scenarios" IPCC estimates an increase by 150-250% to 2.5 – 3.5 billion tons of CO_2 emissions from shipping towards 2050.

AUTHORS: *Jan-Erik Räsänen* – jan-erik.rasanen@fi.abb.com

CASE STUDY 1 : DRILLING RIG

Accurate main sea water cooling pump control with ABB Low Harmonic Drive onboard a drilling rig.

A customer identified a need for a better and more accurate pump control for the main sea water cooling system. The main target for the modification was to remove the mechanical stress this system had on the piping and the pump itself. The pump motor is rated 450kW and the pump system capacity as high as 1500 m3/h with an operating pressure of 7.5 bars and a head of totally 80 mLC. This is a big pump system and as such benefits greatly of a smooth and soft speed control. The operating profile for the pump is 7000h/year with an average flow of 65-70%. The flow control today is done by throttling and by-pass, meaning that the pump is continuously running with 100% power.

Remembering the Affinity law, where the reduction of pump speed will affect the system pressure, Head, to the power of two and the electric power consumption to the power of three, everyone can see that there is a huge

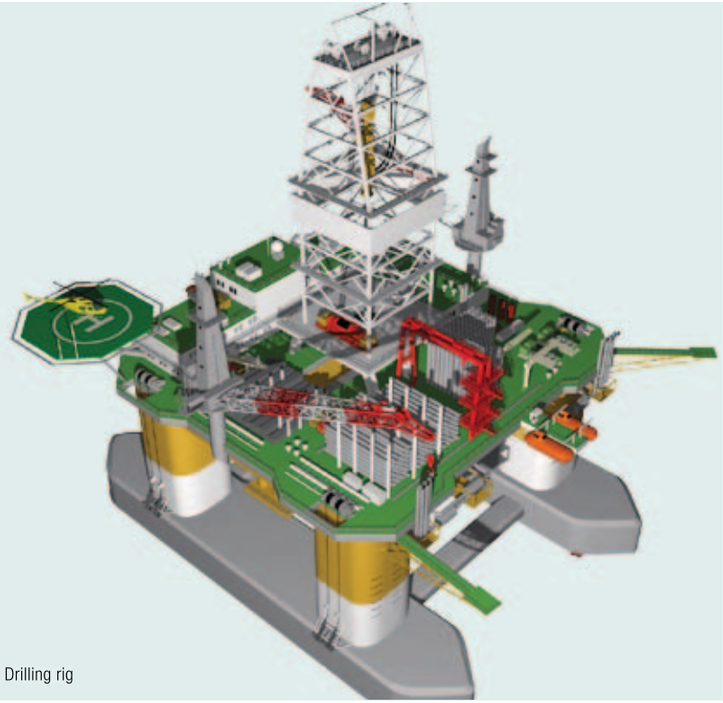
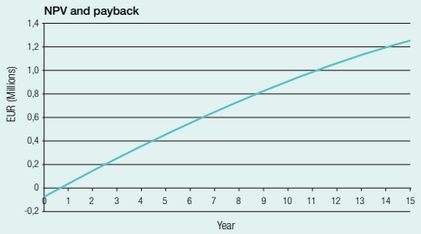
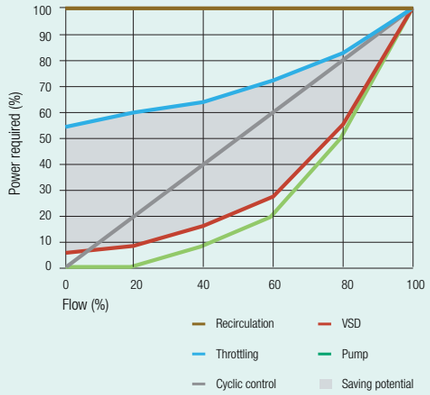


Figure 1: Drilling rig



Graph 1: NPV and payback time for case study 1



Graph 2: Power consumption versus needed flow when comparing throttle- and VSD-control

potential of energy saving by adding a VSD to control the flow and speed.

Calculations indicate that the power consumption with throttle control is 2 457 MWh/year and with VSD control it is 1 220 MWh. The total energy saving per year is 1 236 MWh corresponding to a yearly reduction of 680 ton of equivalent CO2 (555kg/MWh). The saving of 51% of the yearly energy consumption will give a payback time of less than 9 month.

Problems to be solved

- Minimize mechanical wear and damage of piping
- Minimize risk of cavitations in the pump

Benefits

- Soft starting – no big starting currents causing disturbance on the network
- Reliability/technical improvement

Figure 2: ABB drives on board Tallink Silja Europa for both the supply and exhaust air fans

CASE STUDY 2 : ONE OF BALTIC'S BIGGEST CRUISERS

ABB industrial drives for one of Baltic's biggest cruiser: Improved ventilation and lower energy consumption.

Tallink Silja Europa, one of the biggest cruisers in the Baltic Sea, sails between Finland and Sweden. The air quality in the ship's night club improved and temperature fluctuations were reduced with the installation of new drives to control the club's supply and exhaust air fans.

"Two ABB industrial drives were installed on board Tallink Silja Europa to control the fans in the night club's ventilation system. The drives were selected on the basis of air flow measurements performed for Silja by an external consultant. This work showed that the fans required regulating, and this proved to be the correct solution because the air flows are now just as they should be," says Janne Björk of Electric Controls, an ABB channel partner in the drives business.

Separate drives were installed for both the supply and exhaust air fans in the night club's air conditioning unit. This means that the fans can be independently adjusted for a more consistent air flow. In addition, the drives can be steplessly adjusted, making it easier to get the right air volumes.

CONSISTENT AIR FLOW AND ENERGY SAVINGS Both fans previously ran at full speed, which meant that the air flows were not consistent and more energy was used. Energy is expensive on board as it has to be produced using the ship's generators, which are diesel fuelled. Now a consistent flow of air is achieved while saving energy.

"We don't get any more complaints about the temperature. Another way in which we are saving energy is that the temperature settings also take the club's opening times into account. The drives control the fans to blow less warm air when the club is closed and more when it's

Figure 3: ABB Low Harmonic Drive

open," says Jonas Rautelius, the ship's electrician.

VIBRATION POSES EXTRA CHALLENGES "Drives for use on board ships have to meet higher than normal demands for reliability because they have to withstand vibration. The drives installed in the night club have worked well in all respects, so we've no longer had to waste time going to adjust the air conditioning plant," he adds.

"When we choose new equipment for the ship, we have to pay special attention to the availability of service and spare parts, because we only spend one hour at a time in port. If we need something, we have to be able to get it during that hour. ABB has an excellent record in meeting these requirements. They have provided good service, and whenever we have needed ABB personnel to visit the ship they have come," Jonas Rautelius states.

SOLVED PROBLEM

- The AC drives vary the motor speed to match airflow demand, and the area receives a consistent quality of air.

Benefits

- The compact size of the ABB industrial drive.
- Type approved AC drive for reliable operation in marine conditions.
- Accurate control to keep the desired air quality.
- Reduced consumption of fuel through improved ventilation system efficiency.

MARINE TYPE APPROVED DRIVE The ACS800-01/04 product is type tested and approved for marine drive applications. The type approval test is required for essential applications onboard. Essential applications are those related to navigation, propulsion, safety of the ship and passenger, cargo and crew. Examples of essential applications are ballast pumps, bilge pumps, circulating and cooling water pumps.

