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generations

Energy efficiency

Power and productivity
for a better world ™

This issue of *Generations*, dedicated to energy efficiency, features an extensive collection of articles in which engineers share their research findings, the details of new solutions and the thinking behind them. Customer cases and articles introducing key concepts, market trends and insights link technology to business strategy.

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

Chapter A

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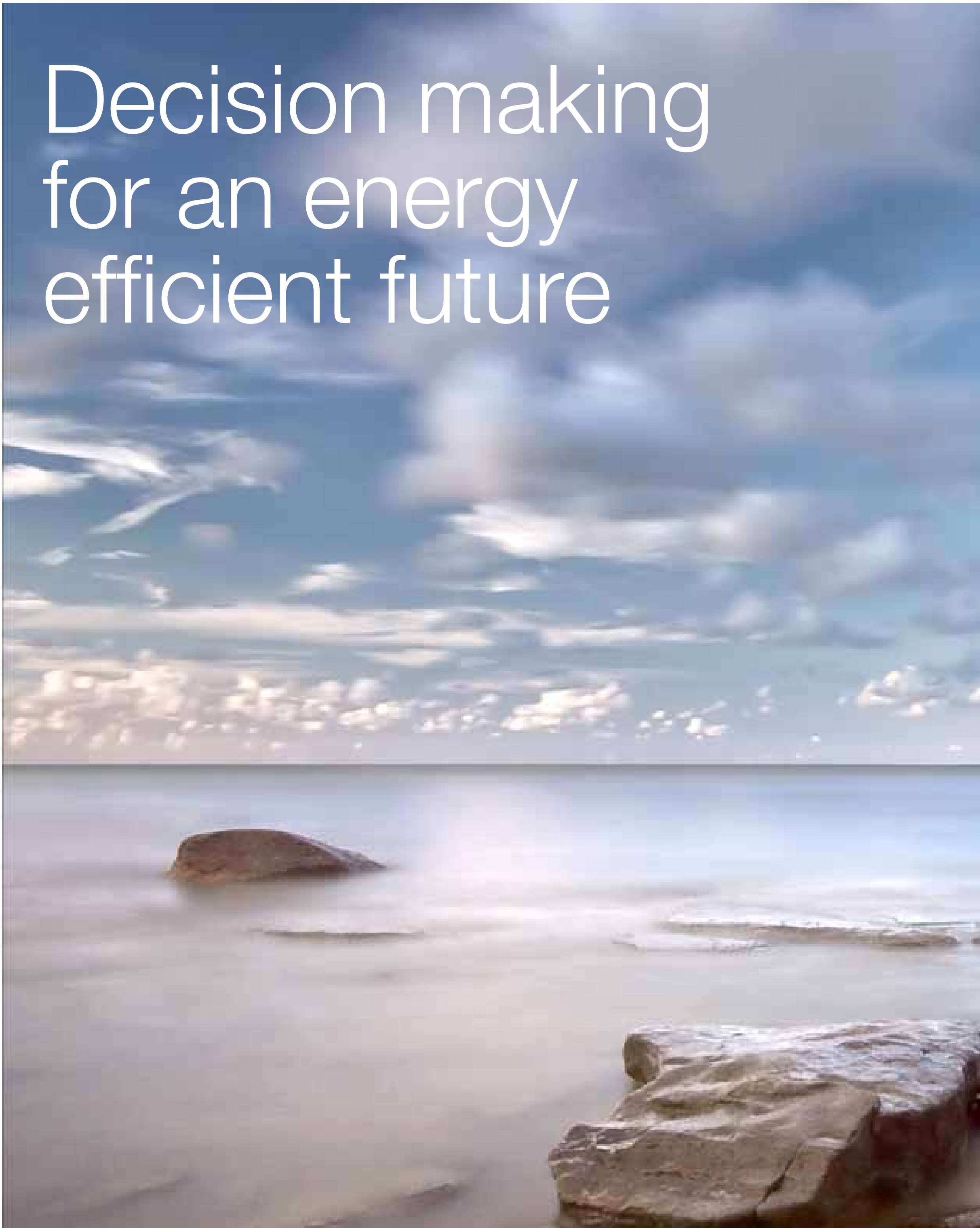
For Chapter B, see page 78

Decision making for an energy efficient future



"Slow steaming" will keep the fleet busy, so why struggle with innovative designs, unproven technology and new concepts for managing the fleet?

When looking at high bunker costs, soft freight rates and the hefty price tag attached to upcoming environmental regulations, a familiar feeling creeps into the decision-making process: the feeling of being "damned if you do, doomed if you do not." That is, until we remind ourselves of the fundamentals:

- Every day the world's population is growing by 57 million people
- The shipping industry is the cardiovascular system of international trade
- A good circulatory system is what the world needs now more than ever

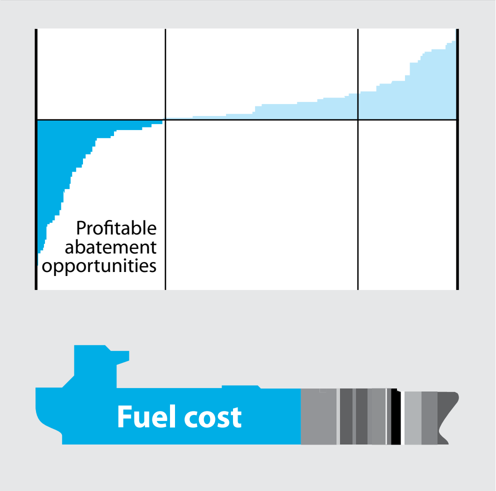
The number of highly uncertain variables can be nerve-racking, resulting in a lot of homework for those who have the guts to become the next generation of leaders in shipping.

It starts with recognizing the fact that there is indeed a new factor to take into account in addition to high and uncertain fuel prices: global warming. No excuse will suffice when our children and grandchildren ask: **What took you so long?**

Maybe they will point us to a 2009 presentation on the Web (see page 7) where Per-Anders Enkvist, associate partner of McKinsey & Company, tells us "For every year you wait, you do not only loose that year, but you lock yourself into a high-carbon world for the next 14 years to come." In other words, he explains, the expectation is that, across sectors, the average concentration of greenhouse gas emissions will peak at 5 ppm (parts per million) higher for every year we wait, not at 2 or 3 ppm, which is the current annual increase.

Because ships are built for a much longer lifetime than 14 years, Enkvist's example is easy to put into the context of the maritime sector. Every ship being built today will be operating during what we hope will be the peak year of greenhouse gas emissions.

CAPEX decisions and shipping OPEX simplified



Profitable greenhouse gas abatement opportunities relate directly to fuel cost

Energy efficiency turns out to be one of the most profitable opportunities for reducing global greenhouse gas emissions.

Enkvist and co-authors Tomas Nauclér and Jerker Rosander are well-known for providing businesses and policymakers with insight by introducing the cost curve for greenhouse gas reduction, also known as the marginal abatement cost curve or global cost curve for greenhouse gas abatement opportunities. This diagram has become a household slide in presentations on energy efficiency. That is because energy efficiency turns out to be one of the most profitable opportunities for reducing global greenhouse gas emissions.

Another question we might have to answer in the future is: **Why did you accept a gap between technology adaptation on land and at sea?**

Traditionally, maritime applications of new technology at sea have come years, if not decades, after successful implementation on land. One commonly stated reason is the equipment that is being moved around the world by sea is exposed to vibrations, wind and harsh weather and therefore is subject to stricter requirements for safety and reliability.

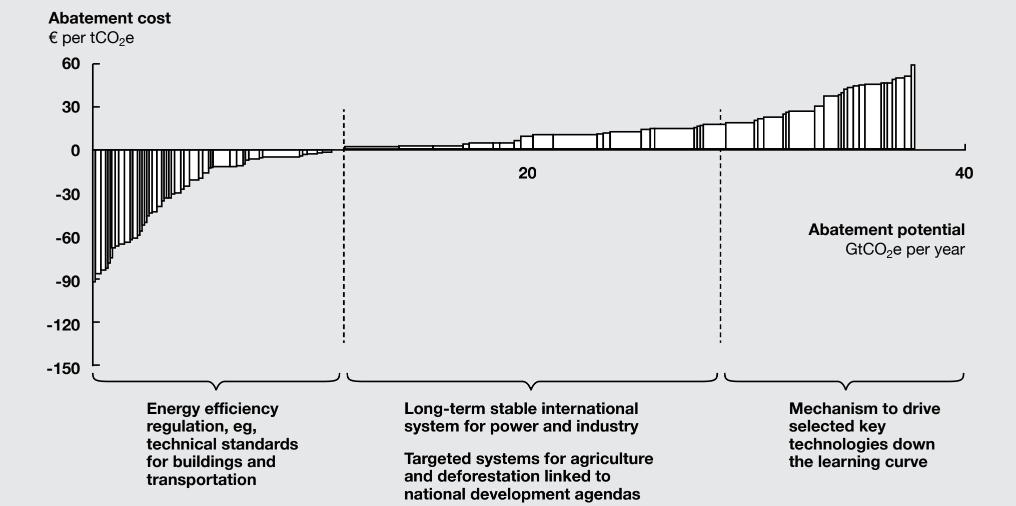
As Eirik Nyhus, director for environment at Det Norske Veritas, points out in his article on environmental regulations towards 2020 (see page 85), shipping is becoming a dominant source of emissions, potentially exceeding land-based sources. The fact that the maritime industry is lagging behind in technology adoption is bound to attract public attention and could result in a faster implementation of regulations.

"We have the technology to slash global emissions," stated the UK's Institution of Mechanical Engineers in a joint statement issued by 11 of the world's largest engineering organizations ahead of COP17 climate change talks in Durban, South Africa, in 2011. The technology needed to cut the world's greenhouse gas emissions by 85 percent by 2050 already exists, according to the groups that explicitly called for a peak in global emissions by 2020 and an intensive effort to train workers for green technology jobs.

A third question to expect from our children or grandchildren, as lifelong users of the Internet, smart phones and 24-7 social networking, is: **Why were 60,000 ships being run as if they were separate kingdoms?**

The ship at sea is no longer offline. The new Ship Energy Efficiency Management Plan (SEEMP) by the

McKinsey & Company's famous global greenhouse gas abatement cost curve, v2.0



International Maritime Organization, required for all existing vessels by 2013, aims primarily at improving energy efficiency of a ship's operations, preferably linked to a broader corporate energy management policy.

In fact, SEEMP guidelines state that onboard monitoring should involve the crew as little as possible. By monitoring the entire fleet and sharing some of the data with the entire industry, a step change in logistics efficiency could be in the making. IT networks and real-time data sharing, combined with statistical analysis and intelligent control systems will identify "the best practice" and implement it in a way that even the best captain could not imagine.

How to read the cost curve

The above cost curve can be understood as the cost beyond the business-as-usual scenario of feasible measures to reduce greenhouse gas emissions. The horizontal axis shows the amount of emissions that can be avoided in billion metric tons per year; in other words, how much each measure can contribute to reducing emissions. The vertical axis shows what this would cost, or the price per metric ton of emissions reduced.

Columns on the graph therefore represent opportunities that are sorted by cost, with the least costly ones to the left and the most costly ones to the right. Opportunities with cost below zero would increase the net profit while reducing emissions.

CAPEX and OPEX

To the left we chose to match two familiar charts as a dashboard for decision making on capital expenditure (CAPEX) and operational expenditure (OPEX) in a situation with high fuel costs.

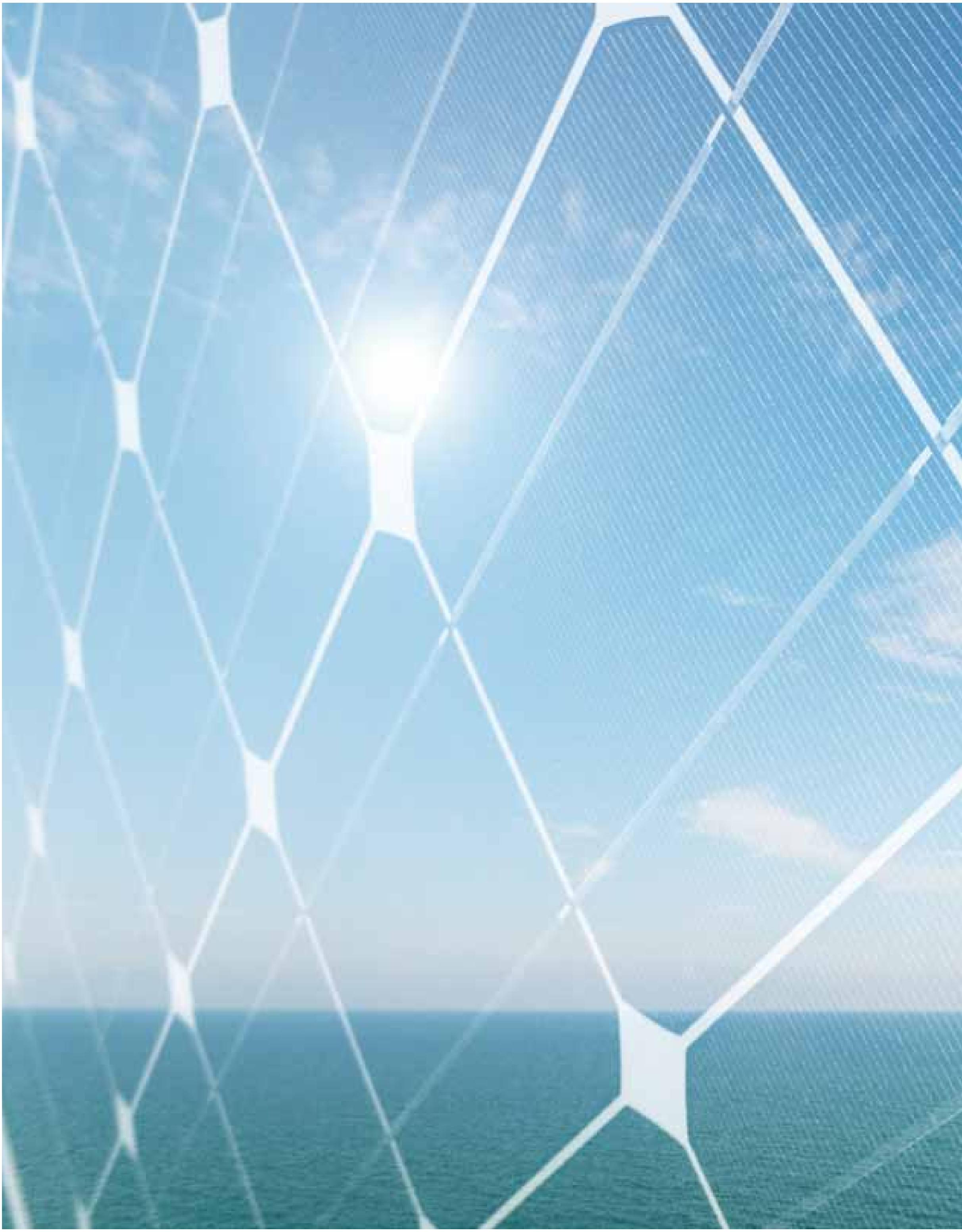
Decision makers at any level need to navigate through a flood of information, looking for the best business cases. Evaluating performance benefits and lifetime costs against alternative investment opportunities is a multi-level, multi-discipline exercise.

However, one thing seems clear: choosing the right energy efficiency improvements could be key to financing investments that have no direct payback, but will become mandatory through international regulations.

Text: Johs Ensby, Vibeke Larøi

Photo: Shutterstock

Watch Per-Anders Enkvist, Associate Partner McKinsey & Company, speaking about GHG abatement at CC9
http://www.cc9.no/index.asp?artikkelid=1947



A vision of 2020

Given the cyclic nature of the shipping industry, its ever-present uncertainty about the future is hardly surprising. However, no shipowner or executive would say no to a sneak preview of what's to come.

Foresight into future economic developments, business drivers, market fluctuations and legislative changes can make or break the best corporate strategies. The question is where to look for your insight. The would-be futurists and media pundits, and their predictions, are many and varied.

Classification societies, inherently sober and cautious as they are, do not make qualitative prophecies without doing their homework. So when the Norwegian classification society and risk assurance group Det Norske Veritas (DNV) unveiled the preliminary findings from its *Shipping 2020* research project at the international shipping exhibition Posidonia, in June 2012, the international press corps was all ears.

One of the first classification societies to establish a dedicated research unit in 1954, DNV has been identifying emerging trends and technologies in its *Technology Outlook* reports since 1995. *Shipping Outlook 2020* is part of an ongoing, in-depth analysis that drills down from DNV's *Technology Outlook 2020*,

Tore Longva is business development manager at Det Norske Veritas (DNV) and a specialist in transport chains, value chains, shipping, logistics and ship emissions. His passion is discovering smart innovations and solutions that make shipping more environmentally friendly and efficient.

Technology Outlook 2020

Aims to share DNV's views and to stimulate discussion about future technologies towards 2020. It gives an overview of the challenges and megatrends in four main areas: shipping, fossil energy, renewable and nuclear energy and power systems. The report covers 27 technologies that DNV believes will affect the future development of shipping. Made by DNV Research & Innovation, it is available at:

http://www.dnv.com/moreondnv/research_innovation/foresight/outlook/index.asp

More insight from the Shipping 2020 report here:

http://www.dnv.com/press_area/press_releases/2012/dnv_reveals_technology_uptake_towards_2020.asp

which highlights technologies likely to have major impact on the maritime and energy sectors.

Key Insights

Commenting on the reports findings, DNV president Tor Svensen said that incorrect investment decisions could be devastating for individual shipowners and collectively they could impact negatively on the environment as well. He suggested that the *Shipping 2020* analysis could give shipowners a clear technology and market context to work in, with the opportunity for targeted analysis of individual ship profiles.

To get a clearer fix on the key insights from *Shipping 2020, Generations* decided to quiz Tore Longva, DNV's business development manager.

Q: What key insights does it reveal on energy efficiency on board vessels?

A: The market will demand more energy efficient ships in 2020. High fuel costs will accelerate this development ahead of the EEDI (Energy Efficiency Design Index) regulatory timeframe. We expect new tankers, bulkers and container vessels to be up to 30 percent more energy efficient than today's newbuildings. Fuel choices up to 2020 will be driven by the time spent in Emissions Control Areas (ECAs), but distillate is a more likely option than scrubbers for most ships.

We foresee major innovations based on new concepts, such as ballast-free ships and hybrid propulsion systems. Hybrid propulsion using marine fuel cells, batteries or solar panels integrated in a diesel-electric system might also be a reality in commercial shipping in 2020, in particular for ships with variable power demands. In addition, there is a wide range of mature technologies, which are expected to increase energy efficiency: from propulsion efficiency devices to frequency convertors.

Q: What key insights does it reveal about shore-side/port power?

A: We anticipate a standardization of plug-in connections for converting land-based electricity to appropriate voltage and frequency for vessels. The main challenge for this "cold ironing" will be power availability and sufficient grid capacity, especially in smaller ports.

Q: What were the major findings on electrification on board vessels?

A: We expect an increase in the use of electric propulsion, particularly in specialized segments, such as offshore, cruise and ferries. This will be done through hybrid systems taking power from a wide range of sources, such as solar, wind, fuel cells and batteries. This will increase the onboard complexity, but will also increase efficiency through better power production and management.

Q: Were there any findings on the cruise ship industry and energy efficiency?

A: The cruise industry will be a forerunner for many new technologies that increase efficiency, especially power production, renewables and hybrid systems. We also expect increased efficiency through the combination and integration of onboard systems, such as waste heat recovery, HVAC (heating, ventilation and air conditioning) and power production. In addition, new types of fuel, such as natural gas and biofuel, will come into play.

Advanced modeling tools for developing and assessing hull designs, propulsors and complex machinery systems are expected to be increasingly used towards 2020, and large-scale demonstrator projects would be the next step required in order to accelerate innovation and technology adoption, while sharing investments and risks among the major stakeholders.

Q: Does it predict any future game-changing factors and technologies in the maritime and energy sectors?

A: Technological evolution is more likely than technological revolution, but we can expect the technology to be used in new areas. We see new fuels coming into play and this may change the demand for shipping, especially in the tanker segment.

The LNG (liquefied natural gas) price is very low at the moment and this will increase its usage, if a distribution chain can be established at an attractive price. But without a stricter CO_2 regime combined with carbon capture and storage, LNG will not achieve its potential as a bridge towards a low carbon energy future.

An analysis of fuel choices reveals that between 10 and 15 percent of the newbuildings delivered up to 2020 will have the capacity for burning LNG as fuel. This equates to about 1,000 ships. Larger vessels will benefit more from using LNG, compared with smaller vessels. Furthermore, a gas-fuelled engine can be justified if a ship spends about 30 percent of its sailing time in the ECAs.

Q: Does it indicate what will be the greatest challenges and opportunities that the maritime industry will face in the future?

A: The main challenge, but also an opportunity, will be the multitude of environmental regulations coming into play in the next decade. Compliance will have to be met with new technology that is still not mature. This requires many investments and creates uncertainty, and many shipowners sit on the fence. However, it also presents an opportunity for those that design innovative solutions and energy efficient ships. The market will be difficult with overcapacity that does not induce high investment, but may also create a competitive edge for energy efficient ships. This is a true dilemma for shipowners.

> The main challenge, but also an opportunity, will be the multitude of environmental regulations coming into play in the next decade.

Climate change will result in increased Arctic vessel traffic, speeding up development of Arctic-specific technologies, such as ice routing optimization software, hull load monitoring and new icebreaking concepts. E-Navigation including ECDIS, weather routing, piracy detection and ship-port synchronization technologies are expected to be widely used, preventing accidents and optimizing performance.

This is a decade of transition, and we have the opportunity to prepare for a more sustainable future by driving new technologies from idea and test stages to full-scale cost competitive solutions.

Text: Kevin Reeder

Photo: Shutterstock

Cruise ship design visionary

Harri Kulovaara's accomplished international career traces the development of the cruise industry over the past forty years. His skills as a naval architect and "realistic visionary" have equipped him to take on some of the most challenging projects in the history of the sector.

Generations caught up with the guru of cruise ship design at Royal Caribbean's offices in Miami for a chance to gain insight into the origin of his passion for all things maritime and to share his insider's view on the industry going forward.

The black sheep

Some have described Harri Kulovaara as a "typical Finn" in his outlook on work and life. He reflected on his background and on how he broke family tradition for his love of the sea.

"I am a typical Finn, proud of my roots, but I have also worked and spent a lot of time in international settings. I think I have inherited some of the innovative Finnish mindset. We can be quite determined, quite focused, with a healthy sense of risk taking and an ability to innovate and look ahead. I think this is part of my DNA.

My passion for naval architecture and cruise ship design can be traced back to my youth in the Turku archipelago in the southwest of Finland. I enjoyed both leisure and competitive sailing and made a strong connection with the ocean and nature. To become a better sailor, I studied the mathematics of aerodynamics, sails and hydrofoils. When this turned into a fascination, I decided to study naval architecture.

When I chose this path, I became the black sheep of the family: my father was a lawyer, my brother was a lawyer and I became the only engineer.

As I began my studies, the Song of Norway *was under construction in Finland. She was the starting point for Royal Caribbean and the first purpose-built cruise ship. I was able to see her at the outfitting pier from my classroom – her lines, shape, bow, funnel and the Viking Crown Lounge all inspired me. Who could have foreseen that one day I would be part of the team designing these kinds of ships?"*

One percent vision, 99 percent hard work

Widely known for his skill in managing huge projects, some with almost a hundred engineers working simultaneously, totaling a million engineering hours, Kulovaara knows what is needed for success on a large scale.

"It comes down to vision and understanding. An enormous amount of passion, energy, intuition, and an understanding of what can and cannot be accomplished.

These projects take a tremendous amount of coordination, so you also need management skills. But I would say that overall it is 1 percent vision and understanding, 99 percent very hard work. They are team efforts involving hundreds of people, huge numbers of design hours and management teams with experience built up by working on smaller, less complex ships. They also rely on long partnerships and deep traditions.

It is an evolutionary process. You have to use the technical insight gained from how earlier ships behaved and what the guest experience was, as well as examine operations and technology. Look at the growth of the Royal Caribbean ships, from Song of

Harri Kulovaara is executive vice president, Maritime, at Royal Caribbean Cruises Ltd. He has pioneered and led some of the highest-profile projects ever undertaken in the cruise industry. An early love of sailing was the springboard for his career.

Born in Finland, Kulovaara graduated as a naval architect from the Helsinki University of Technology before spending three years with Lloyd's Register in London. After returning to Finland, he worked for the Finland Steamship Company and Silja Line, involved in building the early "cruise ferries" *Finlandia* and *Sylvia Regina* and designing revolutionary vessels such as *Silja Serenade*.