The ACS800-01 product is type tested and approved by:

- DNV (Det Norske Veritas)
- LR (Lloyd's Register of Shipping)
- ABS (American Bureau of Shipping)
- RINA (Registro Italiano Navale)
- BV (Bureau Veritas)
- GL (Germanischer Lloyd)

Embedding the power management functions into the electric power plant

Traditionally the power management system has been supplied as a stand-alone system or as part of the IAS. New developments in industrial control technology allow us better to integrate the functionality of the PMS into the electric power plant. In this article we examine the benefits of this integrated system concept.

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INTRODUCTION ABB has for many years supplied engineered, fully integrated electrical and propulsion packages to marine vessels of various kinds. Until recently, the PMS has remained largely independent of the electrical power and propulsion package, requiring more extensive integration work onboard the vessel by the shipbuilder and shipowner.

As control hardware has become more powerful, and networked communication has spread to new areas, new opportunities have arisen for high-level integration of the subsystems which make up the electric power and propulsion package. ABB's extensive product portfolio allows us to perform this integration during the standardization and engineering phases, which contributes to the high reliability of our deliveries.

This article looks at the latest system to be integrated into the complete package: the Power Management System, or PMS. We show that high-level integration of the PMS has real advantages for both shipbuilders and shipowners.

A COMPLETE POWER AND PROPULSION SYSTEM ABB delivers complete power and propulsion system solutions, typically consisting of generators, medium voltage switchboards, distribution transformers, PMS, thruster drives and thruster drive transformers. It may also include process systems like drives for drilling and electrification for oil and gas production processes.

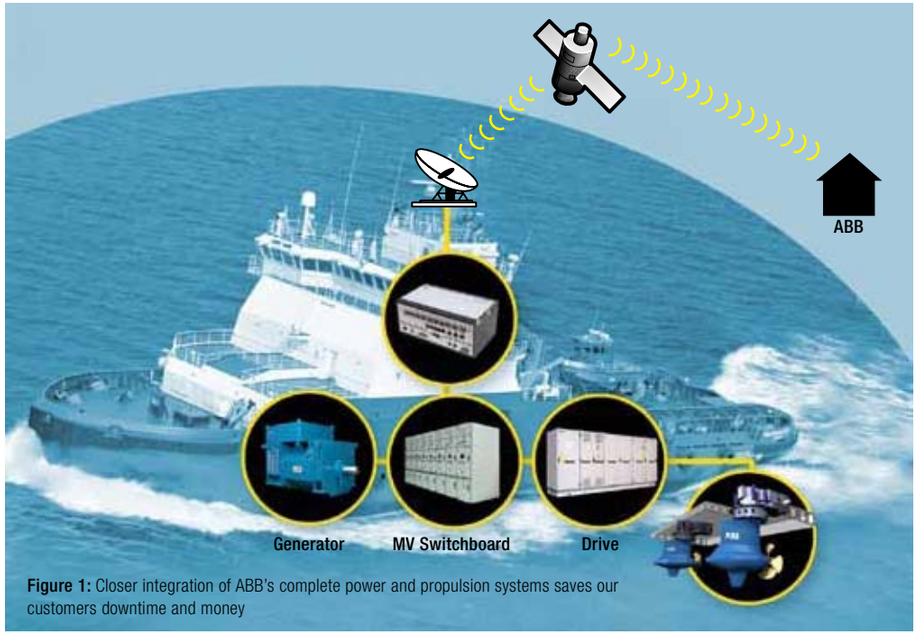

Figure 1: Closer integration of ABB's complete power and propulsion systems saves our customers downtime and money

Figure 2: Relion series protection relay

The main functionality of the PMS

- Generator start and stop dependent on the power demand
- Standby start in response to engine fault or shutdown
- Power system alarm handling and status indication
- Operational modes which can be used to increase spinning reserve
- Blackout and partial blackout handling
- Generator synchronization
- Load sharing control
- Frequency control
- Load control of propulsion drives and drilling
- Load shedding

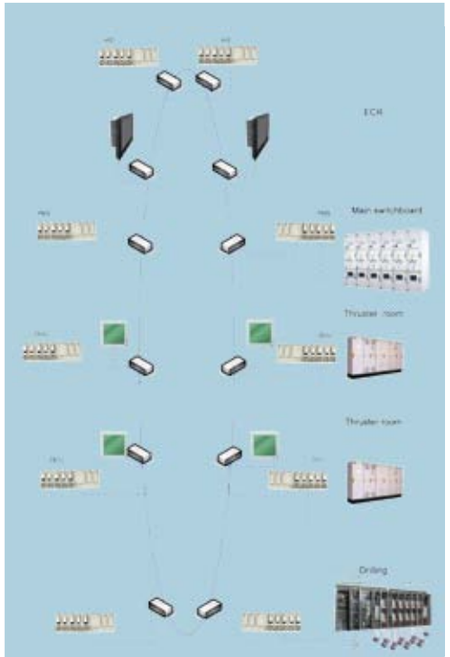

Figure 3: An integrated data network for power, thruster and drilling systems

In order to enhance the reliability and availability of the systems, as well enable operation of the systems at higher levels of energy efficiency, advanced functionalities are developed, such as Fast Recovery after Blackout (FRAB) and Diesel Generator Monitoring System (DGMS). For further description of these systems, see "Blackout prevention and recovery" by Jan Fredrik Hansen and Alf Kåre Ådnanes in Generations number 2/2009.

The PMS provides functions for automatic and manual control and supervision of the power plant. Through the PMS operator stations the operator is able to control how many generators are connected, which depends on the operational mode and load conditions, and which bus-tie breakers connect which switchboards together. The operator bases his decisions on information received from the system. The system also allows the operator to set individual generators to manual control, which may be done for engine or generator maintenance.

The functionality of the PMS must be well integrated with the instrumentation, protection, and functions of the main electric switchboard. Use of new protection relays with better programmable logics and interfacing capabilities gives the system designers a new set of tools to achieve improved integration and performance.

The new generation of protection relays from ABB, the Relion® series, enables us to be more versatile in the design and configuration of the whole power generation and protection system. With the Relion® series we are able to incorporate the protection relays into the main control network. In turn, power plant data flows through the network to the operator in the ECR with a considerable reduction of cabling and mounting space.

A typical ABB propulsion system consists of thruster drives and associated hardware, controlled by a drive control unit (DCU). Our standardized DCU uses the same

AC800M series hardware platform and programming environments that are used for the PMS, IAS and DGMS, Azipod control systems, and drilling drive control. This ensures compatibility between the various systems, making data transfer simple, reliable and rapid. It also gives the customer unique possibilities for combining spare parts for several systems as well as for streamlined, integrated monitoring and diagnostic systems.

For communication between the DCU and the thruster drive, ABB uses DriveBus, a proprietary fieldbus standard specially designed for communication with ABB drives. DriveBus has a much larger bandwidth than other available protocols. This gives us access to all the important information in the drive and allows us to present it at the various operator stations around the vessel.

FUNCTIONAL AND PHYSICAL INTEGRATION As the individual components of the complete power and propulsion package become more powerful and flexible, new possibilities for greater integration arise. ABB's integrated system concept involves utilizing the equipment already installed in the main switchboard and frequency converters in new ways. The components of the system are physically integrated, and the functions of the overall system are optimized to achieve functional integration.