Kulovaara joined Royal Caribbean Cruises Ltd. in 1997 and was appointed executive vice president, Maritime, in January 2005.

My biggest sense of achievement comes from being able to lead the team that is able to create ships on the cutting edge, push development and think for the future.

Norway *in 1970, to* Song of America*, to the mega-class ships at the end of the 80's, leading to* Voyager of the Seas, Freedom of the Seas *and* Oasis of the Seas. *Each of these was built on the partnerships and collective knowledge created by going from project to project.*

Personally, my biggest sense of achievement comes from being able to lead the team that is able to create ships on the cutting edge, push development and think for the future. All these ships are like my wonderful children, but I am most proud of the team of marvelous minds that creates them."

Customer experience, customer satisfaction

At the launch of the *Oasis of the Seas,* Kulovaara said, "In the end, the value of *Oasis* cannot be measured by cost, size, features, or innovative design. After all, we did not build the largest cruise ship in the world to set the record. *Oasis* is large for one reason: to enrich the passenger experience." He explains why customer experience remains at the core of his vision for cruise.

"We have always said that we are not building to be biggest; we want to provide customers with the best vacation, and that remains central. And I think our corporation is very much built around that idea: a relentless focus on customer experience. That has been a driving force for every ship design. Oasis of the Seas *and* Allure of the Seas *were revolutionary because their size gave us the opportunity to create totally different architectural solutions than with a more traditional vessel.*

When we started Oasis of the Seas *and* Allure of the Seas*, we looked at a huge number of designs. The criteria that drove our choices were clearly customer satisfaction and customer experience. These vessels provide amenities, programs, and options that exceed anything on a traditional cruise ship. We had very high expectations and it has been tremendously rewarding to see these ships so well-received by customers. They have exceeded cruisers' expectations.*

Another important thing is that we have been able to provide personalized service on our ships. Hardware is important, but the warm, personalized service you can get on cruise ships is even more vital. We have been able to attract very guest-centric staff that provide service with a smile and make sure our customers are happy. We have been very successful at this."

A view from the bridge

Using his background as one of the shapers of the industry through its formative years and as one of its undisputed innovators, Kulovaara assesses the state of the cruise segment today.

"Cruise is a very sound business, with a solid foundation and very good fundamentals. If we look at our customer base, we have baby boomers with more and more leisure time; we have young generation X's and Y's who are very interested in travel, so we really believe that there is a lot of demand for vacations going forward.

Cruising offers very good value for money. Satisfaction rates for our customers and guests are exceptionally high and that is a very good basis. So I believe that cruising has a bright future. I believe the industry is going to continue to grow at a slightly more moderate rate than in the past. It has reached a 40-year maturity stage and is now a substantial industry in the Caribbean, Europe, the Mediterranean and other areas. And we see that cruising is now picking up quite a bit in the Far East too.

I think that we will see the world facing financial difficulties for several years before returning to prosperity, but we still feel that cruising is a very good place to be. In order to thrive in difficult times, we need to continue doing what we have been doing: keeping the cruiser in focus and making sure our product serves in every possible way to increase customer satisfaction.

I think cruising has some very powerful competitive advantages. We have been able to develop our product to achieve higher guest satisfaction than many other industries. We are more cost-effective than other industries. I think that we can provide better value for money than other forms of vacation, and all this is created by innovative technology.

Take fuel efficiency. We have been working on this for 20 years and we are very proud of our results. By partnering with some of the best minds in the world, such as at ABB, shipyards and engine manufacturers, we are constantly evolving the technology. This gives us the chance to lower our energy and fuel consumption and at the same time raises our environmental performance.

Azipods are a good example; they have extremely good fuel efficiency. When we built Voyager of the Seas, *the Azipods increased its speed by one knot, which converted into fuel efficiency provided a saving of around 10-15 percent compared with conventional propellers, as well as lower emissions."*

Evolution never stands still

We all want a peek into the future. Kulovaara adopts a "helicopter view" to identify trends in innovation and customer demand that will impact the cruise industry going forward.

"We see a constant evolution in both technology, allowing us to learn and become smarter operationally, and customer preferences that drastically impacts ship design and service on board.

With new regulations coming into effect, we need to look at everything. We need to see how we can improve the safety and sustainability of our operation to reduce our footprint. New building standards for future vessels are welcome, and our ships have tried to push the envelope in every aspect. We believe that it is our responsibility to use technology in the best way, and we have tried to adopt new regulations in advance, becoming the benchmark for what technology can accomplish. With a tradition of being a front-runner, we feel that it is positive that the regulatory framework is progressing. Our aim is to go beyond compliance.

New ships will be very different, providing new services and sailing into new areas with greater comfort. But when it comes to architectural solutions, I think that Oasis of the Seas *and* Allure of the Seas *represent a major step, and it is probably going to be difficult to see similar opportunities that will change things radically ahead.*

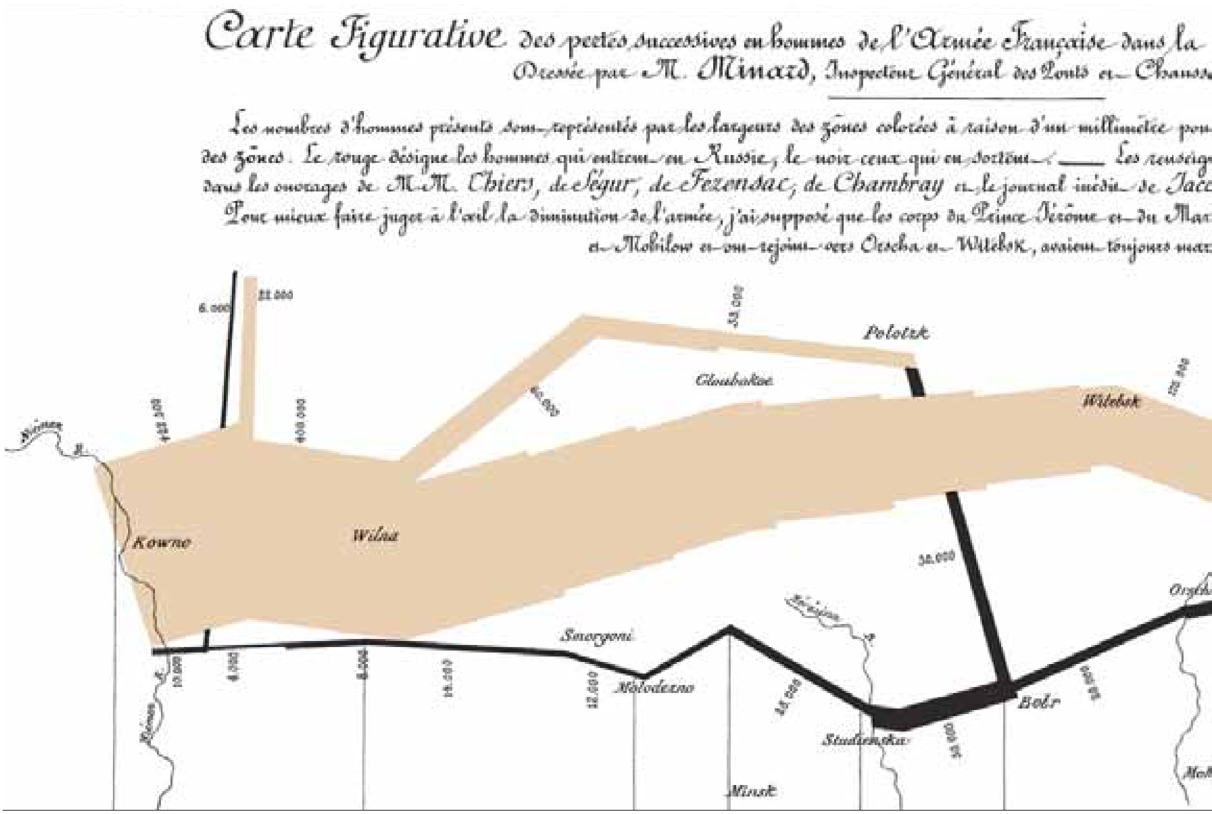
Customers are constantly looking for more options: more variety, more exciting things in every area. That goes for dining options, entertainment, pool decks, open deck activities and so on. Cruising is very much a family vacation, so we focus on how to make sure that children, parents and grandparents all have a great time on our vessels.

Gearing up for the future is really about trying to imagine the needs of all three generations and how they can be met on board. We need to make sure we follow customer preferences and constantly adapt our vessels to stay on the cutting edge of cruise development."

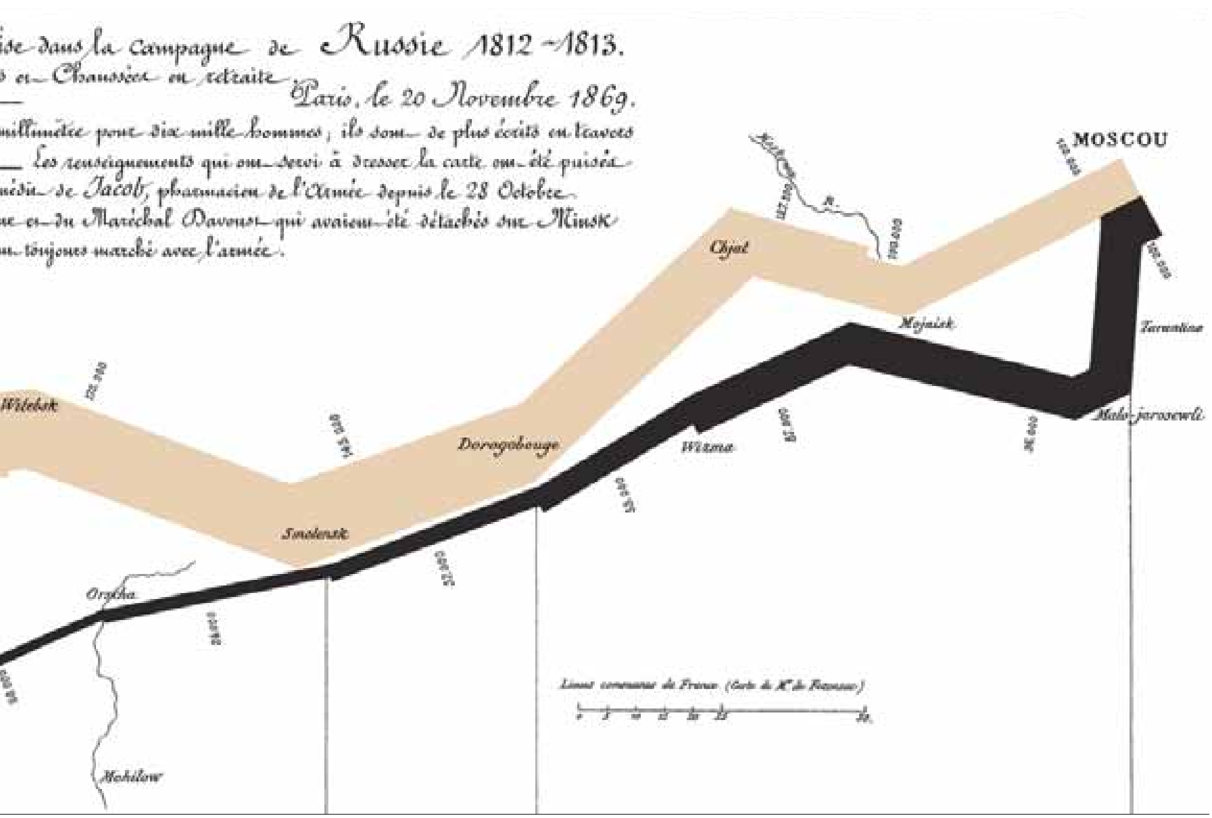
Text: Johs Ensby, Kevin Reeder

Photos: RCCL

Managing the flow of energy



Tracking energy from fuel through its many transformations to useful work is not unlike what the French civil engineer Charles Minard did when he visualized Napoleon's invasion of Russia.



Unable to replace its losses, the Grande Armée returned from the campaign with only a few percent of its original troops. Charles Minard's remarkable diagram is one of the most famous Sankey diagrams, an increasingly popular type of infographic, where the arrow width is shown proportionally to the flow quantity.

By visualizing large amounts of information and complex relationships, diagrams like this quickly show the big picture and interpret quantitative data at the same time. Whether visualizing money, material or energy flows, the Sankey diagram is often the preferred tool. It is named after the Irish engineer Matthew H. Sankey, who first used it in a publication. In the annex to the minutes of a meeting of the Institution of Mechanical Engineers in 1898, he sketched the energy efficiency of a steam engine in comparison to an ideal steam engine without energy losses. Sankey used the same type of a diagram that Minard used to visualize Napoleon's losses three decades earlier.

Generations created a Sankey diagram that visualizes energy flow from fuel to utilization. It is important to note that the values will vary significantly according to the type of vessel, and that a diagram like this does not capture the dynamics of different operational modes. The diagram shows conversion of all mechanical power to elecricity for flexible distribution between various loads. In conventional or hybrid propulsion, a portion of the power would bypass the conversion to electricity and go straight to propulsion.

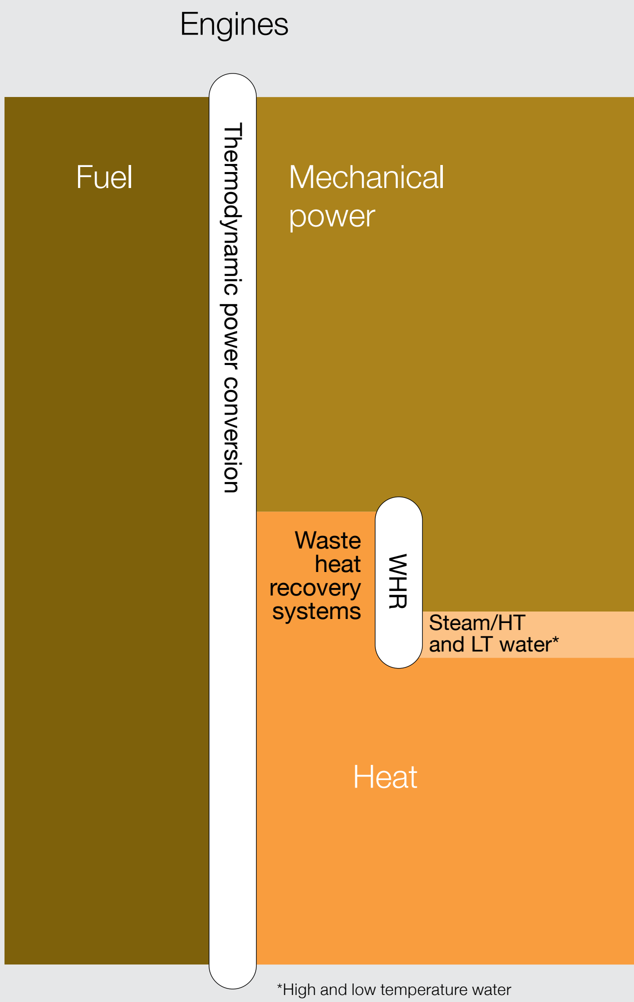
For cruise ships, a primary utilization factor would be the comfort of the guests (the hotel load). For a platform support vessel, it would be dynamic positioning, and for a tanker – the speed from A to B. Useful work would vary, and the width of the arrows, indicating the amount of energy would change from one minute to another. As a static picture, we can, in essence, think of the diagram as the energy accounted for during a year in operation or as the energy flow for an entire fleet.

The aim was to come up with a model that could be used to introduce various technologies and themes discussed in *Generations*.

By reading the diagram from left to right, one can see how a large portion of the fuel turns into waste heat due to the inefficiency of the combustion engine. However, reading the diagram from right to left could give an even more valuabe insight into how the cost driver to the left, the fuel consumption, could be tamed in a better way. Improvements of the processes on the right will affect the left side by a factor of two or three.

The most effective strategy for improved energy efficiency and reduced fuel costs is dead simple: close the gap between optimal and actual demand.

Text: Johs Ensby, Vibeke Larøi



Energy flow

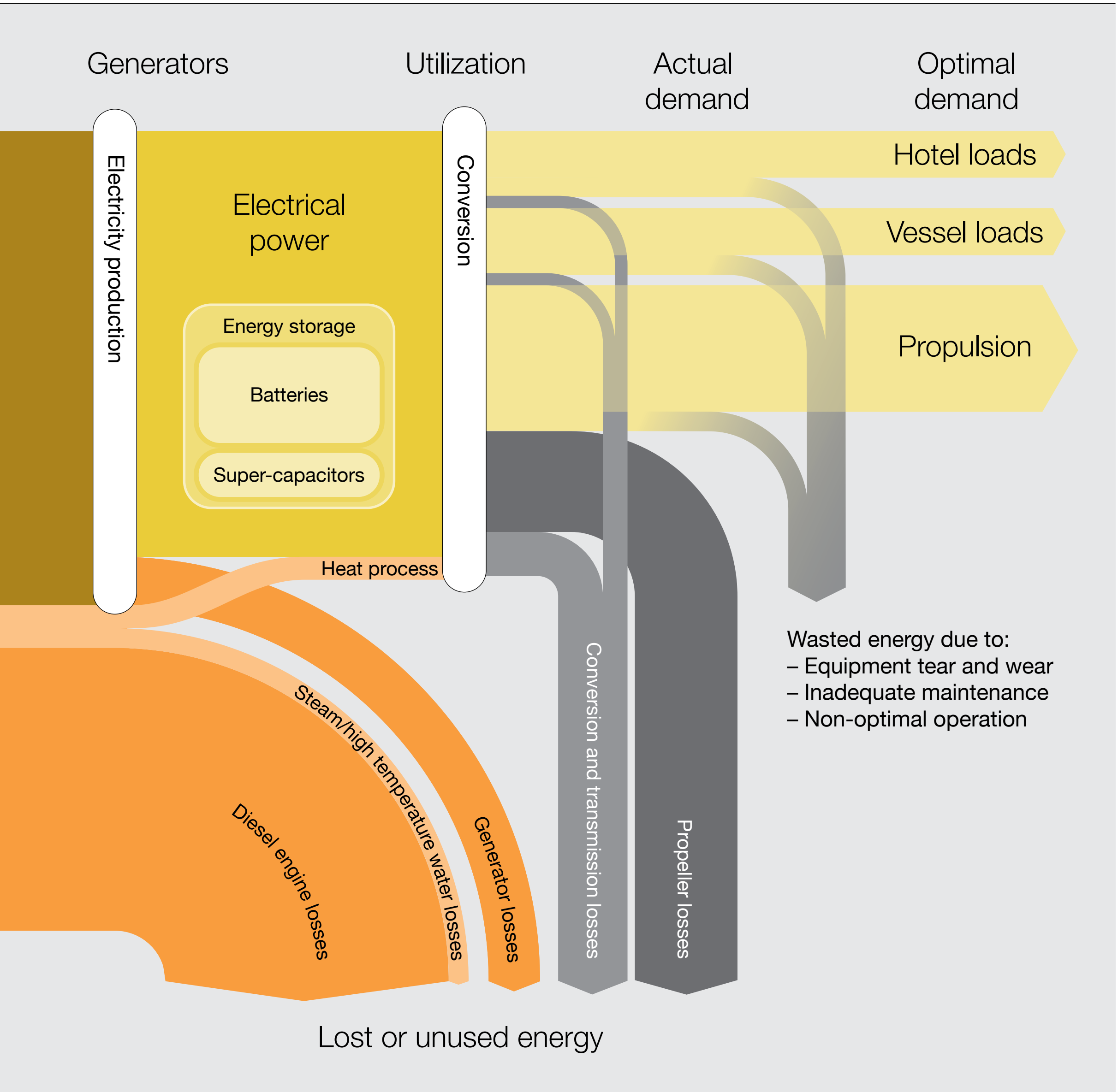
New regulations for SO_x, NO_x and particle emissions to air result from the combustion of marine fuels. Managing the cumulative impact of these regulations is one of this decade's key challenges. Get the full overview of the environmental regulations towards 2020 in the article on page 85.

The cruise industry has been working on fuel efficiency for 20 years, driven by the need to provide the highest possible value for money for their customers. Read more in the portrait of the "realistic visionary" Harri Kulovaara on page 12.

Read more about how liquefied natural gas (LNG) promises increased energy efficiency, lower emissions and a stable resource base on page 38.

On pages 30 and 104, Onboard DC Grid is presented as a bridge to new and environmentally friendly energy sources.

Learn more about what a waste heat recovery system is, how it works, as well as where and when it can be used in the "Achieving improved fuel efficiency with waste heat recovery" article on page 154.



On page 121, find out about how to use super-capacitators as energy buffers, reducing the load variations as seen by the system generators and thereby improving the system stability and fuel efficiency of available diesel gensets. Read more about battery technology on pages 110 and 114.

Total propulsion efficiency is a product of the efficiency in all parts of the propulsion train. See the article on page 136 for more information about propeller efficiency and hybrid propulsion systems.

Improved repair, replacements and maintenance to reduce tear and wear, as well as hull cleaning, propeller polishing, air removal from pipes and filter cleaning, all have a big impact on fuel costs. Small changes in operating conditions through trim optimization, route planning and optimal energy control present substantial fuel savings.
Read more on operational efficiency versus new designs from shipowner's and operator's perspective on pages 60-65.

For more on the dilemmas and opportunities in an industry consuming 300 million metric tons annually, see page 80, and for more information on EMMA™ Ship Energy Manager, refer to page 96.

Energy efficiency classics

When it comes to energy efficiency, there is no such thing as too much reading if you want to keep up with rapidly changing regulations and stay on top of the news on technologies for optimizing energy use. Instead of diving into the abundance of books written on the subject, *Generations* selected the top research and reference materials by the key industry players. Together, they form the ultimate foundation for a library on energy efficiency.

MARPOL Annex VI
by International Maritime Organization (IMO)

The Regulations for the Prevention of Air Pollution from Ships (Annex VI) was added to the International Convention for the Prevention of Pollution from Ships (MARPOL) in 1997, and since then retains the top spot in the marine environmental reading list. It sets limits on sulfur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances.
Annex VI entered into force on 19 May 2005 and a revised *Annex VI* with significantly tighter emissions limits was adopted in October 2008, which entered into force on Jul. 1, 2010.
Available through IMO

Technology Outlook 2020
by Det Norske Veritas (DNV)

DNV's *Technology Outlook 2020* looks at the key technologies in shipping, energy and power systems that will be in play towards the end of this decade. The objective of the *Technology Outlook 2020* is to share DNV's views on shipping, fossil energy, renewable and nuclear energy, as well as power systems and to stimulate discussion about future technologies towards 2020. Authored by DNV's Research and Innovation unit, the report covers 27 technologies that DNV believes will affect the future development of shipping.
Available at http://www.dnv.com/moreondnv/research_innovation/foresight/outlook/index.asp

World Energy Outlook
by the International Energy Agency (IEA)

IEA's annual edition of the *World Energy Outlook* is a must-read for the industry and government decision makers and other stakeholders within the energy sector. Drawing on the latest data and policy developments, the 2012 edition gives detailed analytical insights into trends in energy markets and reflects upon their meaning for energy security, environmental protection and economic development. Global energy demand, production, trade, investment and carbon dioxide emissions are broken down by region or country, by fuel and by sector.
Every year, the *World Energy Outlook* focuses on a particular country, and this time it is Iraq. The in-depth outlook for Iraq's energy sector examines both its role in satisfying the country's domestic needs and its crucial role in meeting global oil demand.
The 2012 edition of the *World Energy Outlook* will be released on 12 November 2012.
Available at http://www.worldenergyoutlook.org

Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve
by McKinsey & Company

To provide a quantitative basis that would help the world leaders in their discussions about the targets for reducing greenhouse gas emissions, McKinsey & Company, supported by 10 leading companies and organizations across the world, has developed a global greenhouse gas abatement database. This extensive study incorporates assessments of the development of low-carbon technologies, macro-economic assessments, a detailed understanding of abatement potential in different regions and industries and other input invaluable for implementing various scenarios for achieving a more dynamic understanding of how abatement reductions could unfold in the future.
Available at http://solutions.mckinsey.com/ClimateDesk

Text: Margarita Sjursen

An introduction to energy efficiency instruments

The ideal energy efficiency indicator should provide an objective, accurate and effective way to communicate performance.

It is common to compare home appliances by a color code and by a letter on a scale from A to F. Cars are compared by fuel consumption per mile. But when it comes to comparing different vessel types, trading patterns and transport work, things get complicated. In spite of this, the shipping industry reached a major policy milestone in July 2011, when 65 governments meeting at the United Nations' International Maritime Organisation (IMO) voted to enforce the Energy Efficiency Design Index (EEDI) standards for the global shipping fleet, marking the start of the process towards reducing emissions. Together with the Ship Energy Efficiency Management Plan (SEEMP), the EEDI will enter into force in 2013. EEDI will mandate improvements in hull design and machinery for new ships, while the SEEMP will require shipowners to have a plan for improving the operational energy efficiency of each of the ships in their existing fleet.