The latest system to be included in this integrated concept is the PMS. It is now possible to physically build a complete PMS into the main switchboard. Some of the PMS functionality can even be distributed to other systems, effectively embedding the functions of the PMS into the electric power plant. This gives compelling advantages in terms of simplicity, reliability, space and cabling. These benefits will be seen by both shipbuilders and shipowners.

The physical integration involves building the hardware for the PMS into the medium voltage switchboard cubicles. Located at each end of each UniGear switchboard section there is a spacious interface cubical, where the ABB AC800M PLC and S800 IO for the PMS are mounted.

However, integration of systems is not only related to the physical embedding and wired signal connections, though those are important features with obvious benefits for installation, testing, and maintenance which are discussed below. Functional integration is an equally important part of the system design, as several subsystems in the installation must be coordinated to achieve optimal functionality and performance. Examples of such functions are black-out prevention, black-out restart and recovery, power limitation, and start-up sequences.

Figure 4: Up to 75% of a stand-alone PMS cabinet is occupied by power and external interface components which can be eliminated with careful integration

Consider black-out prevention for example. This involves not only the PMS functions alone, but also relies on functions in propulsion and thruster drives, drilling drive systems, and measurements from the switchboard. As explained by Frank Wendt in the article "Black-out prevention by taking advantage of the DTC and fast acting load reduction" in this edition of Generations, the coordination between the PMS, switchboard monitoring system, and the drive controller must be highly optimized in order to react fast enough with load reduction after worst case failures of the diesel engines.

Physical embedding is not a necessary precondition for obtaining good functional integration, but it does simplify the design and implementation when data are more easily available in a network of controllers that are based on the same hardware and software platforms, with efficient and reliable means of communication.

BENEFITS FOR THE SHIPBUILDER With the PMS embedded in the main switchboard, significant reductions of external cabling can be achieved. Most of the signals required by the PMS are already available within the switchboard, and can be connected by internal wiring. The signals can also be completely tested in the factory. This, combined with the reduced installation work required onboard the vessel, contributes to significant time savings during the costly installation and testing phases onboard the vessel.

Another benefit for the ship designer is the space saving gained by the elimination of separate PMS cabinets. The embedded concept involves installing the PMS into pre-existing IO cabinets in the switchboards, so the increase in size of the switchboards is minimal. Due to the reduced need for signal isolators and separate power supply modules, the total size and number of the installed components can also be reduced. This reduces the total volume of the PMS installation compared to a stand-alone solution, and improves reliability due to the reduced number of components and wiring.

ABB's long experience of marine power solutions allows us to take a larger overall design responsibility for the total power system, which saves the shipbuilder the job and associated risk of detailed system engineering and coordination between the different vendors.

BENEFITS FOR THE SHIP OWNER After the delivery of the vessel from the shipyard, the shipowner will also see the benefits of the embedded PMS solution. Shipowners operate in industries where time is money, and where downtime may have a high economic impact as well as representing a significant safety risk. Our customers' biggest focus, and therefore ABB's biggest focus, is reliability. Here the greatest advantages of the embedded PMS solution become apparent.

The simple act of moving the PMS hardware into the switchboards improves the reliability of the PMS in several important ways. The change in configuration means that many of the most critical signals on the vessel can be moved from external cabling to internal wiring within the switchboards. This increases the protection of these critical signals by reducing their exposure to physical damage on long external cable runs.

Another important factor for reliability is the number of components. Each additional component reduces the mean time between failures of the total system. The embedded PMS solution allows a significant reduction in the number of components without reduction in functionality or system fault tolerance. Due to the reduction in external wiring, the need for signal isolators, repeaters and amplifiers is similarly reduced. These components serve no real purpose except to protect the external interface cabling, so nothing is lost by eliminating them.

A safe, reliable control power supply is already available within the switchboard, and the embedded PMS can easily use the same supply. Again, the elimination of separate power supply modules increases the mean time between failures of the total system without compromising its robustness.

Other benefits for the shipowner are achieved through improved functionality. In particular, distributed PMS functionality greatly improves the reliability of the system, while remote access allows previously undreamed-of opportunities for rapid expert diagnostics and service in the event of a problem.

Figure 5 shows the results of our distributed power management design, taken during sea trials of a dual fuel diesel-electric LNGC owned by Mærsk. The power plant comprises three generators of 11000 kW (DG1 to DG3) and one smaller 5500 kW generator (DG4). The test was performed with the propulsion initially running at full power, and consisted of tripping the large generators one by one, resulting in a progressively larger instantaneous overload on the small machine.

As the figure shows, the results of the test were excellent. On each trip the propulsion power was instantaneously reduced, then slowly allowed to increase towards the setpoint, which remained at full power. The power on the running generators increased slowly, never exceeding the specification of the engine maker. This resulted in a minimal frequency deviation from nominal. And the most important result shown in this test: No blackout, and no propulsion trip.

As equipment integration progresses, and more advanced functionality becomes commonplace, the benefits discussed above will become greater and greater. An example of the continued development in functionality is the diesel generator monitoring system, or DGMS, which was presented in Generations 2/2009. This system is designed to monitor for, and protect against, diesel engine and generator faults which are not easily handled by

Figure 5: Generator trip test

current protection schemes, including engine governor faults and excitation faults. The need for such systems is becoming ever more apparent on many vessel types, especially on oil- and gas-related vessels where a single blackout may have significant financial impact.

When careful functional integration is performed between the switchboard protection systems and the DGMS, significantly higher levels of fault tolerance and integrity can be achieved.

If both the DGMS and PMS are installed within a switchboard section with three generators, all cabling between the five units can be condensed to internal wiring, and many tens of signal isolators, transducers and redundant power supply modules are eliminated.

INTEGRATED DESIGN, TESTING AND SERVICE ABB's extensive marine power experience and high production volumes allow us to design standardized, integrated solutions for every vessel type and operational requirement. Our customers can be confident that the solutions they receive are designed according to industry best practice and our experience of what actually works onboard hundreds of vessels worldwide.

To ensure the quality of our deliveries, we perform a wide range of tests in the factory prior to delivery. High-level system integration magnifies this advantage, since we are able not only to test individual components or systems, but the complete integrated power package. We are thus able to reduce 'teething trouble', which may be caused by incomplete integration and testing, to an absolute minimum. As it is difficult to obtain all operating conditions during commissioning and sea trials, testing in the factory can achieve results which cannot be replicated at a later stage.

We have also developed compatibility and interfaces with Hardware in the Loop simulators, and established the capability to offer and perform such extended testing.

When a vessel has entered operation, our integrated control network presents opportunities for remote diagnostics and service on the entire scope of power plant, from individual protection relays to PMS, DGMS and thruster control systems. All access takes place using a secure internet access point. |||

Black-out prevention by taking advantage of the DTC and fast acting load reduction

Diesel-electric power systems require a blackout prevention function to act as a fast load reduction of heavy consumers, in order to prevent generators from overloading. The Direct Torque Control (DTC) used in the ABB VSD is proven as being highly beneficial due to its practically instantaneous response in reacting to any load reduction command from overriding systems.

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DIESEL-ELECTRIC POWER SYSTEMS are widely used in marine applications, where load demand varies, due to their better performance and fuel economy in controlling the number of engines running and matching that to the load demand at high engine loading levels. However, these systems may be more vulnerable to cascade type failures, where a single component failure can lead to a complete system failure, espcially when operating with a closed radial or ring network. Such failures must be carefully considered at the design phase, and the systems must be supported by reliable protection functionality and tested thoroughly during the sea trials.