The EEDI has been in place on a voluntary basis since 2009, and classification societies have already verified the EEDI for a number of ships, the first of which was Hapag-Lloyd's boxship *Vienna Express*. Maersk Line received independent verification of its CO_2 emissions data, vessel by vessel, from Lloyd's Register, and Maersk is including the data as one of its eight performance measures.

But because the EEDI targets only new ships, an initiative for establishing a similar design index for existing vessels was taken by Operation Shipping Efficiency, a mission spearheaded by The Carbon War Room, a non-profit climate group co-founded by Virgin Group's Richard Branson and backed by, among others, RightShip, a ship vetting specialist. Their Existing Vessel Design Index (EVDI), hosted on http://shippingefficiency.org, calls for an objective and mandatory measure that provides sufficient commercial incentives and meets their overall goal of mitigating CO_2 emissions from international shipping.

EVDI is a beta version of a service that has no regulatory backing, yet it points to the power of easy access to the environmental performance rankings of ships. Anyone can register, get a username and password, compare the EVDI of two cruise ships and make the environmentally responsible choice as a consumer, just as when buying a dishwasher.

The brand value created for shipowners that stay ahead of the game is one of the benefits of having a common indicator. Those who lead the development of environmentally sustainable shipping industry, are likely to be rewarded by consumers – if not directly, then at least through big brand charterers who carefully optimize their entire supply chain.

EVDI visualization at http://www.shippingefficiency.org

An even more direct reward is offered by the World Ports Climate Initiative (WPCI), which is supported by 55 of the world's key ports and rates ships according to the Environmental Ship Index (ESI) and offers a reduction of port fees to those who go beyond regulatory compliance.

Between regulators, ship designers, equipment manufacturers, yards, shipowners, cargo owners and consumers, there is an endless list of parameters to compare. The creators of energy efficiency indicators face the almost impossible task of unifying the interests of these stakeholders in terms of saving the environment and using less energy. There is no single answer, but we need a simple index for effective communication. The jury is still out on who will strike the right balance between objectivity and simplicity.

Text: Johs Ensby, Vibeke Larøi

EEDI
Energy Efficiency Design Index

http://www.imo.org

In a nutshell

The EEDI is a non-prescriptive, performance-based mechanism. As long as the required energy efficiency level is attained, ship designers and builders would be free to use the most cost-efficient solutions to comply.

SEEMP
Ship Energy Efficiency Management Plan

http://www.imo.org

In a nutshell

A standard for ship-specific plans entering into force from January 2013. All ships must have a SEEMP on board before the issuance of the first IEEC.

IEEC
International Energy Efficiency Certificate

http://www.imo.org

In a nutshell

The IEEC provides shipowners with certification of compliance to new standards. For new ships, the certificate will state both the attained and required EEDI of the vessel.

EEOI
Energy Efficiency Operational Index

http://www.imo.org

In a nutshell

The EEOI is used in SEEMP and is based on vessel's actual operational data. It is designed to be a representative value of the energy efficiency of the ship operation over a period, which represents the overall trading pattern of the vessel.

EVDI
Existing Vessel Design Index

http://www.shippingefficiency.org

In a nutshell

EVDI™ was developed by RightShip and is the core measure used to calculate the RightShip GHG Emissions Rating.

ESI
Environmental Ship Index

http:// www.environmental-shipindex.org

In a nutshell

The ESI is designed to identify and reward ships that perform over and above the IMO's current international legislation. Ships that maintain ESI registration earn up to to 30 percent reduction on port dues.

Type of instrument	Method	Ship types	Regulatory status
Formula for calculating mass of CO_2 emitted per unit of transport work (metric ton-nautical mile).	The actual EEDI of a vessel is called the "attained EEDI" and is calculated based on guidelines published by the IMO. The result must be below the limit ("required EEDI") prescribed in the International Convention for the Prevention of Pollution from Ships (MARPOL).	EEDI is suitable for ship types designed to transport cargo embracing 72 percent of emissions from new ships and covering oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers and container ships.	The MEPC of the IMO has made the EEDI mandatory for new ships, and the SEEMP for all ships. It has also added the requirements for survey and certification, including the format for the International Energy Efficiency Certificate (IEEC).
The SEEMP establishes a mechanism for operators to improve the energy efficiency of ships through a ship-specific plan.	Plan to be maintained on board for self-improvement.	The SEEMP can be implemented on vessels in four steps: planning, implementation, monitoring and self-evaluation and improvement.	The same as EEDI.
Certificate to be maintained on board as part of normal inspection and audit. IEEC is not connected to a survey scheme and does not have an expiry date. It is specific to each ship.	For new ships, an IEEC is issued at the vessel's initial survey, provided the EEDI has been verified and the SEEMP is on board. For existing ships, the IEEC is issued, provided the SEEMP is on board.	For vessels of 400 gross tonnage and above. The IEEC must be re-issued in the case of a major conversion.	The same as EEDI.
Formula for calculating the amount of CO_2 emitted per unit of transport work. Unlike the EEDI and EVDI™, the EEOI will change depending on how the vessel is operated and what abatement measures the owners have retrofitted.	The EEOI could provide a basis for consideration of both current performance and trends over time. One approach is to set internal performance criteria and targets based on the EEOI data.	All ships performing transport work.	The same as EEDI. Part of SEEMP.
Formula for calculating the amount of CO_2 emitted per unit of transport work similar to EEDI.	Values are calculated based on the vessel performance information. Primary sources of this data are RightShip's Ship Vetting Information System, IHS Fairplay database, classification societies and owner/ship-sourced data.	EVDI™ is designed for application with the entire fleet of existing ships.	No regulatory backing. Shippingefficiency.org has organized a call to IMO to as soon as possible apply a design index to existing ships in addition to the application of EEDI to new ships.
Credits (0 – 100) for above-baseline environmental performance regarding NO_x, SO_x and CO_2.	The ESI use is voluntary, based on shipowner's self-declaration. Upon entering an ESI port, the ship may inform the port of its participation in the ESI.The port may then apply incentives.	All ship types. The ESI score is listed for 733 ships as of June 2012.	World Ports Climate Initiative is supported by 55 ports. The ESI formula is built upon IMO's mandatory limits for NO_x and SO_x and on SEEMP for CO_2 performance.

The black-and-white energy efficiency indicator

While reviewing the existing energy efficiency measurements, *Generations* pinpointed two vital criteria for success, communication and integration.

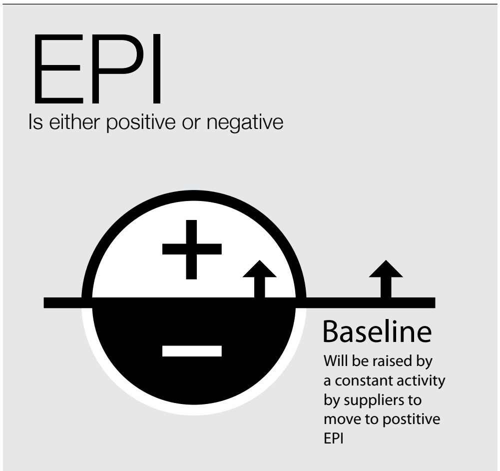
A previous "Brains trust" session lead to a concept idea for moving fully charged container-size batteries on board, utilizing the excellent logistics infrastructure already in place for box ships worldwide. Every third container in the top layer of the cargo could be a power pack with unfolded solar panels for topping up energy during the voyage and even extracting a wind turbine for less sunny days.

Every issue of *Generations* launches a thought experiment. A small group of creative engineers, a writer and an illustrator combine their diverse skills in a "Brains trust" to present ideas about how the future might be.

In the earlier "Brains trust" sessions, the team came up with a concept for propulsion as a service (PaaS) and a model for using container-sized batteries for powering commercial ships without fossil fuels. The latest session was about power distribution systems and it was well about time to attack the problem of energy efficiency indicators.

For this "Brains trust" session, in addition to the internal team, *Generations* invited an engineer from outside ABB. Geir Erik Samnøy, founder and managing director of a Norwegian company Present-Water, is well-known for his work on retrofit projects aimed at fuel savings and making cruise ships more energy efficient. At the time of the "Brains trust" session, Samnøy was busy working on a waste heat recovery technology for his company, and while still in a stealth mode about it, he accepted the invitation to share his insights and join Jostein Bogen, project leader for ABB's Onboard DC Grid and Randi Østrem, propulsion control engineer of ABB, and the editorial team of *Generations*.

What if there was an energy efficiency indicator that would work on all levels, from the smallest piece of equipment to an entire fleet?



Introduction of measurement systems on board the next generation of ships is one of the hottest topics discussed in the maritime industry today. Innovations are taking place all the way from sensors to computerized analysis and advisory systems for captains and fleet management offices.

During the session, the “Brains trust” did not pursue the goal of finding a viable solution, but wanted to come up with something that would be thought provoking enough to spark off new ideas for solving a common dilemma. Here is what the team has ended up with.

Two performance criteria

While reviewing the existing energy efficiency measurements, the “Brains trust” team pinpointed two vital criteria for success, communication and integration. The team was unanimous that there was a need for motivating the equipment suppliers at all levels to create win-win situations through better integration between systems on board. What was also needed was an attractive name for the initiative; one that would point to opportunities rather than focus on existing problems. “Performance” became the key word.

Energy Performance Indicator (EPI)

The discussion quickly homed in on reducing the usage of “dirty energy,” leaving renewable energy, such as solar or wind, out of the equation. In addition to that, the team concluded to sort out waste heat as clean energy. What the team wanted to establish was the quotient of utilization (eg, transport work) and “dirty energy” consumption.

$$\text{EPI} = \frac{\text{Useful work}}{\text{"Dirty" energy used}} - \begin{array}{c}\text{Baseline}\\ \text{EPI for the}\\ \text{category}\end{array} = +/-\ 0$$

For turning it into an indicator, the “Brains trust” team decided that each category of equipment would need a baseline value to be deducted. This would place the EPI as a number above or below zero. This way, the binary black or white indicator would simply identify a piece of equipment as above or below the baseline for a specific category. The definition of and units for “useful work” and “dirty energy” could vary from category to category and still make the EPI a tool for comparison, whether the calculation is made for a particular circuit board, a pump or a an entire oil tanker.

Two routes to a positive EPI

The “Brains trust” thought that dividing each category of equipment in just two groups would create the pressure needed to move the industry towards a more energy efficient approach. And this is why: no one likes to stay below average, and when everyone focus on the achievable goal of just being on the good side of the baseline, the industry average for every category would keep moving in the right direction. And that is exactly what is needed.

Text: Johs Ensby, Margarita Sjursen

Who has the best "fruit basket"?

A Q&A with our "Brains trust" guest Geir Erik Samnøy

Q: Do we have good incentives for energy efficiency regulation today?

A: The real incentive is financial, whatever scheme you get into. There are a lot of theoretical ideas for schemes out there, but we still need to see what will work in practice and become legislated.

Q: Is the EEDI the strongest initiative?

A: Right now it is, but it is still a design index. If you have a ship that does well on the EEDI, you still have to look at how it will be operated. Is slow-steaming an option, for example? In other words, what is the optimal way to transport goods from A to B?

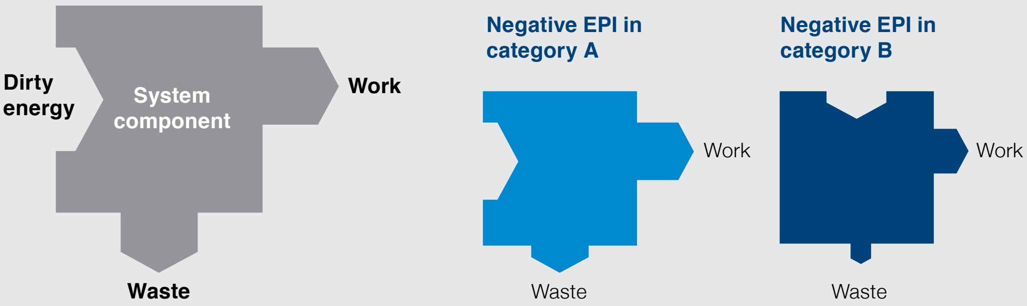
It is the same in the power industry. We might be the best in the world at producing, say, green power, but we are the worst in the world when it comes to consumption and conservation. These two sides of the coin go together. It is a similar situation with water. We can reduce the cost of water tremendously, but if one operator uses 400 liters of water per person per day and another uses 150 liters, where do you put your emphasis? Is it on cost-efficient production, or do you take the holistic view?

Q: What is your response to the statement "Every system is a subsystem"?

A: It is. Classification societies are changing the way they write the rules. Now they are more into functional rather than prescriptive rules. If you look at systems and subsystems, the subsystem has a function but what about the overall function? Being able to see the whole picture is very important. So you can ask what sort of subsystems or combinations of these will be best for the job.

Comparing "fruit baskets," rather than apples and pears

Through exchange of waste energy, components and subsystems with negative EPI may be integrated into EPI-positive systems in another category.



Q: The two ideas the "Brains trust" team had for an energy performance indicator were about communication and cooperation. The indicator should incentivize suppliers to cooperate by thinking of their system as a subsystem and looking for synergies. Do you have any examples of this becoming the key in communication between different vendors?

A: Some of the bigger companies see this as an opportunity to be a total integrator, meaning they are acquiring a lot of smaller companies with special skills and technology so that they can provide, within one company, an entire solution.

Q: A traditional weakness of the shipping industry is that there is such a fragmented market of suppliers.

A: Exactly, but now some of them have their own ship design, ballast water systems, scrubbers. They are looking into energy-efficient technologies and all the big challenges. They are trying to create what is best for their business and keep it internal. That is good because they are capable of doing everything themselves. But they will still be challenged on each subsystem. If you have a system that captures everything but you are still the number four technology within each subsystem, you do not necessarily become the provider of the total solution. The operators have also learned over the years that being in bed with one vendor is not good because it is essentially a monopoly.

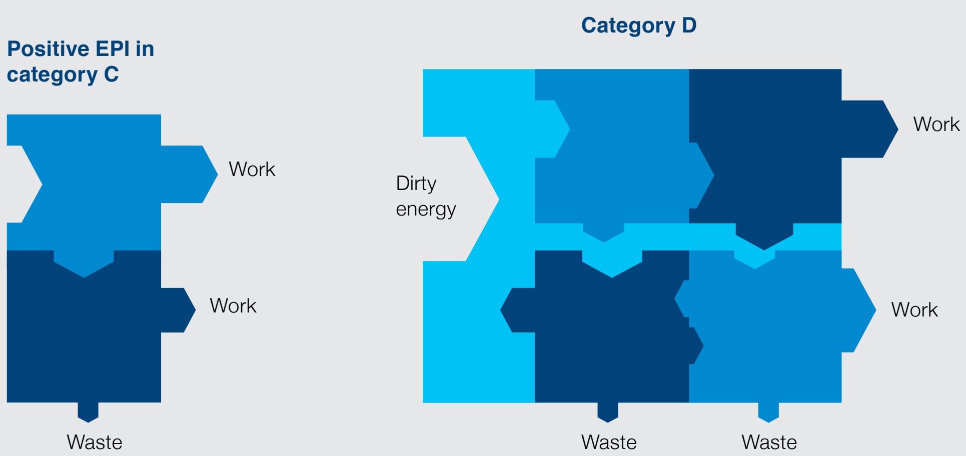
Q: So an energy performance index could provide a benchmarking system that makes it possible to combine apples with pears?

A: Precisely. It is a question of who has the best "fruit basket".

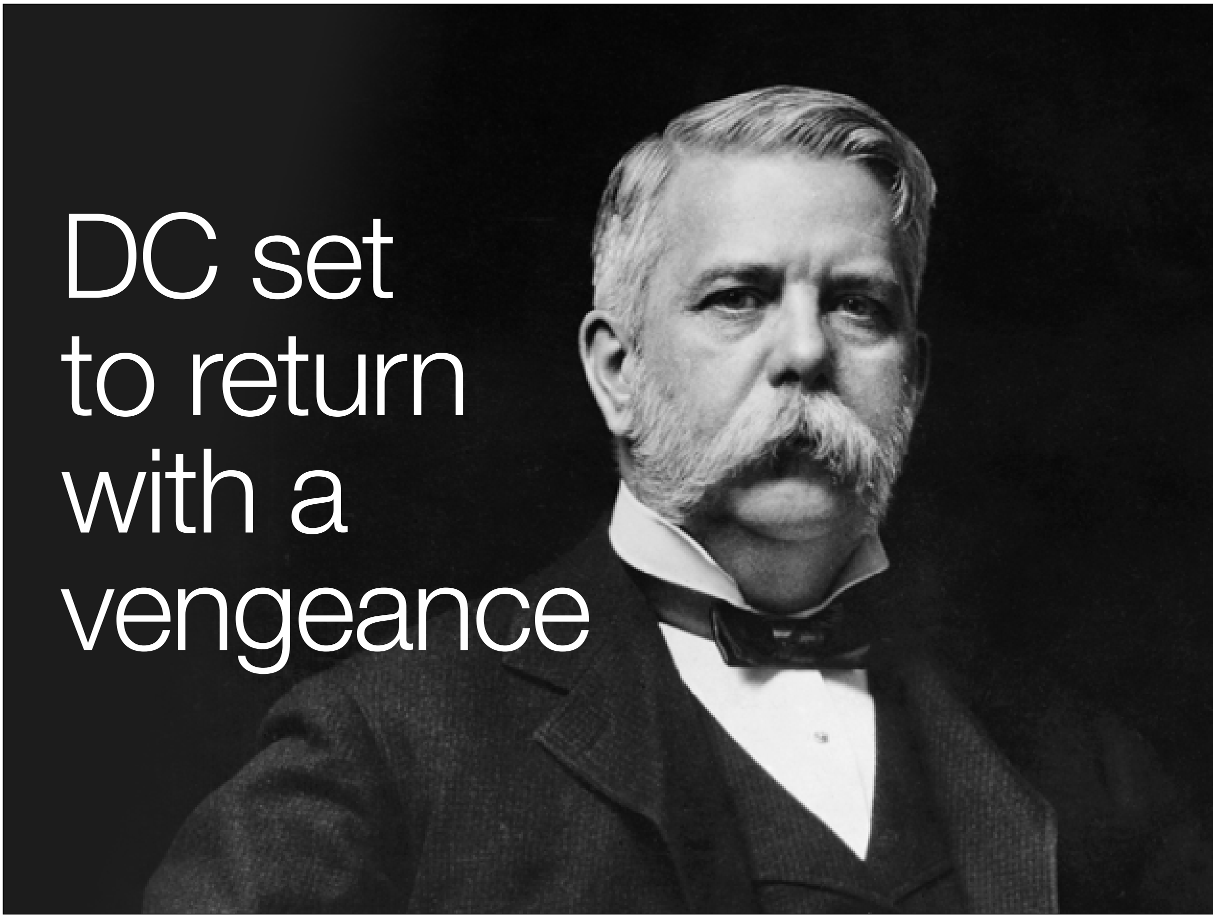
Q: Do you mean moving from one "fruit basket" to another and in that way incentivizing subsuppliers to upgrade their EPI so that they can find a synergy?

A: Yes. As an example of this type of synergy, one provider might have the best solution in their segment for solving one problem but, say, it realises it has a waste problem. Then it looks for a partner that can use this waste to drive its own process. That is the sustainable way for moving forward!

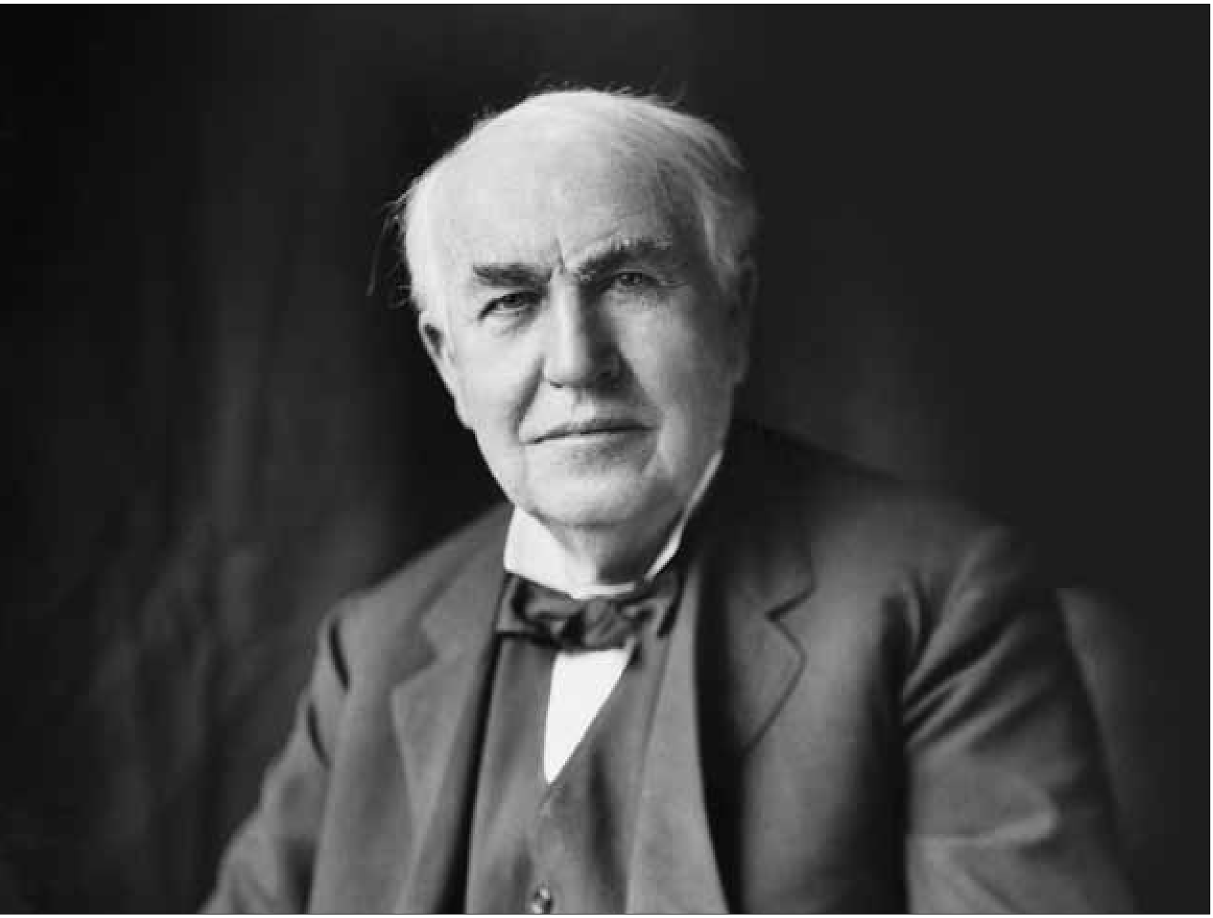
Text: Johs Ensby



DC set to return with a vengeance



Ever since the late 19th century, when alternating current (AC) toppled direct current (DC) to become king of the world's power distribution systems, AC has reigned supreme. But that may be about to change. ABB plans to put DC back on the throne, but this time alongside AC. It will not be a smooth ride, and it can not do it alone, but the planet will reap the rewards.



Dubbed "The War of the Currents," the battle that raged between the DC advocate Thomas Edison and the AC proponent George Westinghouse in the late 1880s sometimes took a nasty turn. Edison spread disinformation about fatal AC accidents, publicly killed animals with AC and even went so far as to secretly pay someone to invent the electric chair – all to promote the idea that AC was deadlier than DC.

Now things are about to come full circle. AC and DC may be about to enter into a "power-sharing" agreement, with the help of ABB. But unlike Edison, the company will not be using smear tactics to get its message across. It has good news for anyone concerned about our planet: that its Onboard DC Grid is more fuel-efficient, decreases emissions, reduces electrical footprint and enables the use of alternative energy sources.

What more could the industry, and indeed the world, ask for? Things are not quite that simple, though. The idea of a DC power distribution system is such a radical departure from the conventional AC standard that it will require a mindset change for a host of industry players.

And, as with any new technology, there are those willing to take the necessary risks and then there are the skeptics shaking their heads on the sidelines. Back in 1893, it took a lot of convincing for the Niagara Falls Power Company to finally award the contract for the world's first AC hydroelectric plant to Westinghouse and to reject General Electric and Edison's DC proposal. Some doubted that the system would generate enough electricity to power industry in Buffalo.

Title picture
George Westinghouse (left) and Thomas Edison (right)

Today, there is a similar mix of feelings about the DC Grid. Engineers, classification societies, owners, shipbuilders and suppliers may be fired with the spirit of innovation or cautious about what this paradigm shift will mean.

Norwegian owner Myklebusthaug is putting its money on the innovative idea. In November last year the company agreed to equip a newbuild platform support vessel (PSV) being built at Kleven shipyard in Ulsteinvik, Norway, with the DC Grid. ABB thus secured its first pioneering order.

Other owners are not steaming ahead quite so fast. However, Bernd Friedrich of MAN Diesel & Turbo, a market leader for large diesel engines, says that while owners may need convincing, once they understand the fuel-saving potential, they buy it.

Until now we knew there was a potential for this but we were not able to utilize it.

MAN Diesel & Turbo is putting its engine know-how together with ABB's expertise in electrical equipment to develop the DC Grid.

Friedrich, who is head of engineering for diesel-electric drives, says the DC Grid is what his company "has been waiting for."

"Until now we knew there was a potential for this but we were not able to utilize it. The idea, of course, was available but nobody did it. The system to handle it has not been available up to now. Since ABB has put money into developing a new standard, we can do it." A big obstacle in convincing owners of the benefits of DC is its old-fashioned image, says Friedrich.

"They are not really used to it because it sounds like technology that was around 20 years ago, so we have to do a lot of explaining in the market."

Another player that needs to be won over is the yard. "In the DC system, you have smaller components and it is spread in smaller pieces. The yard has more flexibility in arranging these things. They want to know where they can place them, how heavy they are, and how the price of the equipment compares to conventional equipment.

"Handling a DC system is not just laying cable, It depends on whether the yard is skilled enough to install it. I foresee some troubles with inexperienced yards."

Like MAN Diesel & Turbo, Norwegian classification society Det Norske Veritas (DNV) has long seen the potential for using DC and had been researching the idea before ABB came up with their proposal.

"It has been on the agenda but we have not made specific proposals that will work in practice," says Arnstein Eknes, segment director for special ships at DNV.

Eknes says DNV's initial response to innovations such as the DC Grid is always "This is interesting and challenging and will give opportunities for new solutions."

"Most important in this phase is to seek partners who are keen to see opportunities and capable of foreseeing the bottlenecks we may have to remove or what obstacles we need to overcome in order for it to succeed."

One of these obstacles is the need to meet the safety demands of current rules and regulations as set by the classification society. ABB has worked closely with DNV to ensure its DC Grid does this. (Read more about how DNV develops new class rules on page 35).

But before ABB could think about the rules, it had to ignore them, says lead engineer on the DC Grid project Kläus Vänskä. "The old rules set limitations by describing conventional solutions. When we first looked into this, we thought, okay, we should forget about the rules, they should not hurt our thinking. We are not going against the rules, though, because we are still following what is behind them," says Vanska.

He seems slightly in awe of what he and the rest of the team at ABB have created and he admits that even they do not understand its full ramifications.

"With the DC Grid, we can optimize the combustion process so you have much cleaner air going through the system. It is hard to imagine all the benefits right now.

"We have been optimizing the electrical parts and each player can optimize their own components. We do not have knowledge about every component because we have not been looking so much outside of our own borders but now we are opening it up fully to other players.

"We are building up the foundation for much wider development. Engine makers will be able to pay more attention to emission reduction. I want to see what they can do."

Meanwhile, the team is carrying out diesel laboratory tests in Finland and the Netherlands, says Jostein Bogen, DC Grid project owner, who came to the project in August 2010. "We are targeting the first installation to be done mid-2013," he adds.

Bogen is full of praise for his team, which he says is great to work with. "I have never worked with such an enthusiastic and innovative team. They are bubbling over with new ideas all the time."

As with any innovation, two brains are better than one. In fact, the more brains the better. Eknes certainly agrees. "If you want to go fast, go alone. But if you want to reach far, go together. So if the intention is to be a step ahead for the rest of the world, the rest of the technology providers out there... then it makes sense to involve them in the sharing process."

Roald Myklebusthaug of Myklebusthaug Management, the first owner to use the DC Grid on board one of its vessels, says he does not feel as if his company is taking a risk.

"We saw that only a few things are new. Most of the equipment is well-known with proven performance. We do not see it as a problem that a new control system and new software is needed." Myklebusthaug is referring to the fact that while the new control system is DC driven, the AC-based components can still be plugged in.

"ABB is a strong company and we expect them to provide us with the best of the best. We count on their backing both before and after delivery of the vessel." Myklebusthaug adds that the company's reasons for fitting its next vessel with DC Grid are "purely economical". "With performance on a par with conventional diesel-electric propulsion systems, the most fuel-efficient vessel will always be the most attractive in the market."

With performance on a par with conventional diesel-electric propulsion systems, the most fuel-efficient vessel will always be the most attractive in the market.

By establishing a full-scale test setup "and doing a very good job of testing everything," Myklebusthaug says his company trusts that ABB is able to eliminate any problems before the onboard installation. "Without this confidence we would never have done this," he adds.

Perhaps a dose of friendly cooperation and trust would have served Edison better back in the 1800s. It may have prevented the AC/DC split, which looks set to come to an end on board the world's ships.

Text: Johs Ensby, Helen Karlsen

Arnstein Eknes, segment director for special ships at DNV

Rules do not block innovation

Bringing people together to share information is what the Norwegian classification society Det Norske Veritas (DNV) does every day. If a new idea like ABB's Onboard DC Grid means the rules need a rethink, then DNV is ready for the communication challenge.

Getting rules changed is about bringing people together to share information and develop a new, improved consensus, says DNV's Arnstein Eknes. This his organization does every day.

As a rule-maker, how does the classification society deal with groundbreaking ideas in the shipping industry that requires its rules to be changed?

The answer can be summed up in three words: communication, interaction and consensus.

As Arnstein Eknes, segment director for special ships at DNV, explains, "You need several parties involved to get the ball rolling. For a new standard to become relevant in the market, a lot of players need to participate."

"Rules exist for a reason. This is like a pyramid. At the top level, there is always a purpose or goal/objective, and at the bottom you should find the prescriptive and detailed rules that represent 'best practice.' When we have experience with technology, and learned what makes sense to ensure a design is safe, it is cost efficient to have rules codifying that experience. In the middle of the pyramid you find the functional requirements and their set of goals."

Between getting an idea for a new standard accepted and making new rules, there is a vital step: cross-disciplinary discussions.

"For a power distribution system like the Onboard DC Grid, we would like to see involvement from players such as equipment makers and designers, who need to understand how to integrate this into a ship's hull, for example. Multi-disciplinary groups should look at the new technology and how it will influence their own areas. The more discussions we can have to understand the different perspectives the better," adds Eknes.

He underlines the need to have a combination of specialist knowledge and general or more holistic competence represented in the process. Technology expert assessments should be combined with an industry-wide perspective on costs and benefits.

"Almost continuously prospective innovators visit DNV, where they team up with anything from five to 20 specialists, who have an opportunity to ask the innovator open questions directly," Eknes explains. "Normally we do not develop new rules just because we have a new technology. Most technologies we see can fit within the goals and purpose of the existing rules and standards."

If you come up with a technology and can prove that it is equally safe or safer but does not fit into the rules, we can still accept it. Rules should not be a barrier for innovation.

"However, once it is clear that an attractive new solution can not be certified according to existing rules, the development of new rules is the logical next step. This involves taking the idea to a wider external network."

For ABB, a key motivation in inviting DNV into a partnership for its Onboard DC Grid project was to start this process of formulating new classification rules and technology verification. The engineers on the project realized this would be necessary very early on.

"To initiate the formulation of new rules we create a proposal and activate a hearing process with different committees around the world," says Eknes.

"We have a group called the rule secretariat that is responsible for ensuring we are formulistic in the way we test the market. We ask our customers questions, give them time to be heard, make time to understand and ask more questions. This is a dynamic process. It should be open and inviting the people who really want to contribute in this area."

Eknes says hearing routines, both internal and external within the industry are important because they give the industry a chance to "criticize and improve our rules." The time involved in the process varies depending on the concerns being raised. A new solution with great benefits and no added risk will obviously be completed quickly compared to one where a lot of issues need to be investigated.

Eknes explains that DNV as an independent foundation invests its own resources into research alongside industry partners, as well as public funders, to fulfill its purpose of safeguarding life, property and the environment: "At any time we have 30-50 active industry projects. Some of them with one single partner, but more often with five to 20 cooperating partners sharing knowledge and costs."

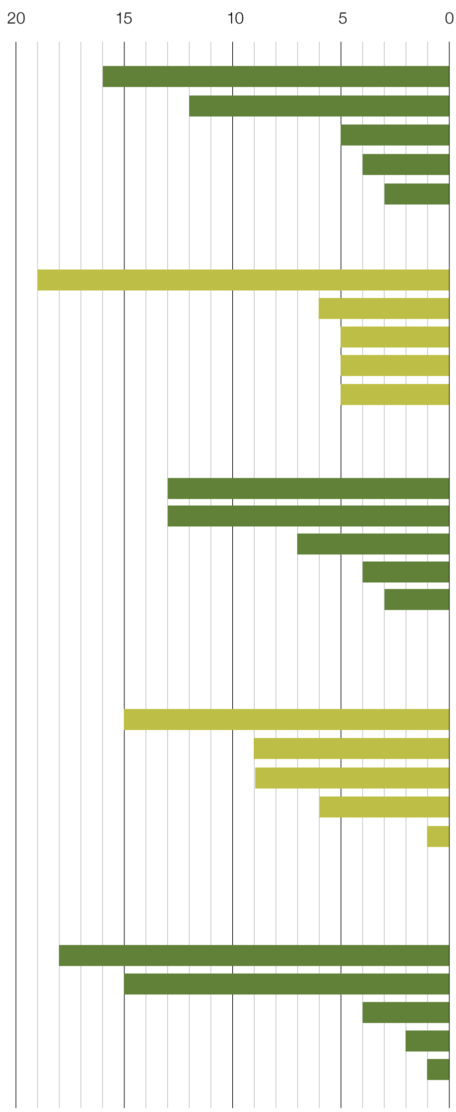
Rather than telling the industry what it can and can not do, DNV seems to facilitate a dialogue that provides an industry-wide quality assurance for new ideas.

For a technology provider, this shortens the time-to-market in two ways, according to Eknes: "Since rules should represent both purpose, goals for efficient use of resources as well as 'best practice' based on lessons learned, they give a sound structure to the decision making during development. Secondly, when a new solution finally obtains its certification, even against new rules, it is proven ready for a worldwide market."

Text: Johs Ensby, Helen Karlsen

Generations poll

We surveyed 40 students of maritime universities worldwide.
Here is what they think about energy efficiency.



Which one of these issues in shipping is the biggest threat to the environment?

Oil spills
CO_2, SOx and NO_x emissions
Disposal of garbage at sea
Ballast water discharge
Poor ship recycling

What is going to help reduce emissions in the future?

More efficient technologies
Increased use of sustainable energy
Governments tightening energy policies
Increase of pollution taxes
Awareness campaigns to decrease energy use

What do you do to address climate change?

Recycle
Ride a bicycle instead of driving
Buy locally made and grown products
Unplug unused electronics
Use energy efficient bulbs

What will be the main alternative power source at sea in the future?

Solar and wind
Biofuel
LNG
Nuclear
Fuel cells

What is the way forward for reducing energy consumption in shipping?

Alternative sources of energy (wind, solar, fuel cells etc.)
Improved energy efficiency
Reduced engine power
Improved voyage planning
Reduce the transport of goods by sea

Opening up LNG

Liquefied natural gas (LNG) promises increased energy efficiency, lower emissions and a stable resource base. With the LNG carrier sector booming, environmental legislation helping promote natural gas as a key marine fuel and steadily increasing demand for natural gas worldwide, the future has never looked brighter for LNG.

Tightening environmental regulation is one of the drivers for expanding the use of LNG as a marine fuel. It is increasing pressure on shipowners to find cleaner fuel alternatives for their fleets, and LNG has a clear environmental benefit over other fossil fuels as it considerably reduces emissions and has a significant potential for increasing cost efficiency.

There are still a number of logistical obstacles on the way of LNG becoming the fuel of choice for shipping. However, the international maritime industry and regulatory bodies, as well as the shipowners that pioneer LNG-powered shipping, are showing the way to cleaner, safer maritime operations.

The International Energy Agency predicts that LNG trade will reach record heights, almost doubling between 2006 and 2015 to 393 billion cubic meters a year. Rapid expansion of the global LNG capacity is leading more shipowners in the direction of the LNG carrier sector, and the technology is quickly catching up, offering alternative propulsion solutions that provide increased energy efficiency.

Should the technology necessary for driving LNG use and transportation continue developing at the same pace, natural gas may soon become the marine fuel of the future, helping the humanity meet growing global energy demands and making the world a safer and cleaner place.

Fuelling the future

The alternative

Pressed by constantly increasing bunker oil prices and tightening environmental regulations that require a significant reduction in emissions, the global maritime industry is looking more towards utilizing cleaner energy sources.

From 2015, vessels operating in the Emission Control Areas (ECAs) of the North European waters will have to comply with stricter environmental standards, bringing down the sulfur content of their bunkers from the present 1.0 to 0.1 percent. Later in 2016, progressive reductions in nitrogen oxide (NO_x) emissions from marine engines will call for stricter controls on engines installed on ships constructed on or after Jan. 1, 2016 and operating in the ECAs.

By 2020, under the revised Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL), environmental standards are to be strengthened further on a global scale, following a feasibility review to be completed no later than 2018.

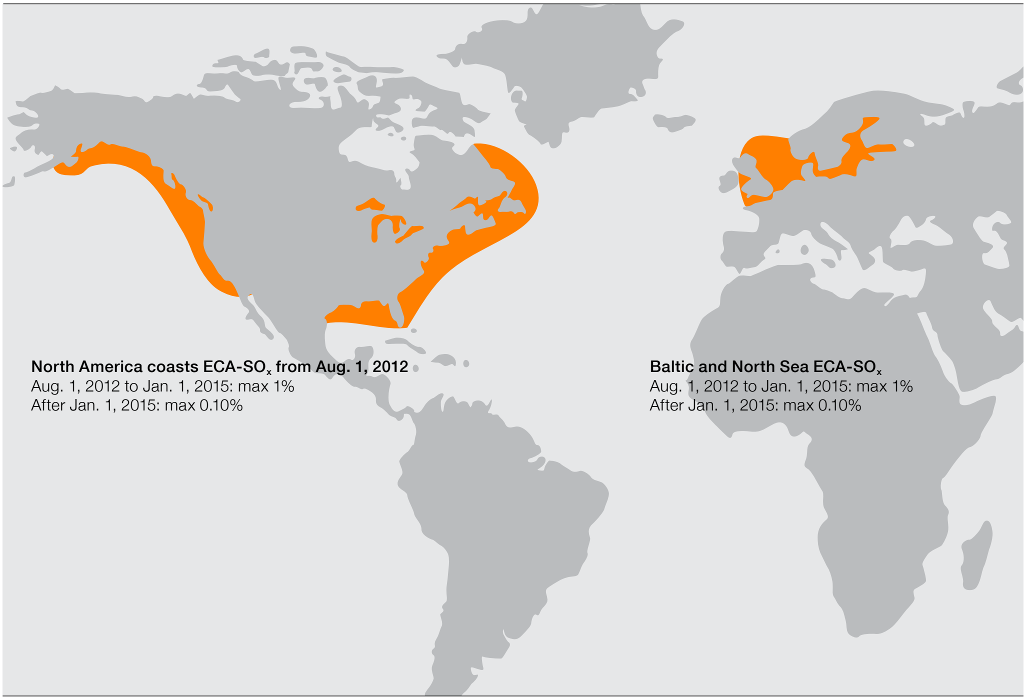
At the moment, shipowners have three main routes for meeting the ECA requirements from 2015 onwards. One is switching to low sulfur fuel, which only requires a number of slight modifications to the fuel system on board. However, the increasing demand for low sulfur fuel, combined with limited availability, is likely to drive prices up. Another alternative for shipowners is to introduce exhaust gas scrubbers that use seawater or chemicals to remove sulfur from the engine exhaust gas. Fitting a scrubber on board would require significant modifications and installing a fair amount of additional equipment. In addition, scrubbers require higher power consumption, which inevitably leads to increased CO_2 emissions.

The third solution is using liquefied natural gas (LNG) as an alternative to heavy fuel oil and marine diesel oil.

Environmental advantage

From an environmental standpoint, LNG has significant advantages over conventional marine fuels. According to Det Norske Veritas (DNV), utilizing LNG as fuel in lean-burn, four-stroke engines reduces the sulfur oxide (SO_x) and particulate emissions by up to 100 percent, NO_x emissions by approximately

Emission Control Areas (ECA)



90 percent and CO_2 emissions by approximately 20 percent. Cruise ships, smaller cargo ships and service vessels with auxiliary power are the ones utilizing four-stroke engines, which explains why most of the pioneering LNG-powered vessels belong to these categories.

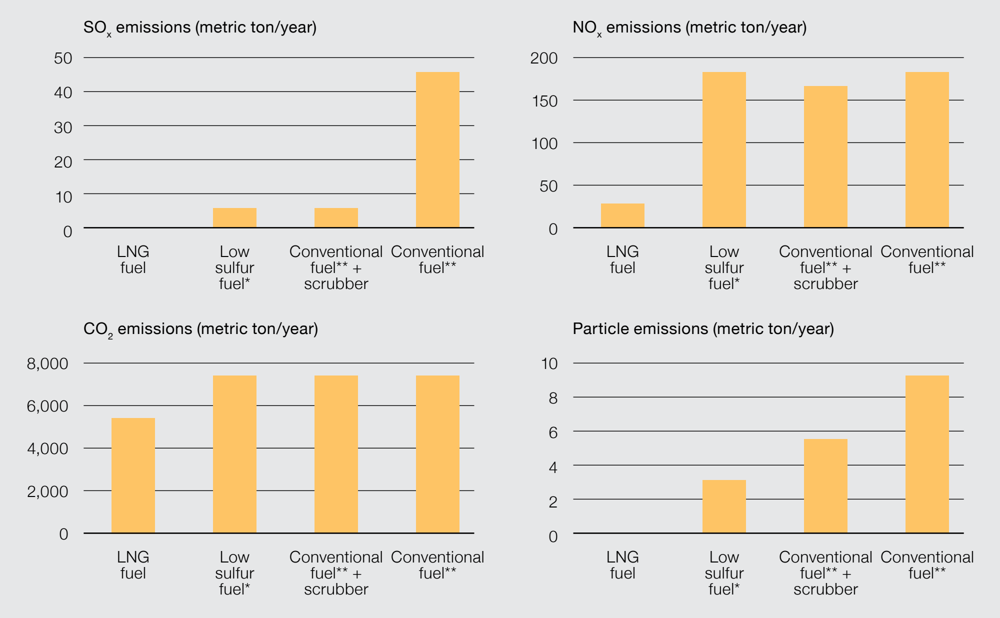
Cost efficiency

Even though newbuildings with LNG propulsion normally require an additional investment of up to 20 percent due to specially designed storage tanks and piping systems, LNG is still seen as a cost-efficient alternative to traditional marine fuels.

To demonstrate the economic advantage of LNG fuel, DNV has conducted a sample calculation on a cargo ship of approximately 2,700 gross metric tons, 3,300 kW main engine and 5,250 yearly sailing hours. Based on experience from ships built and currently under construction, DNV has calculated the additional investment cost for LNG propulsion to $3.6 million. It estimates that in a 20-year perspective, a conservative lifetime for a ship, the LNG solution would cost $4 million less than the scrubber option and $12 million less than the low sulfur fuel option.

By 2020, environmental standards are to be strengthened further on a global scale, following a feasibility review to be completed no later than 2018.

Environmental impact of LNG compared to other fuel options on a cargo ship of with 3,300 kW main engine and 5,250 yearly sailing hours



* Low sulfur fuel contains maximum 0.1% sulfur / ** Conventional fuel as per July 2010, containing maximum 1% sulfur Source: DNV

Understanding LNG

Liquefied natural gas (LNG) is natural gas that has been temporarily converted to liquid form for efficient storage and transport. Natural gas becomes liquid at –163˚C, when it takes up only 1/600 of the space of the gas. This source of energy, consisting mainly of methane, originates from multiple gas fields worldwide, and global reserves are still rich.

Source: DNV

Safety

LNG operations worldwide have a safety record exceeding 40 years. According to a report issued by Sandia National Laboratories, operated for the United States Department of Energy, over the past 40 years only eight accidents involving LNG shipping occurred worldwide. None of these have led to a loss of life or a breach of the vessel's cargo containment system.

Despite these impressive statistics, concerns for LNG safety still remain a sensitive issue, as Fotis Karamitsos, European Commission's maritime transport director, points out. According to Karamitsos, one of the main reasons for people's skepticism is bad press focusing on dangers and suggesting that LNG-fuelled vessels or LNG tanks for bunkering could be linked to gas explosions, while there have been no such incidents.

Scott W. Tinker, professor at the University of Texas and state geologist for Texas, also addressed the safety issue in an interview with *ABB Review* (issue 2/2011). He said people are still a little worried about the safety of LNG facilities and that there is still misunderstanding about the safety of LNG tankers.

Over the past 40 years only eight accidents involving LNG shipping occurred worldwide. None of these have led to a loss of life or a breach of the vessel's cargo containment system.

"Although it hasn't been tested yet – and I hope it never will – simulations show that even if you put a torpedo through the dual hull, the LNG would basically 'flow' out, change its state and burn," Tinker said. "That would generate a lot of heat and wouldn't be good for the immediate vicinity but the tanker wouldn't really explode like a bomb. The event would basically be self-cleaning. In some sense it would be preferable to an oil spill, which is much more difficult to contain and clean."

LNG challenges and solutions

Despite the appeal of LNG as one of the best solutions for complying with tightening environmental regulations, it still has a long way to go before becoming widely used as a fuel alternative for worldwide shipping. At the moment there are only 27 LNG-powered ships in operation, with 29 confirmed newbuildings underway. The majority of these vessels are either passenger or platform supply vessels operating on short-sea routes in the Emission Control Areas (ECAs).

Det Norske Veritas (DNV) estimates that by 2020, there will be 1,000 LNG-fueled vessels in operation. This prognosis is based on an assessment of the age of the world fleet, fleet renewal rates, expected fleet growth, expected adoption of competing compliance measures, as well as expected future fuel prices.

According to Lars Petter Blikom, segment director for natural gas at DNV, for this prognosis to become reality, the LNG infrastructure needs to be fully developed within the Emission Control Areas at big shipping centers and then gradually expanded to other areas. “This is already well underway in key places, such as Rotterdam, Zeebrugge, and Hamburg,” Blikom says. “There is quite a lot happening already on distribution networks and bunkering.”

Bilkom also believes that soon there will be a wider adoption of LNG as fuel not only for the passenger and platform supply vessels, but for the rest of the world’s commercial fleet. “This is already materializing. Currently, general cargo, Ro-Ro, high speed and light craft vessels with LNG propulsion are under construction. We expect larger deep sea vessels to become a reality in the near future.”

However, to reach DNV’s prognosis, the international shipping industry has to address a number of challenges linked to LNG logistics and infrastructure.

Lack of guaranteed fuel supply is one of the main obstacles. According to Blikom, one of the first steps that needs to be taken to address this issue is establishing a distribution system for LNG where it is most needed.

"One aspect is regulatory, and this is being solved with extensive risk analysis and standardization work currently being undertaken. Another aspect is commercial. There needs to be a certain demand before the establishment of infrastructure is economically viable. Incentives to kick-start this development are currently being discussed in several locations," Blikom says.

Fotis Karamitsos, European Commission's maritime transport director, believes that environmental regulations, as well as increasing oil prices, are the factors that can move LNG shipping forward. "This certainly will be the driving force that will let people choose the alternatives to fuels currently in use, with LNG being the most promising one at present," Karamitsos says.

The second issue, according to Karamitsos, is that both governments and industry need to be ready to invest in the infrastructure. "From our perspective here in the EU, we are certainly going to support projects on the infrastructure side of things," he says. Karamitsos believes that new bunkering facilities will appear and this will help accommodate short-sea shipping in an efficient way. Long-distance shipping will follow, he believes.

Even though at the moment the LNG infrastructure is much more developed in the Northern Europe than the rest of the world, Karamitsos says that first project studies are already commencing in other parts of Europe, including the Mediterranean. He believes that the rapid expansion of the LNG infrastructure currently taking place in the United States and Asia will contribute to the worldwide development of LNG shipping, possibly first for transatlantic routes and then in the Pacific.

Knut Ørbeck-Nilsen, DNV's chief operating officer of the Norway, Russia and Finland division, believes that both the technology and concepts are in place and with the current number of LNG-fuelled vessels in operation, the next step for LNG shipping has to be taken by the shipowners.