One such potential single failure is the sudden loss of one power generating set, which would cause high load steps in and possible overload in the remaining power generating set(s). The power output of a diesel engine cannot be changed instantaneously, due to delay via the turbocharger, fuel supply valves and automatic control, which causes the diesel machine speed to slow down and the related net frequency and net voltage to drop.

The rate of the drop is determined by the inertia of the diesel generator set's rotating parts and the overload the diesel engines are exposed to. Other rotating machinery directly connected to the network will also have some influence. According to marine rules for power systems, transient frequency variation after step load should not exceed ±10% of nominal net frequency fn.

Without corrective intervention, the diesel machine speed and related net frequency would under certain load conditions fall below the under-frequency trip limit, causing the disconnection of the initially healthy power generating sets and leading to blackout of the power system. In order to avoid blackout, the load on

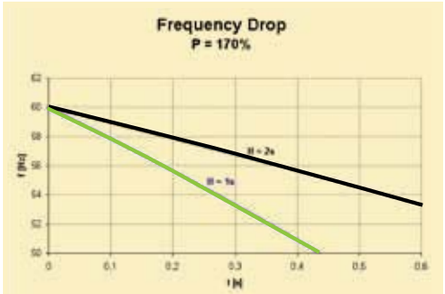

Figure 1: Frequency drop for gen-set with inertial time constant H=1s, H=2s and 170% load

the remaining diesel machines has to be reduced as quickly as possible, and certainly before the speed of the machines can reach the trip limit value. The load change must also be as precise as possible, to meet the present power capability of the machines, and to avoid oscillation and instability in the power system.

Considering a worst case over-load scenario on a diesel-generator set with 170% of rated power, the frequency drops from fn to -10% fn depending on the inertial time constant. For diesel-generator sets used in marine applications the inertial time constant typically lies between 1s and 2s. As Figure 1 shows, for H = 1s the frequency drops within 270ms and for H = 2s within 530ms below the -10% fn (54Hz).

The required response time for the load reduction function will be further reduced in power systems where the net-frequency has a constant negative deviation from the nominal frequency, e.g. it is operating in droop-mode, or the load reduction function is triggered by a low net-frequency limit. Based on the frequency drop curve for H = 1s in Figure 1, e.g with a low fre-

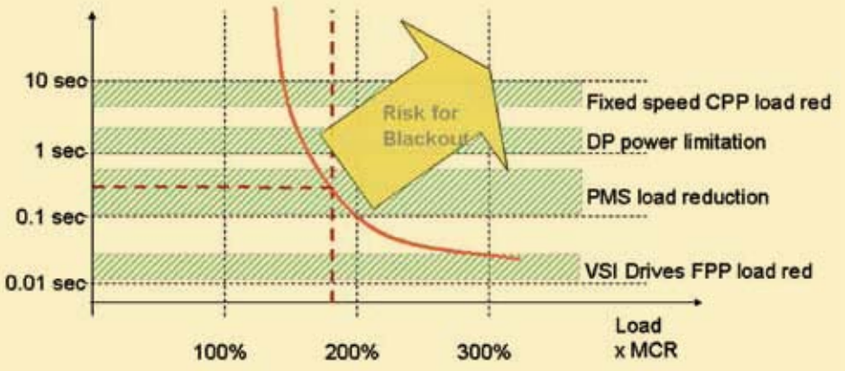

Figure 2: Regulation time responses for power reduction with H = 2s and P = 170%

quency load-reduction set point of 57Hz (-5% fn), the frequency drops within 130ms below 54Hz.

This fast response time requirement sets a high demand on the control systems, either the PMS or application controllers, in respect of fast detection of generator over-load and calculation and transmission of the load limitation command, as well as on the actuator systems in respect of fast and accurate load reduction based on the received limitation command. Any reduction in reaction time, either on the control or actuator side, will improve the stability of the power system.

Thruster, propulsion and drilling systems represent the main consumer of energy in power systems and, nowadays, are controlled by frequency converters. A frequency converter works as an actuator controller for the driven load and offers the properties of fast and accurate load control as required for effective load reduction in connection with blackout prevention. For VSI type low and medium voltage frequency converters, which are the natural choice for those kind of applications in this power range, ABB uses Direct Torque Control (DTC®) as its common control platform. DTC is known as the world's most advanced torque control method for frequency controlled drive systems. The most significant feature of DTC technology is its exceptional dynamic performance in terms of response time, accuracy and repeatability. For DTC, the typical torque response is 1-2ms, compared to more than 10-20ms for a flux vector PMW and 100ms for open loop PMW control methods. Torque

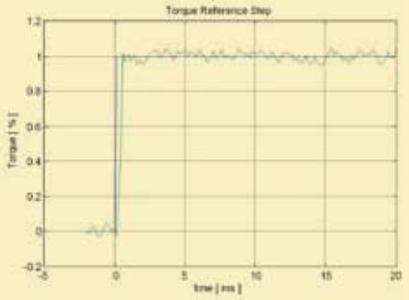

Figure 3: Typical torque step response for DTC controlled frequency converter

accuracy and repeatability is 2% of the nominal motor torque. The response times depend on the motor parameters and the load operating point.

DTC archives this performance by direct control of the real motor variables, motor-flux and torque. At each sampling time of the controller, the switching pattern of the inverter's output switches is determined separately, based on the actual values of motor flux and torque. Thus, there is no need for a modulator with a predetermined switching pattern to control voltage and frequency, as used in the ordinary PMW control method, or any need for an inner current control loop, which would slow down the response time of the torque control. Cutting out these intermediate regulation loops speeds up the response of the drive dramatically.

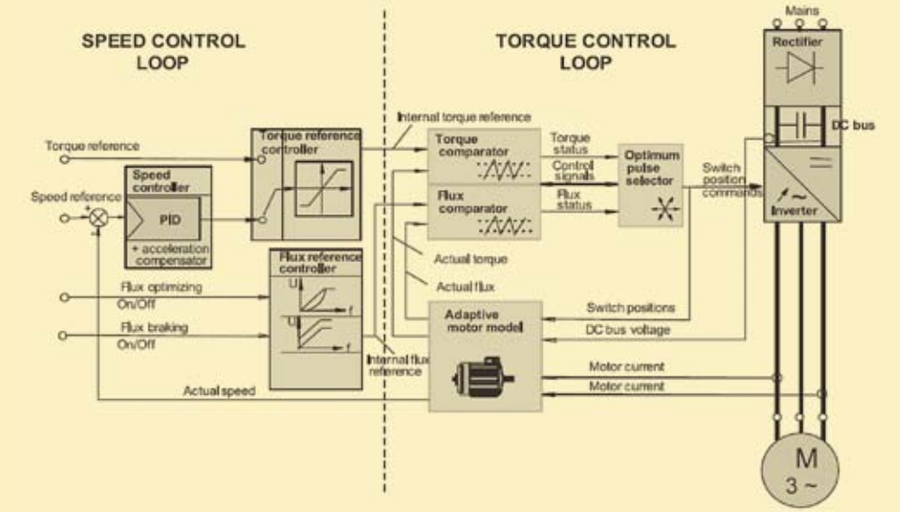

Figure 4: DTC block diagram

In DTC control, the measured motor currents and DC link voltages are inputs to an adaptive motor model that calculates exact values of torque and flux every 25 µs. Motor torque and flux comparators compare the actual values to the reference values, which are produced by the torque and flux reference controllers. Depending on the outputs from the hysteresis controllers, the optimum switching logic directly determines the optimum inverter switch positions every 50 µs.