"As long as [the shipowners] do that, the LNG terminals will become more active in trying to find user-friendly solutions at affordable prices, and everything will start moving in the right direction," Ørbeck-Nilssen says.

Pioneering LNG

Companies operating passenger ships are leading the way in introducing LNG as a fuel, and one of the major pioneers in this field is Viking Line. The Finnish company that runs a fleet of ferries and cruise ferries on routes between Finland, Sweden and the Baltic countries, is currently building a new addition to its collection of vessels, the largest LNG-powered passenger ship in existence, *M/S Viking Grace*.

M/S Viking Grace will serve the Turku – Åland Islands (Finland) – Stockholm (Sweden) route. Even though the vessel is still being constructed at the STX Finland shipyard with an estimated delivery date of January 2013, it has generated so much public interest and has attracted such attention from the press, that many people have already booked their voyages on this newbuilding.

The LNG-powered vessel, representing a new generation of ferries, signals a new era in environmentally friendly shipping for a ship of its caliber – 218 meters in length, 57,000 DWT in tonnage and with an ice class of 1 A Super.

Viking Line estimates that the newbuilding will have 25 percent lower CO_2 emissions than if it was powered by marine fuel oil. The NO_x output will be cut by 85 percent and SO_x by almost 100 percent. This will make *M/S Viking Grace* compliant with the environmental regulations that will come into force in 2016 – the vessel will be able to sail without restrictions in the Emission Control Areas (ECAs).

The LNG tanks on *M/S Viking Grace* are located outdoors on the rear deck. This way, if gas would to come into contact with air, it would simply rise and be ventilated away. In cooled form, the pressure in the tank and piping system is very low, and the pipes are double-mantled. This means that no gas will be emitted in case of a leakage. Should a leak occur, the vessel's comprehensive gas detection equipment would shut off the system, further improving safety.

To reduce the vessel's fuel consumption and greenhouse gas emissions, Viking Line's new vessel will be equipped with ABB's energy monitoring and management system (EMMA™). It compares and analyzes the historical and current operational data of the vessel, then calculates and advises on areas for improvement with easy-to-understand displays. ABB's scope of supply to Viking Line also includes an extended energy management tool that models energy consumption and calculates optimal operating conditions, so that ships can perform at the highest possible fuel and energy efficiency.

"ABB has an innovative approach to saving energy, and one of our top priorities is to lower the emissions and fuel consumption for our fleet," Kari Granberg, Viking Line's project manager for *M/S Viking Grace* told *Generations*. According to Granberg, having both EMMA and most of the electrical equipment supplied by ABB makes it convenient to get the needed information from different consumers into energy management system and use the fuel efficiently from the first day of *M/S Viking Grace*'s operation.

Talking about the potential for a wider adoption of LNG as a fuel not only for ferries and platform supply vessels, but also for the rest of the world's commercial fleet, Granberg says there are still a number of impediments standing in the way. Since LNG tanks take up to four times more space and some extra weight, compared with conventional fuel tanks, a vessel would lose cargo capacity or, alternatively, have to take less fuel on board, thus only being able to take up shortsea routes. Granberg believes there will soon be new solutions introduced to the market that will help solve this problem.

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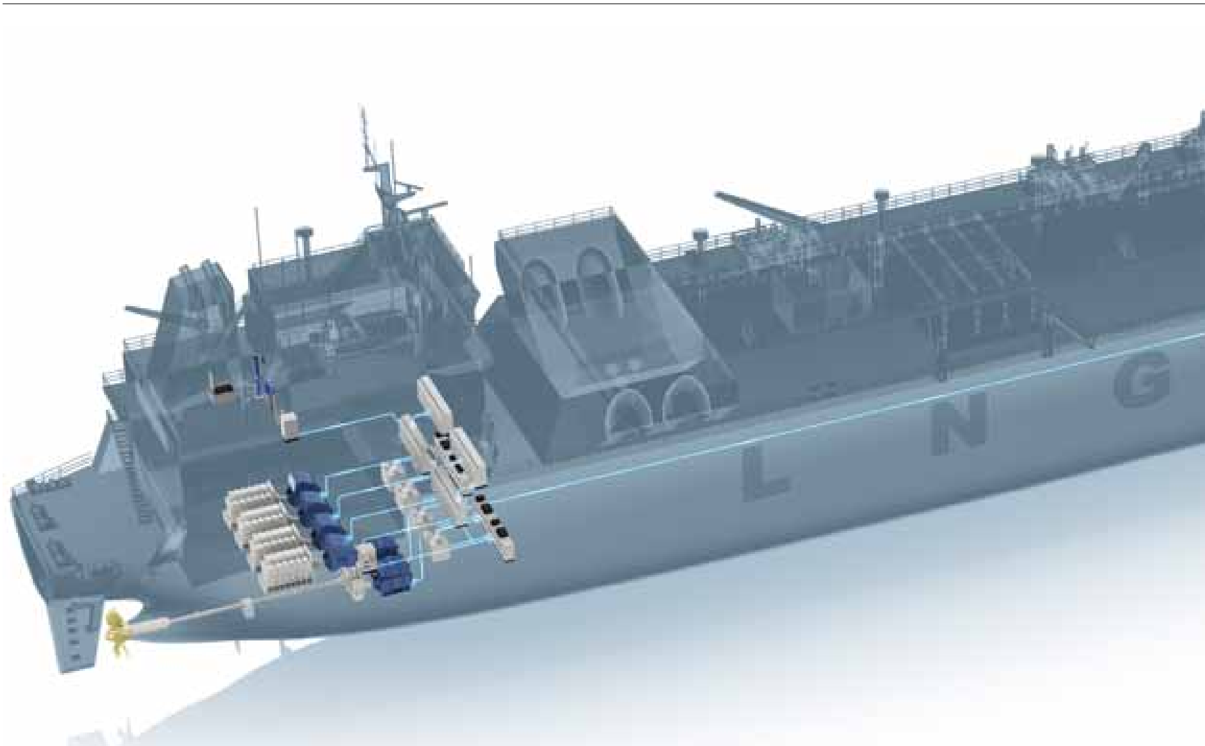


LNG transportation: sea of opportunities

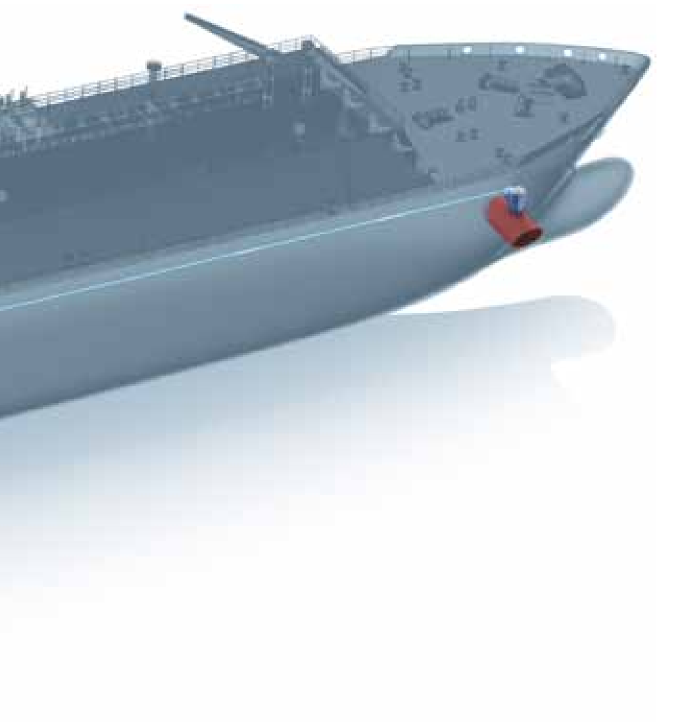
More and more shipowners are attracted to the liquefied natural gas (LNG) transportation market, as this segment offers appealing growth opportunities. The number of LNG newbuilding orders is set to grow to match the expected expansion of LNG availability, and rapid developments of LNG as one of the main shipping fuel alternatives, together with and an increasing long-term demand for natural gas worldwide, create a need for growth in the LNG transportation sector.

In its World Energy Outlook 2011, the International Energy Agency forecasts a golden age for natural gas, with 60 percent increase in demand globally between now and 2035. The world's commercial fleet is rapidly catching up with its LNG carrier newbuildings to meet this demand.

According to Golar, one of the world's largest independent owners and operators of LNG carriers, the worldwide LNG fleet currently stands at 365 vessels including floating storage and regasification units (FSRU), with a further 80 on order including FSRUs.

As predicted by Golar, substantial new supply of LNG is anticipated from Australia in the period 2014 to 2015, which will require significant additional shipping capacity. Additional LNG transportation capacity will also be needed to support the development of new liquefaction capacity, as well as the growing short term and spot LNG trading business, which Golar estimates to be between 18-22 percent of the overall LNG trade. Further development of the LNG export capacity in the United States will also contribute to the increased demand for tonnage.

Golar has recently placed an order for four additional carriers, which brings the total number of newbuild orders to 13 vessels. "It appears to be a good market out there," Hugo Skår, Golar's chief technology officer, told *Generations*, reflecting on the current outlook for LNG transportation companies. "We believe that there is a possible outlook both for demand and production, and have accordingly ordered more vessels. It needs to be controlled, of course, so that there is no oversupply of the shipping capacity."



Typical configuration of an LNG carrier

Dual-fuel electric propulsion has two main core technologies: dual-fuel four-stroke engines and the electric propulsion system. In close cooperation with engine manufacturers, ABB provides electric propulsion system arrangements to meet individual customer requirements and redundancy concepts for both single- and twin-screw LNG ship designs.

The LNG carriers fleet worldwide is moving from steam turbines to alternative propulsion solutions that provide more fuel flexibility and increased energy efficiency. According to the statistics released by *Marine Propulsion & Auxiliary Machinery*, up until 2006 all newbuilding LNG carriers of 18,000 cubic meters and above were provided with steam turbine propulsion units, with only 50 percent of the 184 new LNG carriers that have entered service since January 2006 being steam-driven.

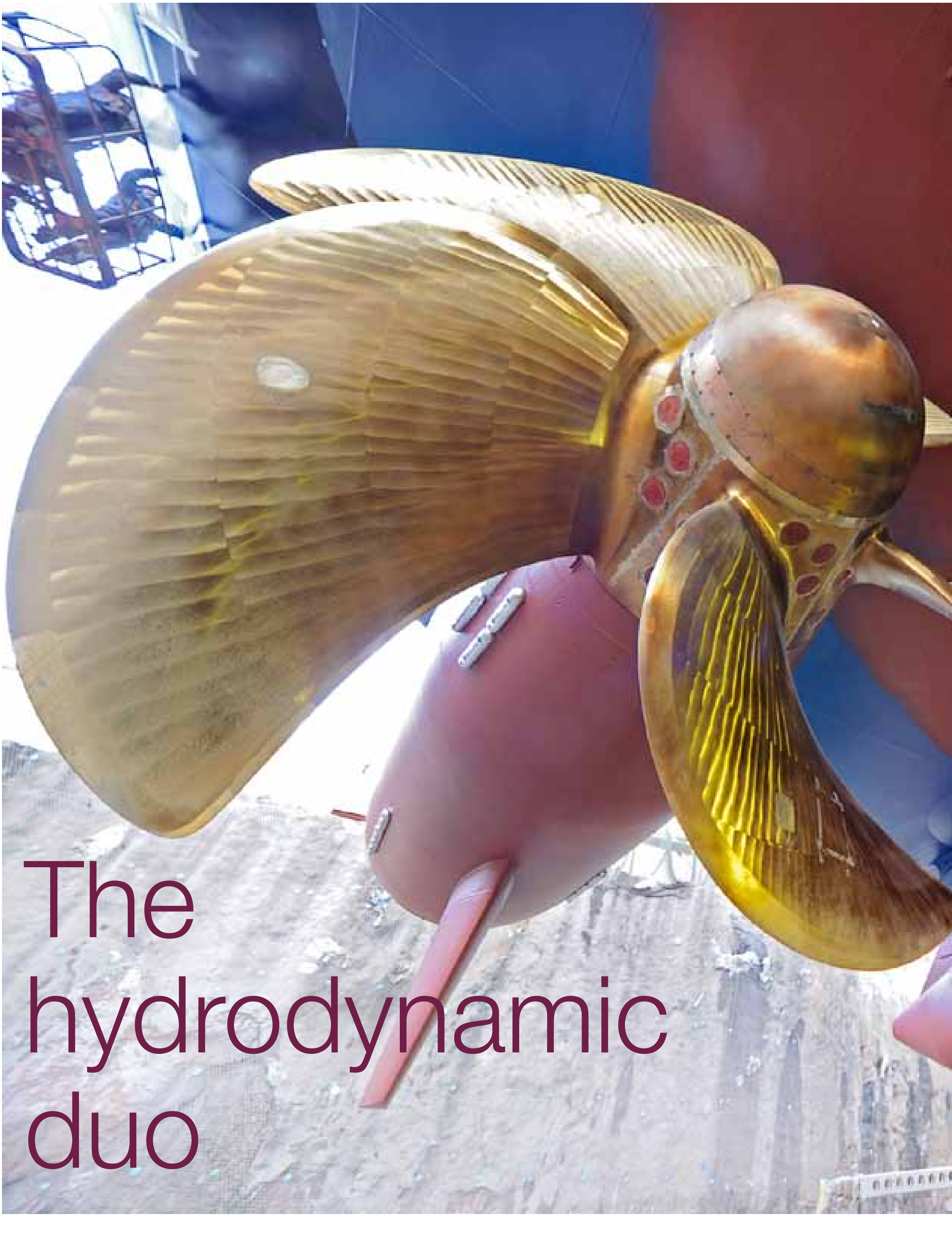
Skår believes that the main incentive that motivates the shipowners to make this shift is the possibility of increasing fuel efficiency. “The other factor has been that the technology for using natural gas for powering engines was not properly developed until recently. As soon as the technology was in place, we saw a shift towards lean-burn diesel engines running on gas. I will not be surprised if the next step will be taken towards two-stroke engines running on gas, which will be more efficient than the high-speed engines that are in use now.” Skår says.

According to Skår, the best technology available today for increasing fuel efficiency in LNG carriers fleet is dual-fuel diesel engines used in combination with electric propulsion systems. Eleven out of the 13 newly ordered vessels are so far confirmed to be equipped with ABB’s power drives. “This will be the first time we introduce dual-fuel engines in our fleet,” Skår says. “Dual-fuel propulsion systems are the future for LNG transportation.”

The first large-size LNG carrier equipped with dual-fuel electric propulsion provided by ABB was launched back in 2006. Since then, numerous new LNG carriers have been delivered with dual-fuel electric propulsion. Some of the main advantages of electric propulsion include lower fuel consumption across the whole speed range, increased environmental sustainability, reduced installed power, enhanced maneuverability and crash stop, variable speed drives ensuring full flexibility in torque, revolutions per minute and power output at the propulsion motor and last but not least, reliability and availability through high propulsion redundancy and standardized, well-proven technology.

Text: Margarita Sjursen

Photos: Shutterstock, Viking Line



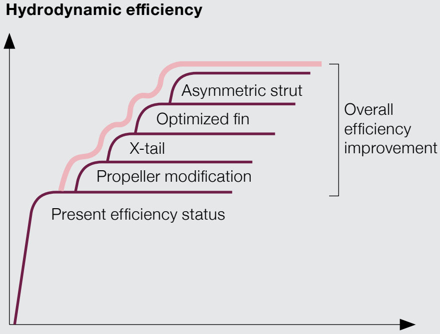
The hydrodynamic duo

Today's best hull forms are so well optimized that it is impossible to make major energy efficiency gains. But significant improvements are still possible – for both cruise ship and Azipod® hulls alike.

Royal Caribbean's new, still unseen class of ships, known as Project Sunshine, has created quite a buzz in cruise. Ship design and engineering experts Foreship and electric propulsion providers ABB have been privileged insiders to the design and construction process at Germany's Meyer shipyard. Although the two companies have partnered up on many cruise ship projects, Project Sunshine is their closest cooperation to date. Hydrodynamically optimized hull design is their common passion.

The cruise ship *Oasis of the Seas* is equipped with Azipod

It was the hydrodynamically optimized hull design of its new Azipod XO that secured ABB the propulsion contract for Project Sunshine. Building on its successful "Rethink the Azipod" program, ABB modified its Azipod propulsion unit frame design in early 2011 to improve hydrodynamic efficiency. The modifications include new strut and fin structures and the addition of X-tails to the pod cap, all designed to deliver the same thrust with lower energy usage.



Azipod Hydrodynamic Optimization offers several new solutions for improved efficiency of Azipod operation. The structural changes in the strut, fin, and pod cap enable the same thrust while the Azipod propulsor uses less energy. The propeller modification is designed to improve the propeller's hydrodynamic efficiency. The new optimization solutions can also be delivered separately, but the best result can be expected when they are implemented simultaneously.

Janne Niittymäki is head of hydrodynamics at Foreship. Prior to joining Foreship, he worked at Deltamarin, where he held the position of senior specialist of hydrodynamics.

The potential saving on fuel consumed for propulsion in large cruise ships can easily be a million dollars a year.

Freedom for shipyards

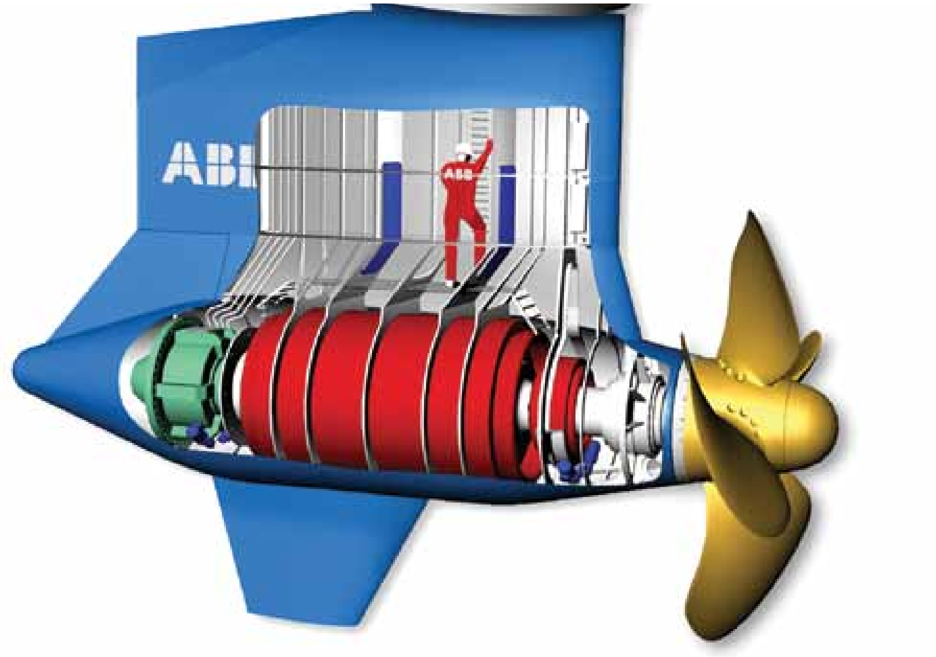
Royal Caribbean's *Radiance of the Seas* was the first cruise ship to utilize the new Azipod modifications, which were completed during her drydock in May 2011. Her sailings from May to September demonstrated a hydrodynamic efficiency improvement of more than 2 percent, compared with a sister vessel and her previous operational portfolio.

As Janne Niittymäki, Foreship's head of hydrodynamics, explains, one of the major advantages of Azipod propulsion is the freedom it allows in hull form design compared with conventional shaft lines. Shipyards benefit not only from flexibility in integrating the Azipod into the ship hull, but also from easier installation due to modular construction and avoidance of high-pressure hydraulics in the steering system.

"The full potential of this has only just been utilized on the very latest cruise ship projects projects," says Niittymäki. "ABB and Foreship have encouraged shipyards to design pod-optimized hull forms, even designing a cruise ship hull form for podded propulsion, carrying out propulsion model tests and giving the results to the shipyards."

It is here that one of Foreship's specialties comes in. Computational fluid dynamics (CFD) calculations, especially in full-scale simulations, hold the secret to small but significant hydrodynamic improvements that can generate significant fuel savings.

Azipod XO main components and new features



Hydrodynamically best

Although Niittymäki says that estimating the energy and cost savings from pod-optimized hull forms is complicated because every ship is different, he maintains that the potential saving on fuel consumed for propulsion in large cruise ships can easily be a million dollars a year.

Commenting on the cruise industry's level of confidence in Azipod, Niittymäki says that it differs from one cruise line to another, but has certainly improved.

"Some owners still remember the reliability problems of many years ago, and therefore do not want pods. However, most cruise owners agree that, hydrodynamically, pods are the best propulsion option." And on one topic Niittymäki is unequivocal: "Azipod still has a role to play in improving the energy efficiency of cruise ships."

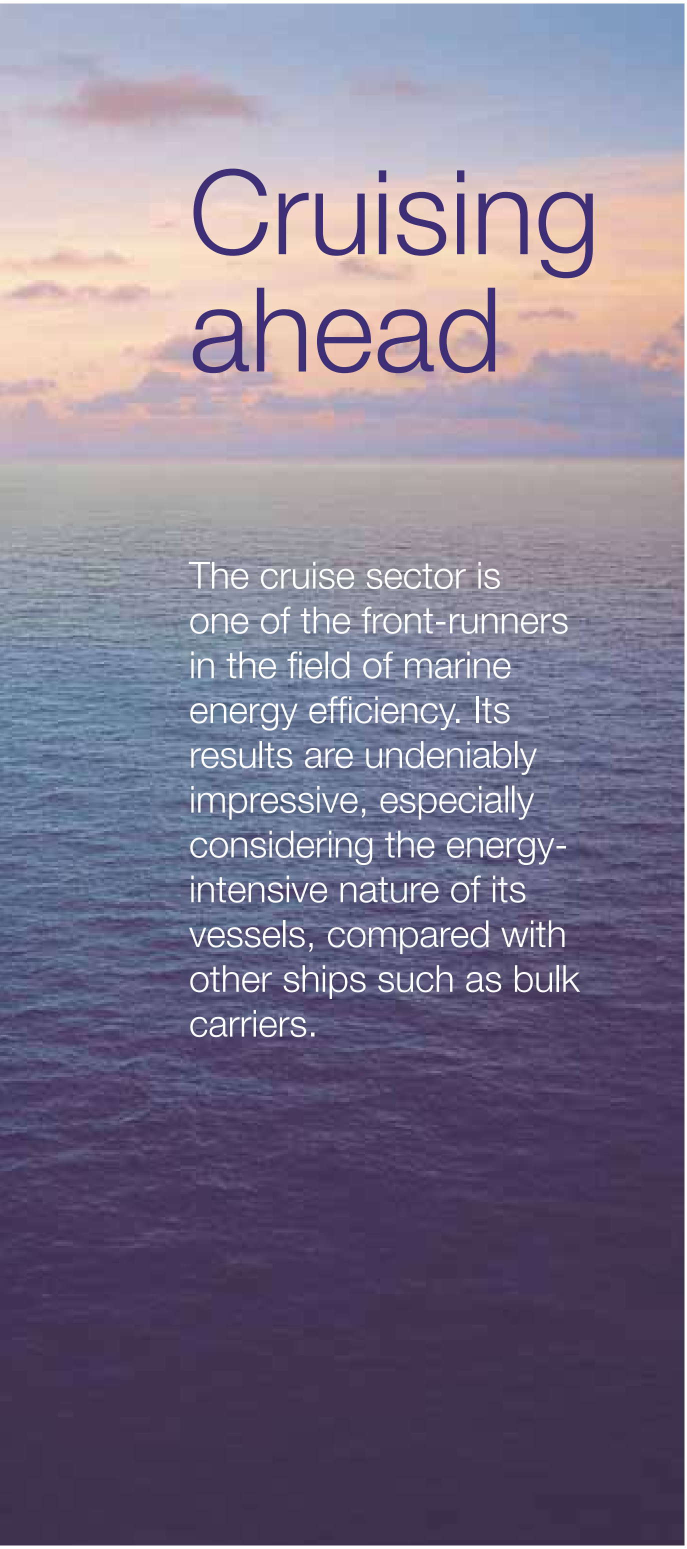
Text: Kevin Reeder

Photos and illustration: ABB

Foreship

Foreship is a highly respected ship design and engineering company known for its expertise in challenging large-scale conversion projects, structural engineering, newbuilding concept designs and expert hydrodynamics. Its staff of naval and interior architects, marine, structural and electrical engineers, and HVAC (heating, ventilation and air conditioning) designers are based in Helsinki and Turku.


STAR CRUISES



Cruising ahead

The cruise sector is one of the front-runners in the field of marine energy efficiency. Its results are undeniably impressive, especially considering the energy-intensive nature of its vessels, compared with other ships such as bulk carriers.

Cruise lines experience the same key business drivers that encourage energy-saving initiatives in other vessel sectors — bunker prices and environmental legislation — but they are also subject to increasing customer and societal expectations. A highly visible industry and an optional form of shipping, cruise is an easy target for criticism.

Passengers increasingly expect cruise lines to demonstrate green credentials, and they seem willing to pay extra for good conscience. Conversely, a perception of poor environmental standards can be disastrous for a cruise company's brand equity. And although cruise can compare favorably with land-based vacationing on energy efficiency and emissions, especially for countries not signed up to the Kyoto Protocol, it can still make major improvements.

Lloyd's Register has suggested that with changes to financial parameters such as fuel prices, charging for CO_2 and a reduction in unit cost of new technologies, the cruise industry's potential energy savings can be up to 40 percent in the medium to long term.

Myriad solutions

As the number of cruise passengers continues to grow, cruise lines are investing in new technology to reduce their footprints. The industry's goal, backed by organizations like Cruise Lines International Association (CLIA), is to make cruise ships the most eco-friendly way to travel. Breakthrough ship design and technology is being incorporated in newbuildings and also to upgrade older ships.

Energy efficiency opportunities for a cruise ship are many. Jukka Ignatus, sales manager at ABB, suggests shipowners begin with the easiest measures to implement, such as dynamic trim optimization, power plant optimization and hull and propeller condition management plans. “Savings naturally depend on how efficiently the vessel has already been operated,” Ignatius says. “But a fairly efficiently operated vessel can get energy savings of around 3 percent from trim (for propulsion energy in the speed range where dynamic trim has an effect, ie, over 10 knots), and a minimum 1.5 percent of total produced energy with power plant optimization. It is difficult to estimate for hull and propeller condition management, but considering hull fouling can cause added resistance up to 10 percent, we can safely say that combined savings are over 4 percent of total energy consumption.”

CLIA estimates modern hull designs can give up to 15 percent energy savings and ecological hull coatings up to 5 percent. Reverse osmosis systems on RCL ships like *Oasis of the Seas* use only 35 percent of the electricity older vessels used to process potable water. The ship design and engineering company Foreship estimates that reducing sailing speed from 22 knots to 17 knots can reduce propulsion fuel consumption and emissions per nautical mile by almost 50 percent.

With advanced energy management systems becoming more common, more ships plugging into shore-side power and the advent of alternative fuels like liquefied natural gas (LNG), the energy efficiency trend seems set to continue.

As Tore Longva, business development manager at Det Norske Veritas, explained to *Generations*, “The cruise industry will be a forerunner for many new technologies that increase efficiency, especially power production, renewables and hybrid systems. We also expect increased efficiency through the combination and integration of onboard systems, such as waste heat recovery, HVAC (heating, ventilation and air conditioning) and power production. In addition, new types of fuel, such as natural gas and biofuel, will come into play.”

Leading star

One of the cruise pioneers in energy efficiency, Star Cruises has spent eight years relentlessly seeking energy savings through a program that now features some 100 different measures.

Started in 2004, the energy efficiency program ranges from small measures with no costs attached to complex processes requiring investments of several hundred thousand dollars per vessel. Star Cruise’s main goal has been to implement as many energy saving steps as possible, as long as the payback time is less than two years. Investments with a payback time of less than a year generally get an automatic go ahead. To date, the program has cut fuel consumption and created savings of more than $7 million per year. *Generations* spoke to Mikael Mattsson, vice president of marine operations at Star Cruise, the man at the helm of most of its energy efficiency projects and innovations.

Q: What were the business drivers that led Star Cruise to develop its energy saving program?

A: It began with a cost-cutting exercise. Towards the end of the 1990s, the cruise segment was struggling and we were obliged to make some savings, not only on fuel but also across the board. This was compounded by fuel prices starting to rise in 2000 and really taking off in 2002.

Although energy efficiency and fuel savings always give positive environmental payoffs, this was not a major driver in Asia when we began the program. However, the cruise segment is naturally more sensitive about emissions and green thinking than other vessel segments, and I certainly expect emissions and environmental factors to become future business drivers in Asia too.

Q: Does the program reflect the company’s business model and values?

A: Our motto is: “We take pride in our work and actively seek new ways of doing things better.” One way to ensure this is to have very dedicated crews. We only employ the very best marine officers and we have an incremental salary system to help retain them – none of our captains and chief engineers has been with us for less than 12 years.

Superstar Virgo

The combination of skills from experienced captains, chief engineers and electricians is important for achieving energy-efficient cruising. It is a complicated team task that involves all officers on board the vessels. Our crews are the major force in our energy efficiency efforts and have taken a lot of initiative with testing, observing and fine-tuning systems. On the other hand, we always put safety of passengers and crew ahead of fuel saving or cost cutting. I think we have one of the best safety track records in cruise, especially considering we are regularly in and out of the two busiest ports in the world, Singapore and Hong Kong.

Star Cruise's main goal has been to implement as many energy saving steps as possible, as long as the payback time is less than two years.

Q: Has your across-the-board approach to energy saving started a cruise industry trend?

A: Energy efficiency is certainly a trend, but cruise lines differ considerably from region to region and therefore have different energy efficiency challenges and strategies. For example, in the Asia-Pacific, our itineraries differ from those of cruise companies in the United States, Europe and elsewhere. We do a lot of short cruises and shorter distances between ports and this means many varying speed profiles, including slow cruising, rifting and anchorage. Itinerary planning is an important fuel-saving measure where we have to strike a balance with passengers' need for enough time in ports, so it involves close cooperation between marine operations and sales and marketing staff.

Superstar Virgo

Q: What are the more than 100 energy-saving measures?

A: There are many opportunities to save, especially on older vessels. Apart from frequency converters on pumps and fans – which we have installed throughout the fleet and can reduce energy consumption by up to 60 percent – we are talking about many internal processes.

The key element is HVAC (heating, ventilation and air conditioning). All our newer vessels have automatic HVAC systems, and we are automating our older vessels to correlate HVAC with air conditioning compressors and chiller and cooling water pumps.

The effects of trim optimization and underwater hull optimization on fuel consumption are well-known, but less well-known is the effect on engine loads. If you create a better hull shape and reduce drag it can save around 10 percent on fuel, but it also means 10 percent less load on the engines. A reduced base load means that you can switch down one engine and run two engines on full load, where they are most efficient, instead of three engines on 60 percent load.

This is where the big gains are. You can always save 50 kilowatts here and 50 kilowatts there, but if you can take one engine offline it can lower the average power consumption of a vessel by 10 to 15 percent.

Our 75,000-ton *SuperStar Virgo* is a good example. Her engines were 12 MW each. When she came to Asia, they were running at 10.5-11 MW, with full air conditioning and everything. After all the fuel-saving initiatives were done, including the HVAC scheduling, we were down to 8 megawatts. The measures included fuel optimization and dynamic trim tools as decision-support for the bridge crew, an anti-fouling system and improving the hull hydrodynamics.

Before considering dry-docking any vessel from now on we will do underwater CFD (computational fluid dynamics) hull simulation to see if we can improve hull performance – establish stern and bow thrusters, pockets and tunnels, eventually maybe even ducktails. On *Virgo* we modified the stabilizer pocket and achieved around 3 percent fuel savings at some speed profiles. Of course, adding a ducktail to an existing vessel is an expensive option, but we are running a trial to assess the potential savings from the improved hull performance. We believe *Virgo* is now close to optimal energy efficiency. At the next dry-docking, we will take the final step by installing new propulsion enhancement.

Energy for propulsion is a major cost in cruise. For propulsion efficiency and maneuverability there is nothing that can compete with Azipods. They are excellent fuel-saving devices due to the hydrodynamics of the propeller flow, and we will use them on our next newbuilding.

Q: How do you decide which energy-saving measures to prioritise?

A: I have to estimate the savings from any automation or efficiency system. However, in choosing a system, what is more important than its cost is its performance – including how it interfaces with other onboard systems – as well as the existence of a good service organization in Asia.

We have installed NAPA Power routing systems on *Virgo* and *Libra* for energy efficiency and will soon have three more optimization programs running for trim optimization and stabilizer control. Trim optimization systems are difficult to implement across the fleet because they are difficult to interface with old equipment on older vessels, and this becomes costly and delivers inaccurate results. On older vessels, it is better to use a less advanced system – potential savings can be less but problems are less too so we save time and effort.

On a new vessel, it is much easier to implement an advanced system like EMMA™, the ABB one. Being plug and play, these systems get you up and running quickly and allow you to show crew accurate results, so they quickly feel confident about using them.

Q: Have you investigated new energy sources?

A: Yes, we are looking into efficiency gains from alternative fuels. We are participating in a workshop in Singapore on a small-scale LNG operation where LNG will be used as fuel for conventional ships, including passenger vessels. Led by Det Norske Veritas and with participation from a number of other major industry players, we are discussing topics like LNG bunkering – not only for LNG carriers but also for commercial shipping. At the moment there are no LNG bunkering stations in Southeast Asia. Singapore (SLNG) will be the first station for bunkering, with facilities planned to be in operation by late 2013.

We believe in LNG as the future propulsion fuel for the shipping industry, but there is still a long way to go before it can guarantee full safety for passengers and crew. The biggest obstacle is the bunkering sequence, which can be very complicated.

Q: What other new energy-saving measures do you have on your drawing board?

A: I'm evaluating retrofit replacements of conventional diesel engines with common rails to improve efficiency. We will probably commence a pilot project with two engines in February 2013.

Mikael Mattsson is AVP Marine Operation at Star Cruises and a specialist in marine new buildings, retrofits, refurbishment and electrical projects. He is passionate about marine industry efficiency and has managed most of Star's energy efficiency projects and innovations.

Star Cruises

Star Cruises, the world's third largest cruise company, has led cruise development in the Asia-Pacific region, where it operates seven vessels between the ports of Singapore, Port Klang (Malaysia) and Hong Kong. Star caters to Asian passengers as well as to North Americans, Europeans and Australians interested in Asian destinations. Its energy saving program has given Star Cruises a best-in-class status in the cruise industry.

Text: Kevin Reeder

Photos and illustrations: Star Cruises

Inevitable change

“It should have happened long ago, it needs to happen now,” says Jens Lassen, managing director of Rickmers Shipmanagement and global head of Rickmers’ business unit Maritime Services, referring to a restructuring of how container ships are designed and operated. *Generations* presents a front-runner’s perspective.

Lassen's background is from the cruise industry, a segment where customers' needs and preferences define the product. Since he joined Rickmers in 2010, he has been part of the team streamlining a shipowner and operator with more than 175 years of tradition into a corporation at the center of the change the container shipping industry is about to undergo.

It all starts with the existing fleet

When it comes to achieving significant efficiency gains, Lassen believes that the existing fleet has a certain potential. "The fuel bill today can make up as much as 88 percent of a container ship's operating cost. Even carriers with fuel bills of billions have not fully tapped or systematically worked on energy reduction measures," Lassen says.

According to him, it is possible for existing vessels to achieve energy reduction of up to 10 percent through a combination of technical and operational changes. This could potentially help some shipowners save hundreds of millions. "We offer energy efficiency improvement as a product and are beginning to implement a sharing of the savings we and a charterer or a carrier can achieve. The majority of the savings goes straight to our customers' bottom line," he says.

When it comes to inspiration on operational efficiency, Lassen points to the tanker shipping industry. "Oil majors like Exxon Mobil, Texaco, Chevron, Shell and BP require the shipowners to meet the Tanker management and self assessment (TMSA) requirements. If you do not comply, you do not get cargo."

Container ship management has lagged behind tankers in terms of performance standards, and Lassen thinks it is important to bring the container shipping up to and even beyond the point where the tankers are at the moment.

The new design team

When it comes to identifying the key stakeholders in bringing about the new generation of container ships to the market, Lassen is certain about whom he would target first. "We need to ask our charterers to share their expectations and knowledge with us," he says. He believes it is vital to understand the charterers' and carriers' long-term vision. By seeing the future through their eyes, Rickmers plans to develop specifications that match demand not only for today, but also for the future.

Jens Lassen is global head of Rickmers Group's business unit Maritime Service and the managing director of the newly established company Rickmers Shipmanagement, where he is responsible for technical fleet management, purchasing and logistics, fleet personnel and risk management.

The fuel bill today can make up as much as 88 percent of a container ship's operating cost.

Other important players that should be involved from the beginning are ship designers. “With shipyards now more open to new designs, our customers will expect that we bring new, more radical design ideas to the table,” Lassen explains.

The technology providers also need to be part of the process at the design stage, ensuring that equipment modules are provided in well-integrated packages. “We expect system providers like ABB not only to take responsibility for the maintenance of their equipment and training, but also to take part in the financing,” Lassen says.

What about the yards?

According to Lassen, Rickmers’ goal is to work with partners that focus on the life cycle performance of the ship, jointly develop innovative designs and then find the right shipyard.

He regards the South Korean yards as extremely successful in streamlining their production. “I worked in Korea in the first half of the 1980s, and until very recently, the yards there have been building ships with almost the same designs. Their attitude has been very much a function of a long period of a sellers’ market. Some of the equipment may have improved, but there are few improvements that are fundamental. We are now beginning to see a change due to the lack of newbuild orders and the recognition that changes are inevitable due to the high cost of fuel.” Lassen is not, however, sure that the shipyards in South Korea, China and Japan are yet ready to design the ships needed for the future, as they might not have the technological ability to do so.

Increasing demand through improved efficiency

Some may think of container logistics as highly optimized, but Lassen disagrees. “I do not think it is optimized yet to the extent possible. Everything from trade routes to port facilities can be improved.” He believes that reduced handling time at terminals, effective door-to-door logistics through integrated multimodal networks and significantly improved reliability still have a way to go. “Companies with a long-term perspective need to get together to design and build ships with at least 30 percent energy efficiency improvement and outperform land-based transport in terms of environmental sustainability,” Lassen says.

Text: Johs Ensby, Margarita Sjursen

Photos: Rickmers Group

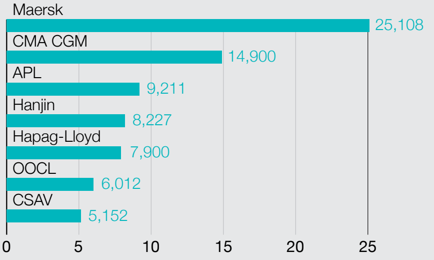
The link between finance and carrier capacity

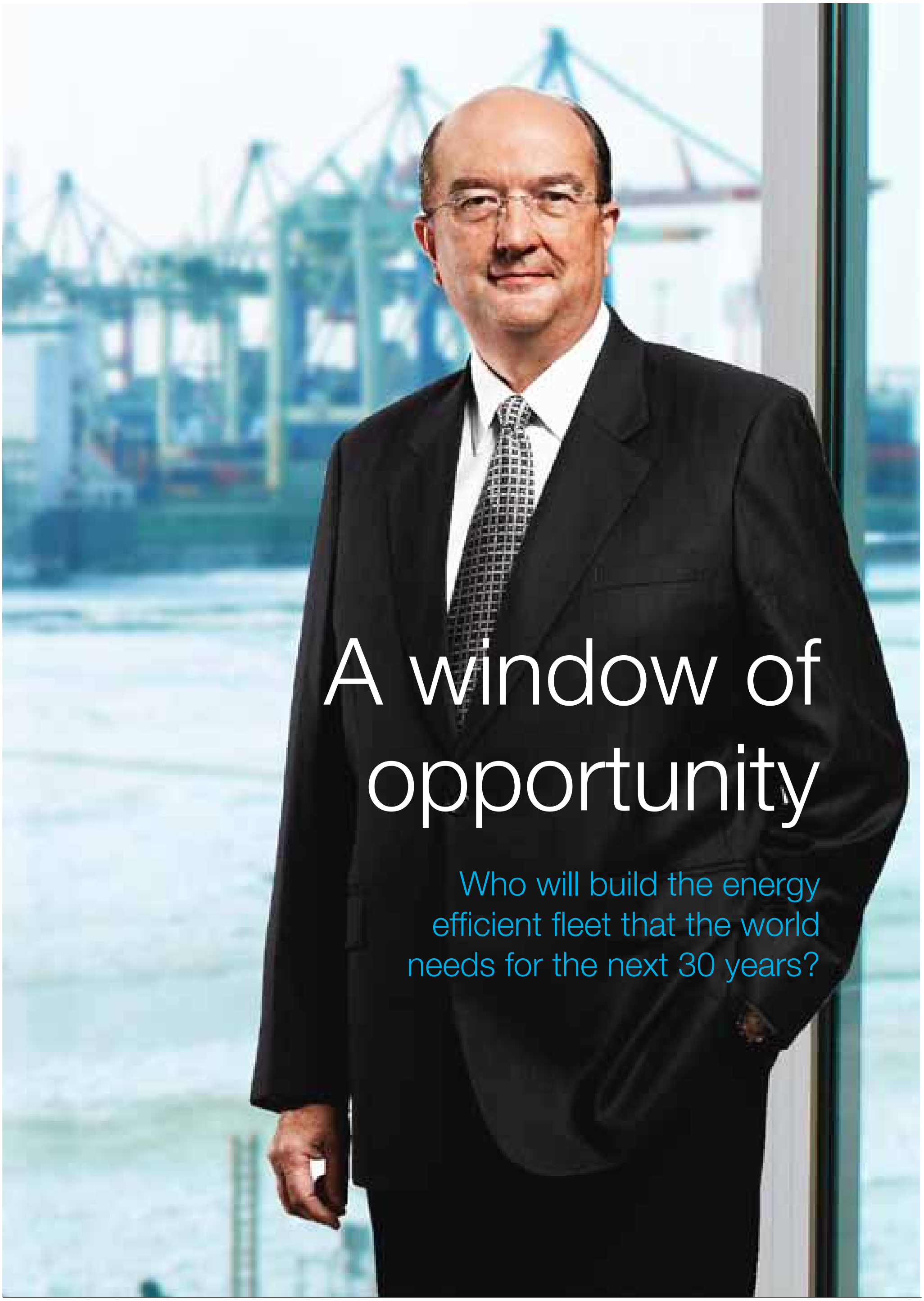
The big cargo handlers like Maersk, CMA CGM, Mitsui O.S.K. Lines and Hanjin Shipping have developed into logistics specialists that operate supply chains through a sophisticated network worldwide, with Rickmers as a major provider of tonnage.

As one of the leading shipowners and managers, the Rickmers Group operates a fleet comprising more than 120 ships with a current market value of over $3.2 billion. Thirty-seven ships are owned by Rickmers. At the center of this fleet are 88 container ships from smaller vessels to very large container vessels (VLCs) with a capacity of 13,100 twenty-foot equivalent units (TEU).

When the world’s largest container vessel, with the Maersk logo painted on its light-blue side, makes a port of call, the ship is likely be one of the eight 13,100 TEU container ships operated by Rickmers. Owner Bertram Rickmers has set Rickmers a goal to be a one-stop provider between the capital and the charterer.

Top 7 carriers 2011





A window of opportunity

Who will build the energy efficient fleet that the world needs for the next 30 years?

Ronald D. Widdows, CEO of Rickmers Holding and Rickmers-Linie

Before joining Rickmers Group in April 2012, Ron Widdows was the group president and CEO of APL and Neptune Orient Lines. Widdows is currently the chairman of the World Shipping Council that represents approximately 90 percent of the global liner vessel capacity.

Rickmers Group headquarters in Hamburg

There has been a series of events that affected the container shipping market in a way that no one saw coming. According to Ronald D. Widdows, CEO of Rickmers Holding and Rickmers-Linie, it all started with the world financial crisis.

"Container carriers started losing their shirt, they stopped ordering ships, the shipyards began to see utilization gaps developing, the carriers continued to see losses in 2011 and 2012," Widdows says. As he explains, in addition to all that, carriers switched to slow steaming in 2009 to save fuel. This was seen by some as a temporary contrivance, but later became the way forward due to high fuel cost and the freight rate pressure.

"If you slow down your assets as a permanent way of operating, you can change the design of the ship. Since the shipyards do not have a large order book beyond 2013, they are now willing to build ships that are much more fuel efficient – both fat and slow," Widdows says.

Growth ahead

Widdows believes that the world markets will grow. Global demand that drives the need for container ships is increasing, and there will be a need for more tonnage. Consequently, any oversupply of ships will be reduced over the next few years, even with the moderate rate of trade growth that global markets are likely to see for the next few years.

"The supply will tighten in the next two to three years. At the same time, there will be a requirement for new and more efficient tonnage," Widdows says.

The number of ships is to a degree irrelevant to some carriers

When it comes to carriers that wish to improve their cost structure, Widdows believes that the fact that there are too many container ships worldwide is not that relevant to their decision making.

"They are not concerned that there is an oversupply of ships in the world today and for the next couple of years; they have to bring down their costs, and fuel consumption is a major driver," Widdows says.

To illustrate his point, Widdows gives an example of a hypothetical carrier that has ships on charter that are consuming a lot more fuel, compared with other vessels of same or larger size. Over the next couple of years, the carrier will have no other choice but to make the use of the existing vessels, as it will take some time before an alternative ship becomes available. However, Widdows believes, when carriers start to have alternative choices and they have a ship that comes up for charter renewal, they are likely to seek the most efficient ship they can find.

The question of when

Widdows believes charterers will take the opportunity to replace existing ships with newbuildings when they become available to them within the next two to three years. “The demand is here,” Widdows says. “You have carriers today that are losing millions of dollars each month. Their biggest cost problem is their assets and what they are burning in fuel.”

Private equity and other non-traditional players begin to show interest in going into building new ships. According to Widdows, that was bound to happen. “More than 35 percent of the world container fleet has been built by German owners, and largely with the KG financing that no longer operates. There is an enormous void in terms of where the financing is going to come from for the assets that are required.”

The questions of who

In a recent interview to the shipping newspaper TradeWinds, Chief Investment Officer of JP Morgan’s Global Maritime Investment Fund Adrian Dacy said that when the Fund invests, it wants to put its money alongside existing shipowners that have had operating experience. “By co-investing, we feel that there are the right checks and balances in place to have both parties observe and protect each other’s interests,” Dacy told the newspaper.

When asked what Rickmers would have to offer these non-traditional financing entities, Widdows pointed to the experience and relationships that go beyond those of a typical shipowner. He believes it all comes down to a combination of capabilities rather than buying a cheap vessel. “It is about buying a ship that can be operated on a cost effective basis over the life of the asset,” he says.

“Rickmers brings to the table deep relationships with the charterers – the carriers, who are going to make use of these assets. It is about counter party risk, so we bring relationships with some of the strongest players in the industry to the table.”

Less financing, more partnerships

Widdows points out that throughout the past decade, shipyards drove their production costs down, building not necessarily the most efficient designs as cheaply as possible. As a result of the seller’s market, these ships did not always meet the needs of the buyers.

“I think it is safe to say that for some years financing is going to be difficult to achieve, with fewer people able to access financing,” Widdows says. “This contributes to a window of opportunity where the yards will certainly have an incentive to partner with people who bring new designs as well as relationships with the strong players in the container space to the table. That environment is going to exist for some time.”

Text: Johs Ensby, Margarita Sjursen

Photos: Rickmers Group

Marine design house

The industry tends to adopt new products by fitting them on existing hull shapes, according to naval architect Henrique Pestana. Together with his colleagues, he proposes a fresh approach to container ship design.

Henrique Pestana

Tom Sand

Eero Lehtovaara

Pestana, head of ship design at Marine Design House, a new concept development and marketing unit in ABB, wants to change the thinking to questioning how the hull shape can be designed if a particular propulsion product is used.

Pestana points out that designing a ship that increases the volume available for cargo on board can mean a significant revenue increase for the "volume vessels," where the end customer pays by volume, not weight.

Not new to the container shipping industry

Eero Lehtovaara, head of the Marine Design House and senior vice president of ABB's Marine and Cranes business unit, does not limit the team's concept studies to ships. "It is very easy for us to relate to the broader scope of container logistics since we have products for almost all parts of the container logistics chain," he says. "We look at the entire value chain for more efficient solutions."

Tom Sand, responsible for ABB's sales related to container ships, explains how ABB's wide range of products and competences help meet the customer's needs in a specific project. "Alternators, transformers, rectifiers, switchboards and control systems are all part of the traditional ABB equipment packages when a new ship is built," he says.

One particular solution Sand refers to addresses an avoidable loss of energy from the main engine. "If you have a 30 MW main engine, you can recover 10 percent from waste heat," Sand says. Saving 3 MW through the waste heat recovery system, together with power from a shaft generator, present a considerable improvement to conventional designs.

Another example from Sand's portfolio of solutions is a method for reducing the amount of installed power for reefer containers. The refrigerator unit of a container with goods that need to be kept below a certain temperature pulls the most electricity the moment a thermostat opts for cooling time. If a large number of units opt for cooling at the same moment, a peak in demand for power would occur.