The motor's mechanical output power can be calculated from rotor torque and speed (precisely angular speed) Pout[W] = T[Nm]*x[rad/s]. As indicated by this expression, decreasing one of the factors (either torque or speed) results in decreased power. With DTC-controlled VSD, the motor torque response time can be controlled very quickly and, consequently, so can power.. Where the maximum load increase of the motor depends on the possible speed acceleration, which is determined by the available acceleration torque and the inertia of the rotating mass, unloading the motoronly depends on how fast the torque can be reduced –with DTC 1-2ms from 100% to zero torque, or any other value below the initial value with a precision of 2% nominal motor torque.

By controlling the motor's mechanical output power,

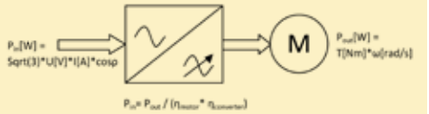

Figure 5: Power flow

the consumed power from the power network is also controlled and, consequently, so is the supplied power from the diesel-generator sets. Any change in the motor's mechanical output power will directly affect the power supplied from the diesel-generator sets, without considerable delay.

Considering the frequency converter controlled drive systems as the main consumers in a power network, this practically instantaneous torque response from DTC controlled frequency converters contributes considerably to the improvement in response time of the load reduction function and the stability of the power system in case of a sudden loss in a diesel-generator set.

Advanced Diagnostics: remote and accessible electric propulsion power plants

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IMAGINE YOU ARE FAR OUT AT SEA, in the middle of a critical operation and, in conformity with The Infamous Law, you start experiencing problems with some critical equipment. You send somebody to investigate. However, the problems do not have any obvious explanations or solutions.

Your first instinct is to send your best engineer down to sort things out. If this fails you call the equipment vendor/system integrator for assistance and try to explain the case at hand to them. Now, if the problem cannot be reolved over the phone, you may be blessed with a redundant system; you isolate the problematic equipment and wait for a service engineer to arrive and hope that your remaining equipment remains healthy. If you are less fortunate you may have to interrupt your critical operation and wait for a service engineer to arrive.

Firstly, while you have a high regard for your crew onboard, detailed knowledge of the inner workings of complex equipment and systems is a lot to ask on modern vessels. Training will reduce the gap, but some issues simply need a more in-depth expert.

Secondly, providing a remote assistant with quality information is challenging - the right data needs to be reported, as do the conditions before and during the fault, and so on; data can be difficult to put together consistently.

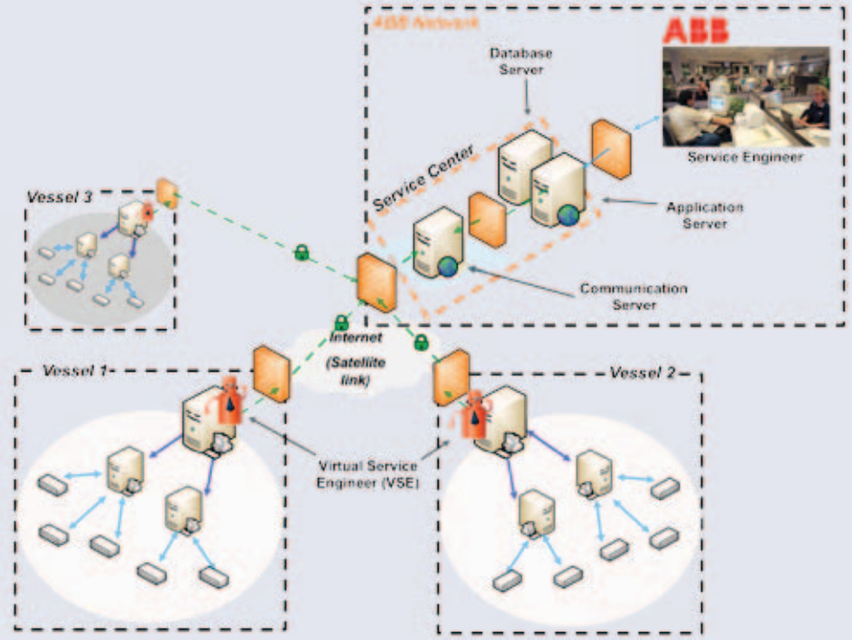


Figure 1: Diagram showing the remote connection architecture for multiple vessels

Thirdly, even with the fastest initial dispatch of a service engineer, it still may be days before he or she arrives on site.

The ultimate solution in this scenario - costs and flawless systems aside - would of course be to have every conceivable expert and spare part onboard at all times. While this is as impracticable as it sounds appealing, ABB Marine has recently made an effort to find a service concept that strikes a more agreeable balance between cost and practicality on the one hand, and functionality and preparedness on the other.

CONCEPT Remote Diagnostic Services (RDS) is a tried and tested ABB service concept that is now being tailored to the Marine segment. With RDS, ABB has standardized on a remote diagnostics and maintenance solution that is secure and simple to implement. It aims to provide the highest level of IT security and make expert knowledge available in the shortest possible time.

The concept comprises the following:

- A Service Agreement
- A Remote Connection
- A growing number of diagnostic solutions for equipment and systems in ABB's scope

SERVICE AGREEMENT AND CONCEPT Large, multinational companies have many advantages over smaller companies. Hhowever, they also face greater challenges in presenting a simple and unified outward-facing image, as the larger scope of supply necessarily also comprises a larger span in technologies and competencies. For ABB, it is therefore very important to define a clear and confidence-inspiring interface with the service receiver. The resulting single-point of contact is a 3-level service concept intended to serve this purpose. The concept, as seen by the customer, is simple and intuitive yet does not restrict the way the organization works behind the scenes.

The 3 service levels are:

- Troubleshooting: on demand connection by ABB Service Engineer
- Preventive: in addition to the above, an ABB Service Engineer periodically connects to the remote system and performs a detailed health-check and documents this, along with advice on on corrective measures in a report.
- Continuous: in addition to the above, critical alarms and process statuses are relayed to ABB service centers and necessary counter-measures can be launched immediately.

REMOTE CONNECTION On our side, the brains of the remote connection operation is the Service Center. This is a central network of high-availability servers at the ABB Computer Center. These servers manage all the customers' systems which can be accessed via RDS and their authorized users. Corresponding rights and roles are defined for each user which includes the determination of the target systems that the user can access.

On the customer's side the brains of the operation is a Virtual Service Engineer (VSE). This is a piece of software that is installed on one of the ABB computers on the customer's side and acts as a type of software-site-manager. The VSE has many roles, the most important of which is to set up a secure, encrypted communication with the Service Center and signal its availability and readiness for a remote maintenance session. So, although the PC with the VSE may be connecting to the internet from anywhere in the world; the VSE will itself make contact with the Service Center making remote connection possible.

When required, an authorized ABB service engineer can log on to the service center and request permission to connect to a vessel's installed diagnostics system. If granted access by the customer, he can then connect and proceed with the maintenance or troubleshooting using the installed diagnostics systems.

THE DIAGNOSTIC SOLUTION Whilst the remote connection solution above will let you connect to a remote system, it will not tell you what has been going on in this system or, better yet, tell you what may be wrong with it. For this purpose another tool has been created; a dedicated monitoring and diagnostics platform called DriveMonitor (DM) whose sole raison d'etre is to collect and correlate data for condition monitoring and troubleshooting. Contrary to what the name seems to imply, DM is a platform that can interface with more than just drives. It was so named because the engineers at the MV-Drives factory in Switzerland were the first to tap into the plat-

form's potential. The DM platform is, in its simplest form, just an OPC client that can read information made available to it on OPC and store it in a database. This basic functionality can be complemented by a range of more sophisticated functions like event-based triggering of actions and complex analysis of systems or its components. A DM system is a modular system that starts with monitoring on a component level. Data between the various component DMs is shared. If a system comprises enough monitored components to make sense of the system, analysis of the system is also possible.

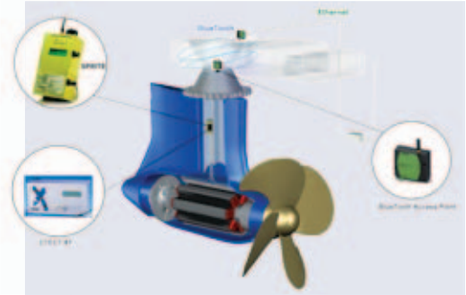


Figure 2: the Azipod with installed vibration monitoring equipment

DRIVES SOLUTION: As mentioned earlier, the ABB MV drives factory in Switzerland was an early adopter of the DM platform and has since developed an award-winning service tool and concept. The remaining ABB drives factories have since started work on similar solutions for their respective drives and most are now offering similar solutions.

To explain how the drives solution works, a hypothetical case can be of a trip caused by a fault in the water cooling unit (WCU) of the drive. When the fault occurs, the drive sends a fault message to the DM. The DM displays the fault message in an event list, together with an explanation of what the message means and possible causes and hints for rectification. The DM will then check whether any of the data loggers in the drive were triggered by the fault. If they were, they are uploaded, stored and displayed in the DM view before they are permanently deleted from the drive by the imminent reset command from a trigger-happy operator. The DM also proceeds with monitoring a number of other signals that it knows, based on a set of predefined rules that are relevant when trying to determine the root cause of the fault. The DM initiates the monitoring of these signals for a predefined period of time. As for the transient recorders above, a buffer that is continuously running makes measurements before the fault is captured. All this information is then stored in an SQL database. By simply performing event-based monitoring, the accumulation of data is slowed to a minimum and available storage space is only filled with high-value data. When the operator arrives at the DM computer to ponder what went wrong, much of the data collection work has already been done. All that needs to be done is to select the relevant fault in the alarm list and all the data related to this fault is then presented to the operator. Another feature of the drives' solutions is parameter monitoring; if somebody should choose to, knowingly or not, edit the drive parameters, these changes are recorded and presented as events in the event list.

If the operator for any reason would like to monitor any signal on demand, there are simple and intuitive functions for this also. All recorded data is stored in the database for later reference. A data export function will also let the operator export data in the database, in full or in part, to be viewed in a DriveMonitor-Light application that can be installed on any windows based PC.

Similar DM solutions for MV Relays have been developed, affording a very simple hardware interface, event driven monitoring of signals and uploading of transient recorders upon faults.

DM solutions for the PLC based control systems for thruster drives (Drive Control Unit - DCU), LNG Propulsion systems (Propulsion Control Unit - PCU) and Drilling Drives have also been developed. This is invaluable for the DM user in that it complements the data already collected from the drive and gives the user a broader systems perspective that is very useful when determining the cause of a given alarm or fault that has its origin in the system's behavior.

AZIPOD SOLUTION: Another example of a component solution is what has been implemented for the ABB Azipod; BeAM is short for Bearing Asset Monitor and is a bearing condition monitor that is integrated in the DM platform. It monitors one of the components with the most criti-

Figure 3: the DM industrial PC and optional touch-screen

Remote Connection Security

Remote Diagnostic Services use a secure SSL-encrypted communications tunnel between the customer system on site and the ABB expert's RDS Workplace. The design of RDS is quite distinct from other solutions in terms of functionality and security. Unlike point-to-point based solutions, RDS does not open a "back door" to the customer's IT environment but instead is integrated into the plant operator's existing IT security design. Compared with standard VPN, no external networks are connected to each other at the IP level (OSI level 3). Rather, the connection is established between applications.
The following is a list of frequently asked questions:

Q: Do we need to open a hole in our Internet firewall to support this solution?
A: No. All communications are initiated from within the customer's site infrastructure by the VSE software, utilizing normal Internet access.

Q: Are communications, data transfer and access secure?
A: Yes. All communications utilize the Secure Socket Layer (SSL) protocol through https Port 443 and the access control scheme uses several levels of authentication.

Q: Will these communications tie up my network?
A: No. The software messaging protocol is designed to deliver mostly small, efficient (0.5 – 3Kbytes) messages to minimize bandwidth utilization.

Q: Will the installation of the VSE affect the performance of assets being monitored?
A: No. The VSE runs on the computer that is interfaced to the device being monitored, minimizing any processor or memory burdens on the device itself.

Remote Diagnostics Service Levels

TroubleShooting
Diagnostics on demand will be performed based on a support event or upon a customer's request. A remote connection will be made on-the-spot, enabling information retrieval for immediate evaluation and resolution. Access to this information will assist the ABB technical specialist in providing a quicker and more educated response to maintenance personnel.

Preventive
ABB technical experts will periodically initiate a remote connection to retrieve and evaluate information. ABB will utilize the diagnostic solution as described above to enable asset health assessment.
After the assessment has been completed, a health report is prepared identifying conditions and providing recommended corrective and preventive actions, including hardware and software upgrades.

Contiunous
Based on the assets that are selected to be monitored, real-time samples can be weighed against pre-defined thresholds. When a threshold is breeched, a real-time alert is automatically sent to the Service Centre so that corrective or preventive actions can be taken immediately.

BeAM – Bearin Asset Monitor

Bearing Asset Monitor is an integrated part of the DriveMonitor system and performs the following diagnostics:

- BEACON analysis
- High-frequency root mean square (RMS) value
- Peak–to-Peak value
- Crest Factor
- Modified Crest factor
- Kurtosis
- Spectrum calculation
- Envelope analysis
- Early Shock Pulse Detector analysis
- Maximum Energy of One Shock Pulse
- Energy of Shock Pulses per One Rotation

cal impacts on the entire Azipod system performance; a set of bearings mounted on a short motor shaft that drives the propeller. These bearings are exposed to extreme, dynamic loads coming straight from the propeller. For early detection of such rolling element bearing defects, a set of novel diagnostic algorithms were developed. The system concept is simple enough, yet incorporates some advanced techniques. Vibrations in the bearing housing are collected with an industrialised, rugged PC data acquisition unit mounted inside the Azipod, where they are transferred wirelessly to an access-point and on to the DM. Well-known high frequency enveloping techniques, as well as newly developed algorithms designed for early shock pulse detection, are used to process the vibration data.

The entire cycle of data flow, from measurements to calculations, is automatically triggered at regular intervals and an accurate assessment of the bearings' health can be made. Trends of selected parameters can also help expose deteriorating bearings at an early stage. Tests are also underway with a bearing oil monitor that can compliment the above by establishing cumulative particle concentration and ferrous and non-ferrous metal particle quantities in the lubrication oil. In time this could be used to estimate remaining bearing lifetime.

In the pipeline is a Machine Solution offering advanced condition monitoring of electrical machines. The solution bases its analyses on, among other things, high-resolution current, voltage and vibration measurements and is able to determine and the machine's condition accurately, and develop trends over time. Until now, this sort of analysis required a visit on site by a service engineer, followed by lengthy analysis in the office.