This peak can be avoided by installing a control system that lets reefer units queue up to be switched on at intervals of a few seconds. As a result, the required installed power can be reduced drastically, losing weight and saving space in addition to lowering the price of the power plant.

Where Sand's duties as a specialist for the container vessel type end, ABB's port specialists' responsibilities begin. Electrification and automation of cranes, as well as shore-side electrical power to a ship at berth, are among the solutions that ABB offers today.

Using dumb boxes intelligently

The container itself is still just a "dumb box" with a label on. Not even its weight is known, let lone the state of its contents. This may come as a surprise to most people, however, it is a well-known fact in the industry. Even when the weight is stated on the container's manifest, as it is done with valuable cargo, the reality may be quite different. This is where ABB's port-to-port involvement can play a big part. The cranes can capture the data about a container's weight and center of gravity and provide it to the IT systems used to load the ship. Systems that track the goods can compare the container's weight at the next handling point and detect those that have been tampered with.

Managing data intelligently could lead directly to reduced fuel consumption, believes Pestana. "You load the ship to a certain level and then slow down to see how each batch of containers will affect your draft. In the end, you slow down quite a lot. If you know the exact values, you wouldn't have to do this," he says.

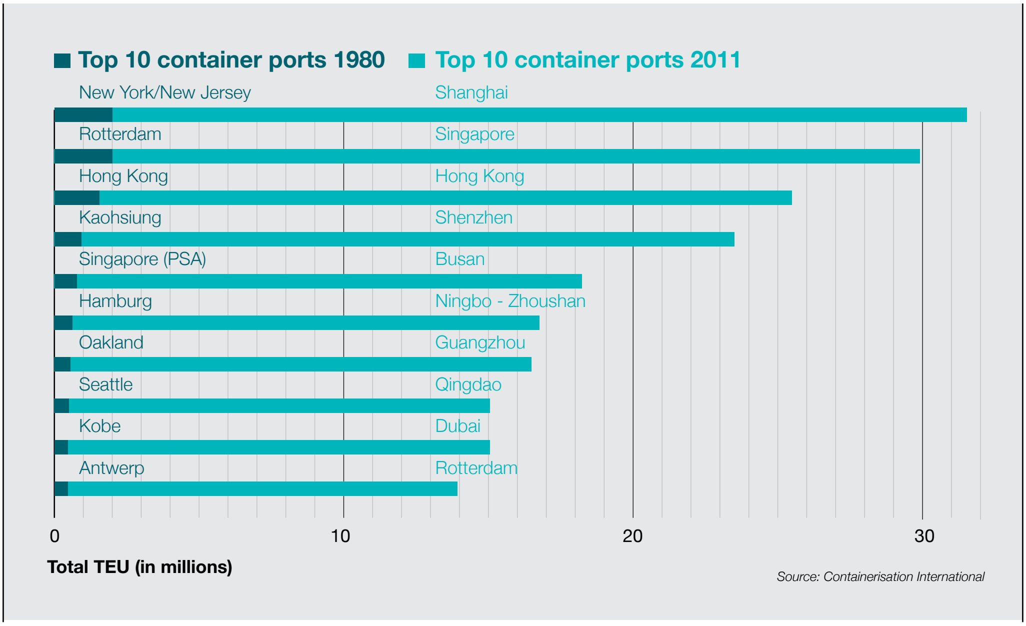
Pestana adds that in case of having numerous light containers at the bottom and much heavier containers at the top, the weight would need to be counteracted by ballast water. "Ballast water gets you into more problems with the need for water purification and change of ballast during the voyage," Pestana says.

Talking to the decision makers

Equipment manufacturers develop close relationships with yards to make sure new ships are built on time and according to budget. Shipowners are also well aware of technologies available before they order new tonnage.

However, according to Lehtovaara, sometimes the decisions are made at the charterer's table, adding insurance companies and financers to the list of key decision makers involved in optimizing container logistics. Lehtovaara's team is preparing concepts and documentation that will provide all key decision makers with better access to ABB's expertise in power, propulsion as well as in automation. Stay tuned.

Text: Johs Ensby, Margarita Sjursen
Infographics: Daniel Barradas
Photos: Johs Ensby



Arctic ambition

Sovcomflot, Russia's largest shipping company and one of the world's leading energy transporters, has revised its course towards specialized energy shipping services and the offshore market. Technical director Alexander Sokolov talks about the future of Russia's shipping industry and the company's ambitions to carve a niche in arctic energy shipping.

Q: which Sovcomflot's achievements make you the most proud?

A: Our Arctic voyages. Having a strong fleet of ice class vessels, we have recently resumed transporting oil and oil products through the Northern Sea Route. It is twice as efficient as the traditional route via the Suez Canal.

Since 2001, when we first started our ice operations in Primorsk Oil Terminal in the Baltic Sea, our tankers have been transporting oil from the Murmansk region and the White Sea. After acquiring sufficient experience in ice operations, we started transporting oil from the Varadei Terminal in the Barents Sea.

Another achievement is our development of a relationship with the Russian gas giant, Gazprom. In June 2011, Gazprom Global LNG and Sovcomflot signed a long-term lease agreement for two ice class liquefied natural gas (LNG) carriers. This is a new and very promising market segment for us – after all, gas is the fuel of the future. We are also proud of the average tanker age of our fleet, which is only 7.2 years.

Alexander Sokolov, technical director at Sovcomflot

It is quite possible that Russian shipbuilding will compete with that of Korea and China.

Q: Sovcomflot's development strategy until 2017 envisages, amongst other things, an increased share in the company's specialized energy shipping services, in particular LNG transportation and shuttle tanker operations. How is it going to affect the newbuilding programme?

A: It appears that all new projects will require building fundamentally new kinds of ships with a higher ice class. To give an example, the Yamal LNG project for developing the South Tambey field in the Arctic area of the Yamal peninsula is currently underway. We are working on a concept for building new cargo ships to operate in arctic conditions and are analyzing various configuration options for propulsion units. As rudder propeller units are one of the main propulsion options for icebreakers, ABB's Azipods could play a big part in this.

Q: How does the new strategy reflect shifting market demands?

A: Crisis in the tanker segment and in the shipping market in general does not appear to be ending in the near future, making Sovcomflot seek new

Sovcomflot's new icebreaking supply vessels are designed for extreme arctic conditions

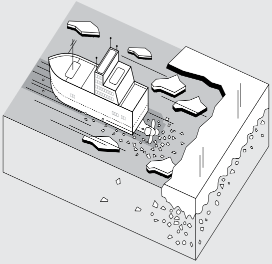
opportunities. This is why we are taking on offshore projects and looking into converting our existing tankers into shuttle tankers that could transport oil from international platforms. We have also entered the seismographic research vessel market for the first time. Difficult market conditions are making many companies review their strategies and enter new areas of development.

Q: The construction of two multifunctional icebreaking supply vessels by the Arctech Helsinki Shipyard seems to be an important step towards Sovcomflot's further expansion in upstream services. How did this project start and what is its current status?

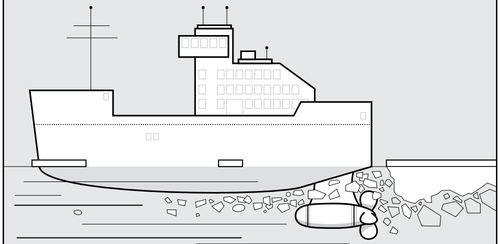
A: In 2009, Exxon Neftegaz Limited announced a tender for a long-term charter of two icebreaking supply vessels to transport supplies to the Sakhalin-1 platform developing the Arkutun-Dagi offshore oil field in the Russian Far East. Sovcomflot was successful with this tender, and in December 2010 signed an agreement with Exxon Neftegaz Limited to build these vessels at the Arctech Helsinki Shipyard in Finland.

These two vessels of 4,000 DWT each are designed for extreme arctic conditions and will operate in ice of up to 1.7 meters thick. Both vessels will have ABB propulsion and electrical systems. A Russian shipbuilding company, Vyborg Shipyard, is constructing the hull elements of the new vessels. A keel laying ceremony was held at the Arctech Shipyard in January 2012, marking the start of the construction. Both vessels are scheduled for delivery in the spring of 2013, but we are hoping to receive them a few months ahead of schedule.

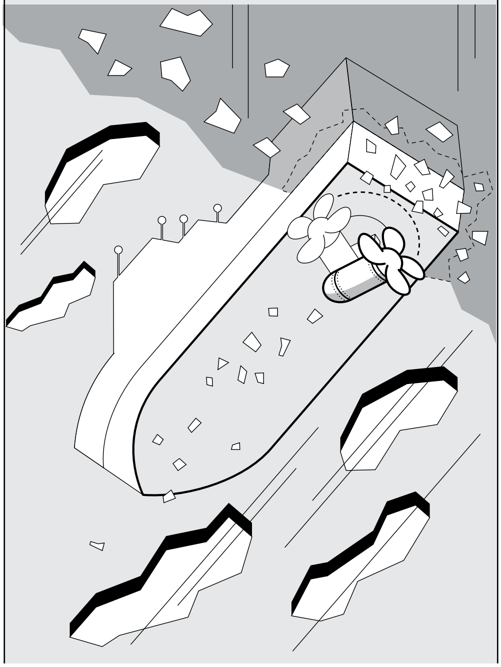
How Azipod® breaks the ice



When icegoing vessels equipped with Azipod propulsion systems run astern in ice, the propellers mill the underwater part of the ridge, cutting a passage through.



The water flow generated by the propeller flushes the hull, making it easier for the ship to move through the ridge field.



Q: What were Sovcomflot's main reasons for choosing ABB as a supplier of the propulsion and electrical systems for those vessels?

A: Sovcomflot has a policy of not interfering in commercial negotiations between shipyards and equipment suppliers. We agree on a list of suppliers during the pre-contract stage. The main condition for choosing a supplier is full compliance with the technical specifications that we develop together with the shipyard. The fact that ABB could provide not only the Azipod propulsion units, but also the power generation and distribution systems was definitely an advantage. Having all the equipment from one supplier significantly simplifies vessel maintenance. This has been our first experience with ordering a complete power and propulsion solution from ABB, as we are taking our partnership to a new level.

The fact that ABB could provide not only the Azipod propulsion units, but also the power generation and distribution systems was definitely an advantage.

Q: What are Sovcomflot's previous experiences with Azipod in ice conditions?

A: Oil transportation from the Varandey Terminal to Murmansk and over three years of successful operations in the Barents Sea. Arctic shuttle tankers of the Vasily Dinkov type have already proven their capability for operating in extremely low temperatures. Cargo operations took place in temperatures as low as -32°C. Our Arctic tankers were able to operate without the need for any ice-breaker escort in harsh ice conditions in the Novaya Zemlya region, where the drift ice thickness exceeds 1m and pack ice gets as thick as 2.5 meters. So far, the Sovcomflot tankers have transported over 10 million metric tons of crude oil from the Varandey Terminal in harsh ice conditions.

Q: Were there any challenges in terms of Azipod operations?

A: Yes, with our Timofey Guzhenko tanker, which transports oil from the Varandey Terminal. In 2009, Sovcomflot signed an agreement with ConocoPhillips, Samsung Heavy Industries and ABS to install additional equipment on the vessel to create a 'floating ice laboratory'. This equipment included a system of sensors and measuring instruments that allowed monitoring of ice pressures and loads. After assessing the over torque capability of the ABB propulsion system, we could see that the Azipod drives had to be adjusted to match the technical specifications. We tried doing that ourselves and failed, so we called in a group of experts from ABB, ConocoPhillips and the Central Marine Research and Design Institute to help us. They managed to adjust all the necessary parameters and we got positive results straight away. After the experts measured ice loads, we could see that the propulsion system could reach 50 percent over torque, as stated in the technical specifications. This has significantly increased the icebreaking capability of the vessel.

Q: Did Sovcomflot get any evaluations of Azipod performance from independent experts?

A: Experts from the Krylov Shipbuilding Research Institute in Saint Petersburg expressed doubts regarding Azipod's performance on ice thicker than 1.5 meters. One of the main concerns raised by the scientists during their theoretical discussions was the strength of the nacelles. However, ice model tests of Arctic shuttle tankers, previous operation of Azipod ice breakers and Sovcomflot's over three years of successful experience in tanker operations in the Barents Sea have confirmed that we were right with choosing this option.

Q: What have been the key recent Sovcomflot voyages?

A: That of *SCF Baltica* through the Northern Sea Route in August 2010 was quite remarkable. This was the first voyage attempted by an Aframax tanker of more than 100,000 DWT along this shipping lane. SCF Baltica transported 70,000 metric tons of gas condensate from Murmansk to Ningbo, covering a total distance of 7,000 nautical miles, about 2,500 of which were via the Northern Sea Route. The traditional shipping route to China via the Suez Canal would take about twice as long. The world's two most powerful nuclear-powered ice-breakers – *Rossiya* and *50 Let Pobedy* – escorted *SCF Baltica* during this voyage. The main goal of this voyage was to determine the

Sakhalin-1 platform developing the Arkutun-Dagi offshore oil field in the Russian Far East

feasibility for transportation of hydrocarbons from the Barents and Kara Seas to the markets of Southeast Asia along the Northern Sea Route on a regular, economically viable and safe basis.

Last year, the 160,000 DWT Suezmax tanker *Vladimir Tikhonov* completed the same voyage, carrying a cargo of over 120,000 metric tons of gas condensate. This voyage set a new record by accomplishing the Northern Sea Route transit in just seven days and with the average speed of 14 knots.

Q: Has Sovcomflot moved closer to year-round shipping in Russia's Arctic waters?

A: Even though it might be a bit early to talk about year-round shipping, our experience with the Northern Sea Route voyages shows the potential for navigation in the Arctic region. All the new offshore projects are linked to oil and gas exploration in the Arctic. This means that in the future we will need not only to supply vessels, but also large tankers that can transport oil and gas from the Arctic region all year round. Even despite global warming, the average Arctic ice thickness is over 3 meters. This would require icebreaker cargo ships that do not exist at the moment. A substantial icebreaker escort could be an alternative solution, but there are not that many icebreakers navigating the Northern Sea Route.

Q: The development of offshore oil fields in Russia's Arctic seas lacks investments mainly due to high taxes. How does this impact Sovcomflot?

A: To give you an example, our fleet includes two Arctic shuttle tankers built by the Admiralty Shipyard for transporting oil from the Prirazlomnoye field, the first commercial offshore oil development in the Arctic. But due to lack of finance, the field development has been continuously delayed. As a result, these vessels have been operating as storage tankers for over a year now. As soon as they leave ice, their economic performance falls, and the best way of using them – especially in difficult market conditions – is as storage tankers. One of these vessels has been operating in African waters for quite a while, and the other is still operating in the Black Sea. Not exactly the Arctic!

Q: Apart from tax reform, what can improve this situation?

A: Shipyards need to change their management system. Many of them are still living in the old reality of the Soviet Union and are expecting orders from the government, as well as public funding. They do not even consider self-financing. When we first started working with the Admiralty Shipyard, one of the largest shipyards in Russia, we could see that it was not yet ready to comply with international

industry standards. But since 2001, the shipyard has made significant progress – it has started loaning from banks and distributing the funding provided by Sovcomflot. Unfortunately, this is more of an exception: most of the shipyards are still lagging behind. I would say that the only other shipyard in Russia with a modern management system is Krasnoe Sormovo.

Q: What other challenges does Russia's shipbuilding industry face today?

A: Historically, Russian shipyards specialized in building warships. Civilian shipbuilding was not a priority. In most cases, a shipyard would commission a project to an external construction bureau, while governmental bodies would manage the construction processes. Today, shipyards in Russia rarely work on building modern vessels. There are no construction bureaus within shipyards, and it is increasingly difficult to break the trends of the past. Another problem is that Russian shipbuilding capacity is currently limited to constructing vessels of up to 90,000 DWT. All existing docks and slipways are designed for building long and narrow vessels, for servicing the needs of the military. There are also technical challenges that hamper the development of the shipbuilding industry in Russia. Most modern international shipyards use sectional construction as a building method, while Russian shipyards do not have large enough docks and still have to use inclined slipways. Building a new, modern shipyard would be a significant step forward.

Q: What are Sovcomflot's strategies regarding the newbuilding programme, considering that the Russian shipbuilding industry is facing many difficulties?

A: Sovcomflot is actively cooperating with the United Shipbuilding Corporation, which was established by the Russian government in 2007 to unite all shipbuilding subsidiaries in Russia. This cooperation has already resulted in a number of contracts, including an order for construction of six Aframax tankers at Zvezda-DSME shipyard, a joint venture between the United Shipbuilding Corporation and Daewoo Shipbuilding & Marine Engineering.

The establishment of the United Shipbuilding Corporation is a major step forward for the Russian shipbuilding industry. The Corporation is currently working on a project for building a new shipyard in Kronshtadt on the Kotlin Island west of Saint Petersburg. If this is a success, it is quite possible that Russian shipbuilding will be able to compete with that of Korea and China.

Sovcomflot in numbers

– 156 vessels of 11.78 million DWT

– 15 newbuildings of 1.58 million DWT

– 7.2 is the average age of the tanker fleet

– 5754 seafarers

– 2213 shore-based personnel

Text: Ryan Skinner, Margarita Sjursen

Photos: Sovcomflot

Deciphering energy efficiency

Energy efficiency terminology is a collection of acronyms that may present a deciphering challenge even to those that work in the industry. *Generations* decoded some of the most common ones that you will come across on the pages of this issue.

ADO
Azipod Dynamic Optimizer
A software-based system for optimizing the toe angle of two Azipod units.

AHTS
Anchor handling tug supply vessel
Vessels that are mainly built with the purpose of handling anchors for oil rigs, towing and anchoring them up.

BIMCO
The Baltic and International Maritime Council
The oldest of the international shipping associations, comprising a membership of a broad range of stakeholders with vested interests in the shipping industry, including shipowners, managers, brokers and agents.

BMS
Battery management system
A battery management system manages a rechargeable battery by monitoring its state, calculating and reporting secondary data, protecting the battery, as well as controlling and balancing its environment.

CFD
Computational fluid dynamics
Computational fluid dynamics uses numerical methods and algorithms to solve and analyze problems involving fluid flows.

CLIA
Cruise Lines International Association
The world's largest cruise association that is dedicated to the promotion and growth of the cruise industry.

DCU
Drive control unit
ABB's application control system for a thruster drive.

DNV
Det Norske Veritas
Norwegian classification society and an independent foundation with the purpose of safeguarding life, property, and the environment.

DP
Dynamic positioning
A system that helps the vessel to automatically maintain its position and heading through the use of propellers and thrusters.

ECA
Emission Control Areas
MARPOL Annex VI Regulations for the Prevention of Air Pollution from Ships establishes certain sulfur oxide (SO_x) Emission Control Areas with more stringent controls on sulfur emissions. In these areas, the sulfur content of fuel oil used on board ships must not exceed 1.5 percent m/m. Alternatively, ships must fit an exhaust gas cleaning system or use any other technological method to limit SO_x emissions. These areas include the Baltic Sea, the North Sea and the Caribbean Sea.

ECR
Engine control room
A command center of the engine room.

EEDI
Energy Efficiency Design Index
A non-prescriptive, performance-based mechanism that leaves the choice of technologies to use in a specific ship design to the industry. As long as the required energy-efficiency level is attained, ship designers and builders would be agree to use the most cost-efficient solutions for the ship to comply with the regulations.

EEOI
Energy Efficiency Operational Index
Means for enabling ship operators to measure the energy efficiency of existing ships. This index is expressed in CO_2 per ton mile, for the efficiency of specific ship thus enabling comparisons between similar ships.

EMMA™
Energy monitoring and management system
Integrated solutions for decision support in the search for optimal energy management.

EPI
Energy performance indicator
Energy performance indicator is intended to show the energy performance and use.

ESI
Environmental Ship Index
A measure for air emissions relative to IMO rules and provides a tool that will assist ports and other parties to promote clean shipping.

EVDI
Existing Vessel Design Index
Measure of a ship's inherent efficiency in the IMO climate regulations.

FSRU
Floating storage and regasification unit
A floating vessel used by the offshore oil and gas industry for the processing of hydrocarbons and for storage of oil.

GHG
Greenhouse gas
A gas in the atmosphere that absorbs and emits radiation within the thermal infrared range.

HFO
Heavy fuel oil
Pure or nearly pure residual oil.

HVAC
Heating, ventilation and air conditioning
A technology for controling the quality of indoor and automotive environment.

ICS
International Chamber of Shipping
The principal international trade association for the shipping industry, representing all sectors and trades.

IEA
International Energy Agency
An autonomous organization, which works to ensure reliable, affordable and clean energy for its 28 member countries and beyond.

IEEC
International Energy Efficiency Certificate
A certificate mandatory for all vessels of 400 gross tonnage and above.

IMO
International Maritime Organization
The United Nations' specialized agency responsible for improving maritime safety and preventing pollution from ships.]

ISPS
International Ship and Port Facility Security Code
A comprehensive set of measures to enhance the security of ships and port facilities, developed in response to the perceived threats to ships and port facilities in the wake of the 9/11 attacks in the United States.

LNG
Liquefied natural gas
Natural gas converted into a liquid form for the convenience of storage or transport.

MARPOL
International Convention for the Prevention of Pollution from Ships
The key international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.

MCR
Maximum continuous rating
The maximum output that a generating station is capable of producing continuously under normal conditions over a year.

MEPC
Marine Environment Protection Committee
A committee of the IMO that meets every nine months to develop international conventions relating to marine environmental concerns including ship recycling, controlling emissions, and invasive species.

NO_x
Nitrogen oxide
NO_x is a generic term for various nitrogen oxides produced during combustion.

OPA
Oil Pollution Act
Oil Pollution Act was passed by the 101st United States Congress to mitigate and prevent civil liability from the future oil spills off the coast of the United States.

PM
Particulate matter
Tiny subdivisions of solid matter suspended in gas or liquid.

PMS
Power management system
ABB's family of unique solutions that ensure reliable and stable energy supply for energy-intensive industries.

PSV
Platform supply vessel
A ship designed to supply offshore oil platforms.

SC
Super-capacitor
An electrochemical capacitor with high energy density.

SEEMP
Ship Energy Efficiency Management Plan
SEEMP is meant to incorporate the guidance of best practices of each individual ship, including voyage planning, speed and power optimization, optimized ship handling, improved fleet management, cargo handling and energy management.

SFOC
Specific fuel oil consumption
Engine fuel characteristics at variable speed.

SoC
State of charge
The equivalent of a fuel gauge for the battery pack in a battery electric vehicle, hybrid vehicle, or plug-in hybrid electric vehicle.

SOLAS
International Convention for the Safety of Life at Sea
The key international treaty concerning the safety of merchant ships.

SO_x
Sulfur oxide
Sulfur oxide refers to many types of sulfur and oxygen containing compounds such as SO, SO_2, SO_3, S_7O_2, S_6O_2, S_2O_2, etc.

VFD
Variable frequency drive
A type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage.

WHRS
Waste heat recovery system
A combination of equipment installed on board to assist the ship's main propulsion machinery recover a part of the energy contained in the fuel that cannot be efficiently utilized by the main engine.

Chapter B

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Energy efficiency in marine vessels

ALF KÅRE ÅDNANES – It is not many years ago that fuel efficiency was a minor or even neglected topic of many marine industrial conferences and journals. Today, together with safety and availability, it ranks at the top of the agenda of the marine community. So what happened to make such a dramatic change in awareness in such a short time?

The answer may be complex and the causes may be various. But above all, it is clearly a result of the dramatic variations and high level of fuel costs and income rates, leading to bleeding losses for those ship operators that are not prepared for the rapidly changing fuel costs and lack the ability to adjust vessel operation and operational expenses. Another factor is related to the increased public awareness of pollution and environmental emissions that leads to political decisions of global or local rules and regulations. These could be considered as a burden to ship operators, but could also create vast opportunities for the foresighted operators with long-term perspectives of their strategy.

This article will introduce some of the areas ABB works within in order to be able to offer solutions that help shipowners and operators reduce their fuel bills today and in the future and to support the yards in offering vessel designs for the future needs of the marine industry. Further and more detailed presentations of core technologies can be found in the subsequent articles in this magazine, contributed by internal, as well as guest writers from the industry.