Another candidate for a DM Solution is the popular Automatic Voltage Regulator (AVR) Unitrol1000 of which there are hundreds in operation, and more waiting to be installed and commissioned.

SYSTEM SOLUTIONS While the DM solutions that have, and are being developed for individual system components are very useful in their own right, the true benefit of this modular system only becomes apparent when the various sub-systems are woven together in a multi-discipline diagnostic system. By standardizing on one platform, the stand-alone component diagnostics systems can be woven seamlessly into one time-synchronized system with little or no need to alter the component systems. Firstly, joining the systems together drastically simplifies troubleshooting at a system level. Secondly, with so much high-quality, harmonized current and historical data available,a plethora of possibilities is opened up within system condition monitoring.

The Propulsion Condition Monitoring System (PCMS), developed by ABB Marine in Finland in cooperation with our corporate research center in Poland is one example of such a multi-discipline diagnostic system. PCMS has been installed on a number of Azipod-equipped cruise vessels and incorporates DM solutions for the following:

- power plant - medium voltage protection relays
- excitation, supply and propulsion transformers
- propulsion control units, Azipod interface units
- frequency converters – fully redundant drives
- main shaft bearings

Data from all these sources is used to calculate system parameters, such as:

Power quality :
- voltage asymmetry
- voltage distortion
- power factor distribution in MV system

Energy related parameters:
- Efficiency index
- Total power consumption
- Fuel cost estimation vs. data from ship power management system
- Total power distribution between generators working in parallel
- Power flow in propulsion system (Generator-drive-motor)

Power system statistics
- MCB opening/shorting counts

Trend development and analysis of these parameters provide valuable feedback to the operator on how he or she is operating the vessel.

DM HARDWARE At the heart of the DM concept is a purpose-built industrial PC with a Windows XP operating system where the DM software is installed. Operation of the DM PC is either done using an optional touch screen, conventional screen and keyboard or by using standard remote desktop software.

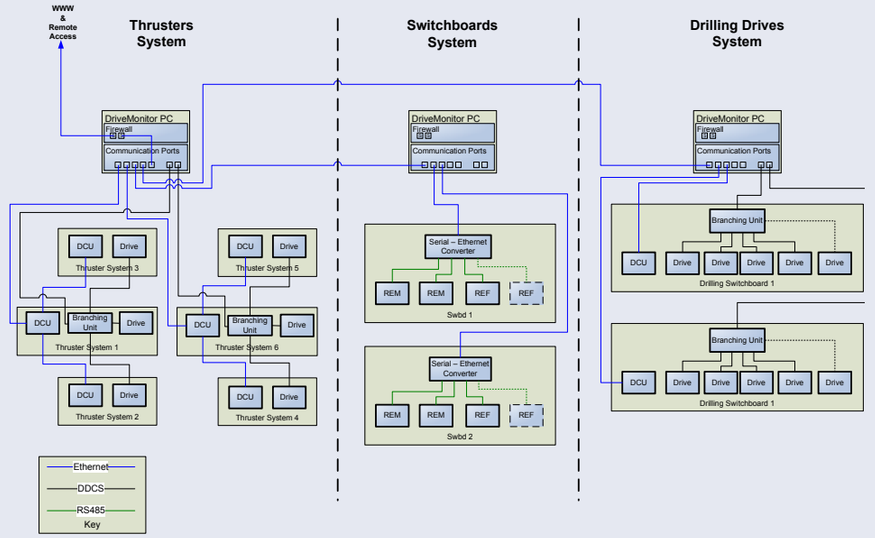
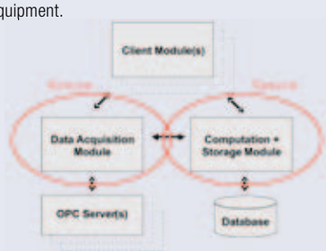


Figure 4: Showing a possible hardware architecture of a diagnostic system for an example drillship

IN CLOSING... Most technical problems have, in reality, very clear root causes. However, due to lack of consistency in data or poor quality of available information, the root cause can be elusive and seem overly complex. This is where the DM aims to make a difference; it seeks to shine a light on the problem by furnishing the user, be it a local operator or a remotely connected service engineer, with accurate and relevant information right at the start of the fault-finding process. |||

BeAM – Bearing Asset Monitor

The DM software is built up of 4 main functional components or modules, as shown in the diagram below. The two services are responsible for collecting data from OPC sources and computation and storage of the collected data. The database archives the data and the client modules present the data, raw and processed to the user. In the standard DM PC all these functional modules are running on the same PC. However, the DM software is flexible and the various modules can be distributed on multiple PCs. This allows the system designer, for example, to:
- place the database on one central server for security and larger storage capacity,
- configure client modules, in the form of user-interfaces in multiple strategic locations
- place the service modules on PCs close to the monitored equipment.



Improvements in thrust bearings

This article gives basic information of the new TBU roller thrust bearing unit, as well as a description of how the development occurred and how bearing testing is performed.

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BACKGROUND AND DESIGN METHODOLOGY The thrust bearing unit is one of the most crucial components of an Azipod propulsor – it carries the propeller thrust. It has no redundancy, and to perform an overhaul the ship needs to be dry docked. The design criteria for the new roller thrust bearing unit TBU ("Thrust Bearing Upgrade") is targeted to improve reliability over existing units.

The project started by data collection - Azipod operation and bearing damage data was collected and analyzed in search of damage patterns and correlations with parameters such as calculated lifetime, type of application, and operator. It was found that, in cases where the bearing had not reached the expected lifetime, there is no correlation between the calculated lifetime and actual lifetime. Thus, it was concluded that simply increasing the bearing size might not solve the problem at all. Also, it was found that many smaller bearings appeared to be working better than large ones, even though manufacturer guidelines on suggested that the opposite should prevail.

Early in the project, a two-day workshop took place, where design processes and different factors affecting bearing lifetime were benchmarked. The factors were considered as risks affecting the bearing lifetime incorporated into an FMEA sheet and given a Risk Priority Number (RPN). To evaluate the effects of each risk factor, they were benchmarked against the results of data analysis; and if the data analysis supported the existence of a given risk, the risk was selected as a point of improvement in new design.

The FMEA was further developed with results of functionality analysis of existing thrust bearing designs. Thus, in this project an FMEA was utilized to guide the design concept, instead of being utilized to evaluate a concept already given.

It should be noted, that the selected improvement points are in the field of application engineering; that is, selection and arrangement of bearing elements and surrounding design for the most favorable bearing operation. It has been recognized that during the lifecycle of a bearing, it is influenced by the actions of the bearing manufacturer, ABB, the shipyard and the operator, as well as all of the transport and installation procedures in between. Shipyard and operator originated risks are covered in design by, for instance, providing sufficient service hatches to ease cleaning and inspection; manufacturer-originated risks are incorporated as part of the test program. This will be discussed later.

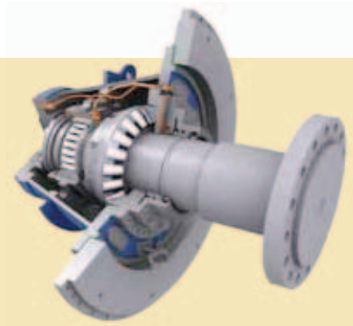

Figure 1: Section view of TBU thrust bearing unit

DESIGN DESCRIPTION The new TBU roller bearing concept is a three-bearing arrangement with one bearing for each main load direction – radial force and aft and fore axial thrust. Some points of change to note are:

- Radial bearing is CARB-type. This is to make sure that the axial movement within bearing unit clearance limits does not create axial forces beyond the capacity of the radial bearing.
- The unit has dry sump lubrication with direct oil injection to raceways. The purpose of this change is to make sure that there is no re-circulation of particle contaminated oil within the bearing housing. Oil bath lubrication is possible as an alternative; in this operating mode, a screen inside the housing and housing design prevent re-circulation of particles.
- Increase of load ratings due to the possibility of dynamic forces due to pod movement.
- Design of housing to make sure that there are no pockets or cavities, where possible wear particles could accumulate.

A lot of attention has been paid to oil cleanliness during operation: for instance, the seal system is designed so that seal cooling and lubricating oil does not flow through the bearing; instead, a separate return pipe has been provided.

Inspection and flushing possibilities have been improved by the addition of service hatches around the entire bearing circumference and boroscope/flushing pipe access, even extended to the aft side thrust bearing.

Bearing units are insulated against bearing currents by a separate epoxy-wound insulator flange; this is now a self-contained part with a steel support ring. This solution is logistically favorable over a solution where the insulation would be wound and machined directly to the bearing housing. Also, replacement is now easier, should it be needed.

TEST METHODOLOGY Very little test data are readily available for this size of bearings. Test equipment and test bearings of this size are very expensive and bearing manufacturers have not been able to justify systematic testing within existing production volumes. At the same time, bearing reliability is at the core of the entire Azipod concept reliability. For these reasons, an extensive test program was developed. Testing of the new TBU thrust bearing unit has two purposes:

- To verify that the unit functions as expected (design change-related risks)
- To cover the risks not covered by risk analysis at the concept phase.

The first group covers features such as change of the lubrication principle, structural load carrying capacity, sufficient cooling etc.

The second group is more challenging and deserves certain explanation. Some of the recognized risks can be categorized under the so-called "size" or "scale effect" phenomenon. This refers to validation of bearing suppliers' design assumptions and design formulae, which are based on extrapolated results of small-size bearing test series. A traditional approach is to test groups of bearings by varying the operating parameters; the output is the effect of each parameter on bearing lifetime.

Figure 2: Test rig

Figure 3: Control panel

Tools and methods of development

Six Sigma -quality improvement process and tools are utilized in defining the design changes, and then again in the testing phase. Some of these worth mentioning are:

- Process mapping, utilized for recognizing the data and material transfer within a bearing lifecycle
- Statistical analysis of Azipod operating history and bearing defect cases
- Failure Mode Effect Analysis (FMEA), utilized for recognizing potential improvement points in existing designs
- Design of Experiments (DOE), utilized for testing the bearings. The target is to formulate an empirical model of bearing behavior and perform hypothesis testing against bearing suppliers' design guidelines and formulas.

Figure 4: Test site installation crew gathered for a portrait prior to first start-up

The bearings may be driven to failure or they may be examined after a certain number of cycles, and judgment is based on bearing condition and wear. In this test, the judgment is based on direct measurements of influencing phenomena, such as roller force distribution, lubrication film condition and local heat transfer.

The tests are being carried out with the Finnish research institute VTT, which is responsible for instrumentation, data collection and signal analysis.

Designed experiments (DOE) are utilized for most of the testing. This means, that the bearing input parameter space (operating speeds, forces, oil viscosity etc.) is factorized, at first stage on two levels of each parameter. Based on experiment results, it will be possible to perform hypothesis testing by means of an empirical bearing model against expected behavior, based on manufacturers' guidelines. Experiments are replicated and randomized, in order to increase the reliability of results.

In order to fix a baseline for an existing product, TBU will be driven against an existing thrust bearing unit, and essentially the same measurements will be taken from both for comparison.

TEST RIG The test rig consists of two opposed thrust bearing units, which are connected by a shaft line. In the middle of the shaft line, a radial bearing is arranged for incorporation of the radial load. The shaft line is rotated by an ABB induction motor and frequency converter. Thrust force is applied to one end of the test rig by a horizontally located hydraulic cylinder at the top of the rig, and radial force is applied by a vertical cylinder which affects the middle shaft bearing. Both units see the same axial and radial load. Both loads can be independently adjusted and dynamically varied by means of a digital controller, and rapid changes can be applied to simulate different operating conditions.

In addition to test bearings and the actuating system, the test set-up consists of the same components that are used in actual applications – oil treatment units, particle counters, condition monitoring etc – and when combined with extensive test instrumentation, a lot of new information can be gathered about bearing internal operation can be expected, based on the various conditioning monitoring signals.

The test rig components were built and supplied by the existing Marine supplier network and the test site and assembly work was mostly performed at the ABB Service in Turku, by the same personnel who do maintenance work at dry-dockings.

The test rig will also be used for testing the "Hybrid" thrust bearing, discussed in "Generations" 2/2009. Final results for TBU testing are expected within Q3 / 2010.

Commissioning and testing of the test rig itself were an important part of this project – such a test rig has not been set up before and it was important to verify its vibration characteristics, elasticity under different load combinations, etc.

Safety and ease of operation was considered very important and an easy-to-use control panel was developed for the purpose, with indications and alarms for system monitoring.

RISKS AND RESULTS Designing and setting up the test rig was a major task itself and comparable to a combined R&D and delivery project of similarly sized machinery. During installation and commissioning, as understanding of the test rig behavior increased, several modifications were suggested and performed to ease operation and increase reliability.

In this project, the phenomena which are typically tested are approached by direct measurement. One of the most challenging features of a roller bearing is, that the contact area, which is of special interest in researching local contact pressure, lubrication film thickness and temperature, roller rotation etc., is effectively hidden between raceways and constantly rotating rollers, and direct measurements of the small area are not possible without making changes to bearing design and construction. One of the earliest basic decisions was to utilize bearings as they come off the factory line; that is, no modifications were made to bearings. In some cases, this means that the conclusions have to be based on more indirect measurements, but the advantage is that the bearings represent the actual application and there is no need for speculation, whether or not some modification due to instrumentation might have affected the results.

So far, the test rig and test bearings have been operated from medium to nominal operating loads, and the first indications of behavior and measurements are encouraging. For example, actual roller force distribution of a bearing is visible and the system is able to spot variation and differences between each rollers. |||

Figure 5: Testing is teamwork. Matti Tervonen from ABB Marine prepares to give the test rig a blow with impact hammer to measure its modal characteristics, while Aki Kinnunen from VTT is ready to record the results.

The team

All development and design work described herein is a result of teamwork within ABB Marine and supplier partners. Design work has been done together with and subjected to approval of major rolling bearing suppliers. VTT (Finnish Research Center) plays a key role in measurement and signal analysis of test phase. Development and test project has been guided by a Steering Committee, consisting of members of ABB management, specialists from different technology fields and customer representatives.
Some of the key roles in completing the project have been played by following persons and their teams:

- Project Manager, Juho Kock: project management, overall design and quality
- Lead engineer, Antti Aapro: concept development and design of new thrust bearing unit
- Lead engineer, Jarno Vänni: test rig development
- Team Leader, Antti Matilainen, and Teemu Jehkonen: system operation control and automation systems and commissioning
- Petri Mäkikyrö, Katja Saviaro and entire purchasing team: component and parts supply management
- Senior strength analyst, Matti Tervonen: research and analysis at various stages of project.

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