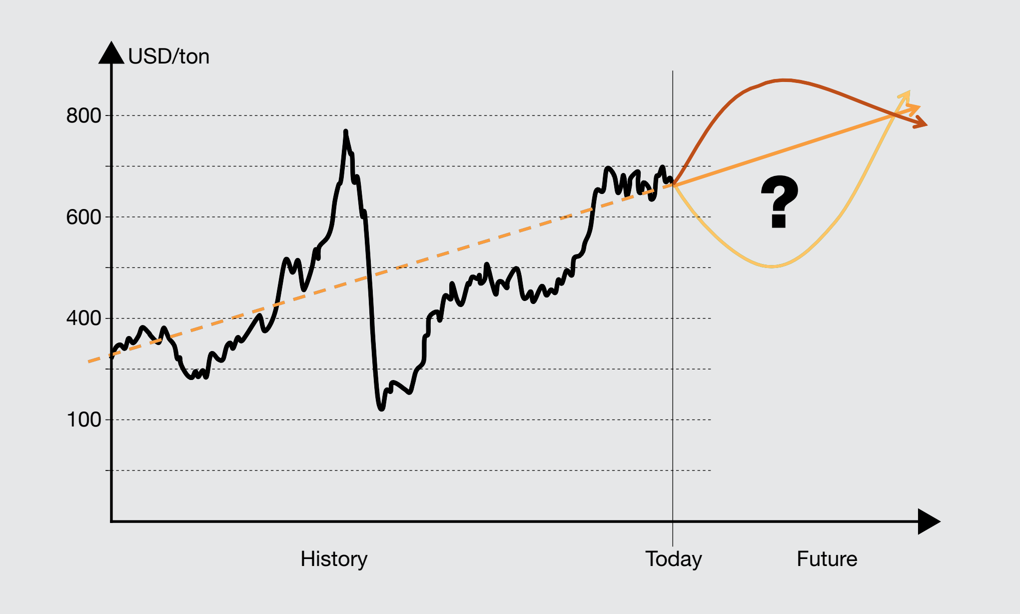
The fuel dilemma and opportunities

Global shipping consumes about 300 million metric tons of fuel annually, with heavy fuel oil (HFO) in transportation and larger ships and marine diesel oil (MDO) in the offshore and smaller near-shore vessels. As HFO is a residual oil product from refining, it is the fuel with lowest price and will not be replaced as a main source of fuel for shipping in the near future. However, the use of lower sulfur and cleaner fuels, such as MDO and liquefied natural gas (LNG), will take over parts of the HFO market as environmental regulations and local restrictions on emissions get strengthened.

During the last decade, the energy market has been turbulent, with increasing and changing fuel prices. There are few voices heard that predict this to be different in the next decade. Among shipowners and designers, there is a clear trend to increase the efforts in designing vessels for flexibility in fuel source and operational loading of the propulsion system.

The challenges of reaching the macro targets of stabilizing CO_2 emissions to reduce accelerated global warming will also, without a doubt, affect the shipping industry, although global rules and regulations are not in place yet. Such goals cannot be reached with the use of today's technologies alone, and will require new ways of designing and operating vessels and fleets, as well as further development in technologies and energy sources. While this is a challenge, there is a clear money driver for the long-term

1 **Price of marine bunker oil, how will it develop through the lifetime of a new build vessel?**



strategic players. While the HFO cost of today is above $600 per metric ton, the total fuel bill of the shipping industry is at an annual level of at least $200 billion. For the providers of energy-efficient solutions that reduce fuel consumption for environmental gains, there should be enormous funding opportunities only by sharing the reduced fuel bills.

Generations invited Det Norske Veritas (DNV) to make a summary and trends in development of rules and regulations. Their reports are presented in this issue of *Generations.*

Optimizing operations

With the means of communication and data transmission being installed to cover practically all oceans, there is no need to continue a tradition of running a fleet as independent ships with individual objectives. An enabler for the next generation, integrated systems are the introduction of IT networks extending the traditional integrated automation systems to tightly connect to the power and propulsion plant. High-speed networks with fault integrity and high reliability replace traditional hard-wired or serial communication links to provide easier installation and higher data transparency. IT and real-time data management that has revolutionized other industries is now entering the marine.

For shipowners and designers, it is a clear trend to increase the efforts in designing vessels for flexibility in fuel source and operational loading of the propulsion system.

2 The EMMA™ suite of solutions for energy management and fleet optimization; next generation advisory systems entering the marine industry

EMMA™ Fleet Control
Business intelligence data discovery to complete fleet management

EMMA™ Onboard Tracker
Onboard energy, fuel and process data and monitoring

EMMA™ Advanced Optimizer
Easy to use optimization modules for even the most complex onboard processes

> There is an increasing interest in gaining benefits of electric propulsion in new vessel segments, in particular in hybrid propulsion concepts.

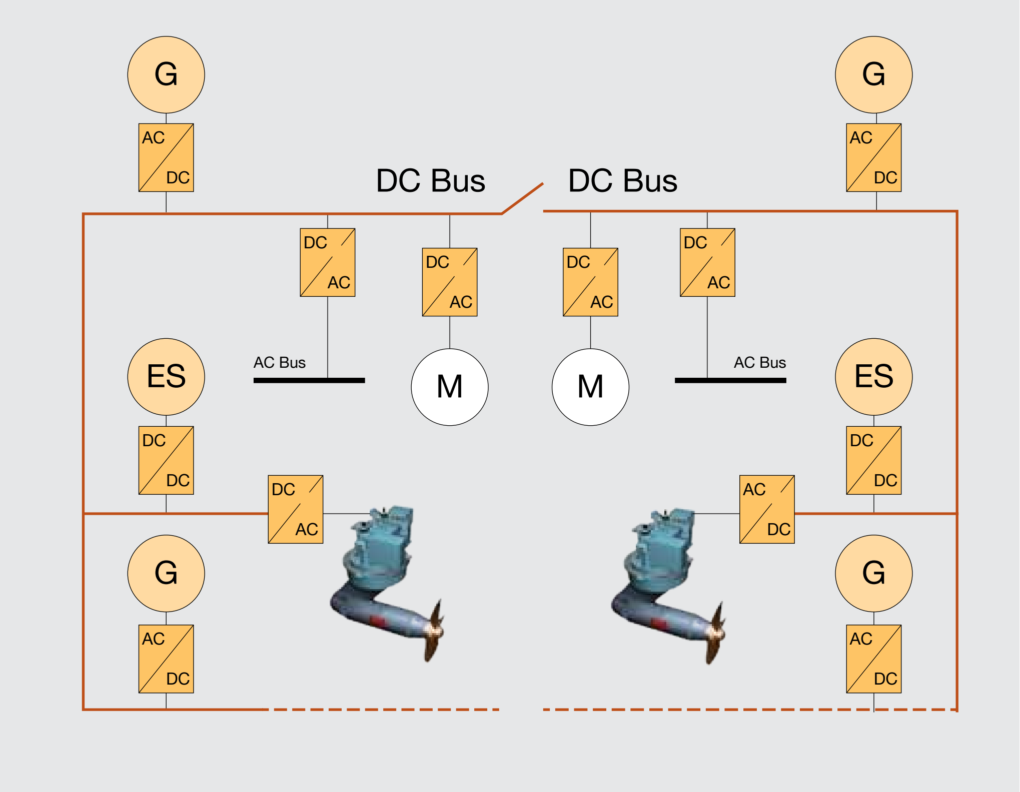
In order to support the optimization of vessel and fleet management, ABB has launched the EMMA™ suite of solutions for ship operators and owners. While being a solution package that can be adjusted to many ship types and equipment solutions, it also provides integrated information sharing with the onboard propulsion and control systems from ABB to take advantage of the large data that inherently are available in an integrated system. Features of EMMA are presented in the article on page 97.

Advances in electric propulsion

Electric propulsion has been applied in marine vessels over many decades, while the real expansion and wider use started in the 1990s. With exceptions of introducing Azipod® propulsion and the developments within variable speed drives technologies, one could say that the electric propulsion has evolved in a step-wise manner. Technologies from other industries have gradually found their ways into marine applications.

There is a clear shift in focus in the way marine society of designers, operators, and technology providers approach electric propulsion design. The shift is from adapting to marine to designing for marine. As the marine industry is small, compared with the total industry in terms of numbers of vessels and size of markets, the basic technology and product development efforts will still vastly be carried out by land-based industries. However, the solutions and systems for the marine industry are being reshaped to support energy efficiency of the vessel processes, including propulsion.

3 Onboard DC Grid with generators (G) and energy storage devices (ES)



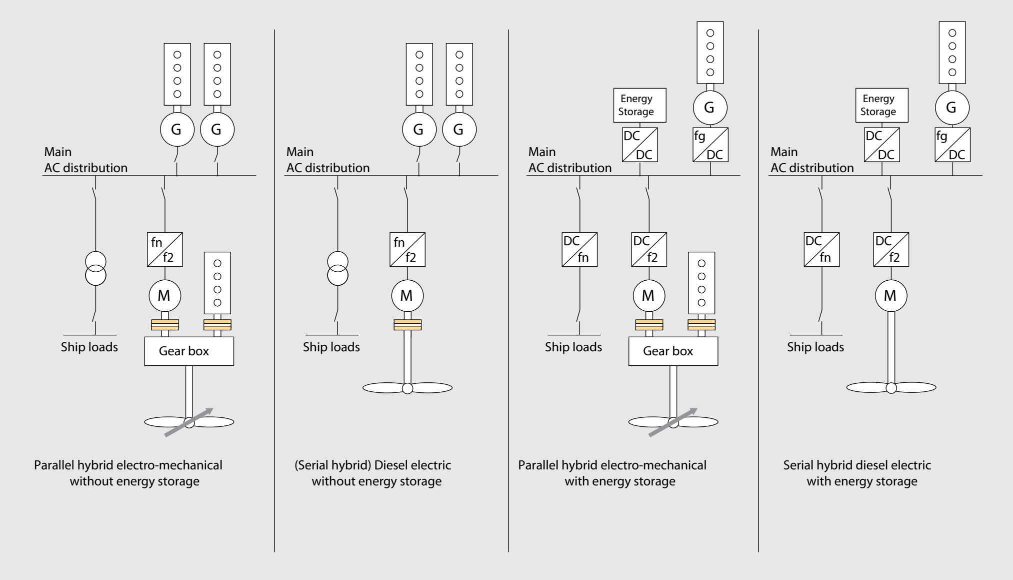
Electric propulsion is still a solution mainly used in passenger vessels, special vessels for ice-going or dynamic positioning, or in vessels powered by LNG. However, there is an increasing interest in gaining benefits of electric propulsion in new vessel segments, in particular in hybrid propulsion concepts, where the electric system either is parallel hybrid to a mechanical drive train, or the electric generation plant is supplemented with an energy storage system. Read more on the experience in hybrid propulsion systems for anchor handler vessels in the article on the recent technologies in gear drives for hybrid propulsion on page 136, contributed by guest authors from Scana Propulsion. *Generations* also presents thoughts on integrating battery and super-capacitor energy storage in electric systems for increased reliability and fuel efficiency, particularly suitable for the Onboard DC Grid concept. An article on trends in battery development is contributed by Corvus Energy.

ABB's product portfolio of Azipod® is going through an upgrade program, whith the new large size Azipod XO propulsor launched in the market recently to a very positive feedback from shipowners. The upgrades are described in detail in a paper in this magazine. The smaller Azipod CZ with nozzle has been expanded in power range to also fit the newer drillship designs. The article presenting that highlights the benefits for shipowners and ship designers by utilizing the simplicity of the thruster design, as well as increasing the awareness of the fuel and cost saving effects on the complete power plant by taking advantage of the high efficiency of the Azipod.

Hybrid propulsion

The term "hybrid propulsion" covers a variety of system designs and solutions. Many are already familiar with the concept of hybrid propulsion when it comes to cars, and the difference between series and parallel hybrid solutions there. For marine propulsion, hybrid propulsion has traditionally been used to describe a propulsion line where a mechanical prime mover is the main driver for the propeller, with a direct or geared electrical driven booster motor to supplement

4 Onboard DC Grid with generators (G) and energy storage devices (ES)



the prime mover, or to use in low load conditions for higher energy efficiency and redundancy.

With the introduction of energy storage to the propulsion system, hybrid propulsion is also used to describe that the diesel generators are supplemented with electric energy storage. As the similar terms are used in both automotive and marine industries, but with different tradition and meanings, a brief description of the various marine concepts are shown in Figure 4. It illustrates the differences between serial and parallel hybrids. In parallel hybrid, both a diesel engine and an electrical motor can be used, separately or together, to drive the propeller through a gear box as shown, or in line with a common shaft. In serial hybrid, the propeller shaft is driven solely by the electrical motor. The power plants can be equipped with or without energy storage. In this figure, only DC distribution is shown with energy storage devices as that is the most feasible solution, although it could be possible to integrate energy storage in AC distribution systems as well.

Waste heat recovery boiler systems are commonly used in ships, in particular with larger engines, to provide steam and electricity for the vessel. Today, there is a trend to increase the waste heat recovery capacity and produce more electrical energy. In order to utilize this energy, which can be substantially higher than the onboard processes demand, a hybrid propulsion line is needed to take advantage of the recovered energy from the engines. As the paper on this topic presents, the overall energy efficiency will increase by about 10 percent for such hybrid propulsion lines.

Summary

Historically, there have been a few big step changes in the design of the electric propulsion system, with continuous smaller steps of improvements in technology and system design. It is believed that during the next years there will be significant changes in such solutions becoming available for the market.

Generations collected a series of articles that show a selection of recent and ongoing development activities, with a belief that they give an indication of what the industry will be heading towards in terms of applied technologies. These changes should support ship yards, designers and shipowners to increase efficiency of energy consumption and reach target settings on operational flexibility, earnings and environmentally sustainable business.

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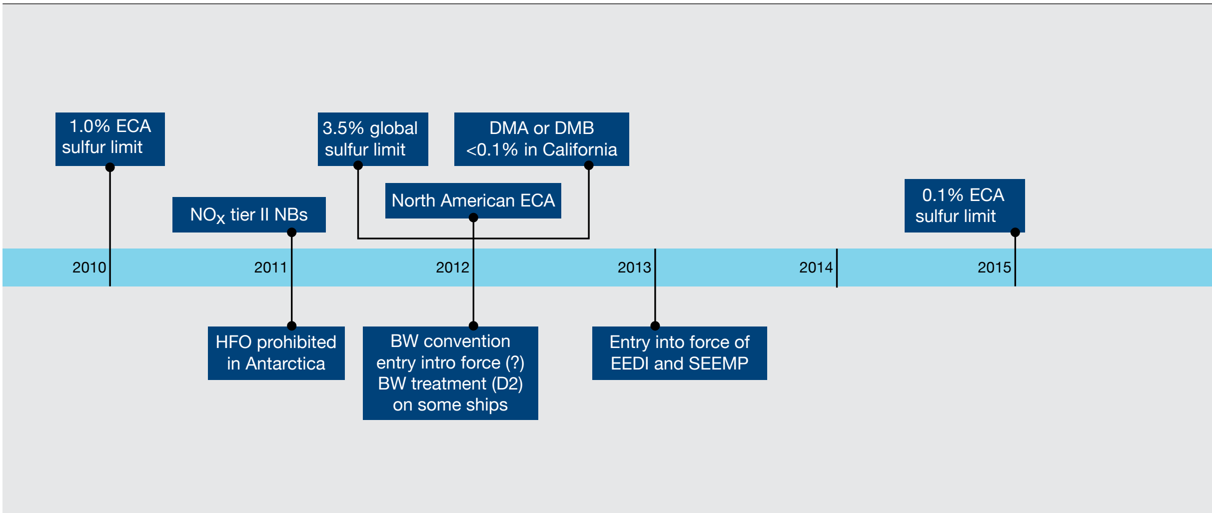
Environmental regulations towards 2020

EIRIK NYHUS – International shipping is a heavily regulated industry. Nevertheless, this decade there will be a plethora of additional regulations coming into force, with significant economic and operational implications. Managing the cumulative impact may be one of the decade's key challenges, and companies failing to make the right choices may see their long-term viability suffer.



Shipping today operates under a complex set of international and domestic regulations. Traditionally, the leaps in regulations have been driven by events and in some cases by circumstances outside the sector. Well-known examples are the *Titanic* disaster, which led ultimately to the International Convention for the Safety of Life at Sea (SOLAS), the Exxon Valdez oil spill, which resulted in Oil Pollution Act (OPA 90), and the 9/11 attacks, which resulted in the International Ship and Port Facility Security Code (ISPS Code). Environmental regulations, however, have lagged behind those of other industries. This situation is changing.

The increased focus on global and local environmental issues in general, combined with the growing realization of the actual pollution burden imposed by shipping, has led to an upsurge in both international and national regulations. Some are ready and will be entering into force in the near future, while others are still under development and will have an impact only in the intermediate term.

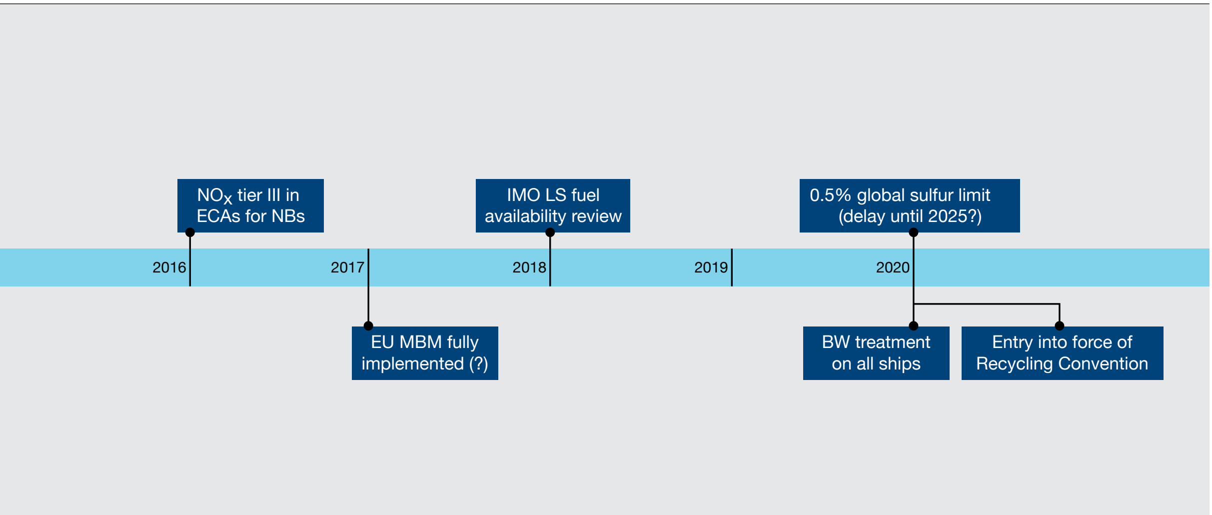
The key issues with significant regulatory impact this decade are, broadly speaking, sulfur oxides (SO_x), nitrous oxides (NO_x), particles (PM), greenhouse gases (in particular CO_2) and ballast water management.

Sulfur oxides, nitrous oxides and particles

SO_x, NO_x and PM are all emissions to air that result from the combustion of marine fuels. The local environmental effects of these are generally well-known and include acidification and eutrophication, both having potentially severe impact on the ecosystem and negative health effects on exposed populations.

The impact is generally wel-understood and has in some parts of the world (eg, EU, United States) led to strict regulations of emissions from land-based sources. In recognition of shipping becoming a dominant emission source and potentially exceeding land based sources, emissions have been internationally regulated by the International Maritime Organization (IMO) through the International Convention for the Prevention of Pollution from Ships (MARPOL). This gives a combination of general maximum global emission levels and significantly more stringent levels applying to designated sea areas, generally known as Emission Control Areas (ECAs). The regulations allow for mitigating emissions through either changing fuel type or by exhaust gas cleaning. Key dates that represent crucial regulatory deadlines for shipping are:

– Jan. 1, 2015 – 0.10 percent S in ECAs
– Jan. 1, 2016 – NO_x Tier 3 in ECAs
– Jan. 1, 2020 or 2025 – 0.5 percent S global cap



Prior to 2015, operators will have to make the choice of either installing technically complicated and most likely expensive exhaust gas cleaning systems (scrubbers), or switching to low-sulfur fuel for all ships operating in an ECA. Realistically, low sulfur fuel options will be either expensive distillates or liquefied natural gas (LNG), the latter in practical terms being an option only for newbuildings. For newbuildings from 2016 onwards and operating in an ECA, the NO_x requirements add another layer of complexity due to possible technical integration issues between SO_x and NO_x solutions. Finally, in 2020 or 2025 (pending an IMO decision in 2018) the 0.5 percent S global cap will enter into force, changing the economics of the decisions made in the preceding years.

Making the right technology choice is an exceedingly complicated issue as it hinges on decision parameters with inherent huge uncertainties:

– Refinery distillate production volumes, availability and price locally and globally
– LNG fuel price versusheavy fuel oil and distillates
– Technology maturity, availability and price
– Shipyards' retrofit capacities
– General technology risks
– Likelihood of further ECAs
– Trading patterns, time in ECAs

The key issues with significant regulatory impact this decade are, broadly speaking, sulfur oxides (SO_x), nitrous oxides (NO_x), and particles (PM), greenhouse gases (in particular CO_2), and ballast water management.

Complicating the decision-making process further is the fact that there are local and regional regulatory initiatives in addition to international IMO requirements. One key example is the EU where one possible outcome of the ongoing revision of legislation may be the implementation of ECA-style requirements in all EU waters. Needless to say, this can significantly affect operator considerations.

Uncertainties notwithstanding, the international regulatory deadlines are clear and the key strategic decisions need to be made. The only certainty is that all solutions are going to be costly and there is no "one size fits all" fix available.

Ballast water

There have been many cases of alien species being introduced into new environments, and ballast water is currently the dominant global transfer mechanism. Organisms carried in ballast water can establish themselves in new environments, causing dramatic shifts in food webs, outbreaks of disease and accelerated rates of species extinction. The cost of these invasions has been estimated at more than $100 billion each year in the USA alone.

In response to this the IMO adopted the Ballast Water Management Convention, a set of regulations seeking to severely limit the number of organisms carried in ships' ballast water. A key part of the convention is eventually making ballast water cleaning mandatory for all ships. The convention is unique in that it has a fixed timeline and most ships in international trade must have ballast water cleaning systems installed by the end of 2019.

The convention is close to ratification and once ratified, a strong surge in system demand can be expected.

While there are numerous suppliers of approved systems in the market, all systems have had relatively limited operational experience and come with an inherent technology uncertainty. Furthermore, as system performance depends on water quality, trading pattern specifics may be a crucial determinant when deciding on type.

An important complication is the fact that US states under US law are, if they so desire, legally entitled to impose their own ballast water cleaning standards, above and beyond the IMO standards. Several states intend to do so. However, ongoing political processes and legislative work in the United States may result in unified US requirements aligned with IMO requirements.

With the relative technological novelty of the systems, the fact that the convention has not yet entered into force, regulatory uncertainty in the United States, and a price tag of systems easily running into several million dollars per ship, industry uptake has been slow. But the implication of the ratification threshold being reached in the near future is that several thousand ships will need to have systems installed within a short time span. It remains an open question as to whether supplier, yard and engineering capacity will be sufficient to meet pent-up demand once the floodgates open.

Greenhouse gases

Greenhouse gases such as CO_2 are generally held to be the primary mechanism for anthropogenic warming of the atmosphere, with the international community working for more than 20 years to establish effective international regulations. Shipping, along with aviation, was not covered by the key pillar of these efforts, the Kyoto Protocol, primarily due to the complexity of allocating ownership of the CO_2 emissions.

With the resurgence in international concern about CO_2 emissions in the first decade of this century, the IMO committed itself to addressing ships' CO_2 emissions through a combination of technical, operational and market-based means. This commitment was further stimulated by the European Council's decision to develop regional CO_2 control mechanisms if effective international mechanisms were not in place by the end of 2011.

Painstaking negotiations at the IMO led to the adoption of the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) in 2011, entering into force from January 2013.

The EEDI, in setting increasingly stringent requirements to the energy efficiency of new ships, is intended to stimulate development of more energy efficient ship designs, indirectly leading to reduced operational CO_2 emissions. The SEEMP is designed to directly stimulate more energy efficient operational practices.

The regulatory mechanism remaining on the table is Market Based Measures (MBM). Negotiations on MBM have encountered significantly less success than those on EEDI and SEEMP, and until fundamental political differences are resolved during international climate negotiations, there is limited likelihood of progress at the IMO.

In the absence of IMO progress, the EU will be proposing a regional mechanism for CO_2 reductions from shipping. While policy details remains unclear, three general principles will be embodied in any proposal:

1) an attempt at universal coverage of all vessels trading in Europe
2) the possibility of broadening the scope of a regional mechanism to make it truly international
3) the willingness to shelve EU plans if the IMO delivers. The likely implementation will be in 2017-2018 barring an IMO agreement.

Implications

Taking into consideration all these issues, it should be apparent that navigating the regulatory landscape to decide on the appropriate technical and operational solutions is not a trivial task.

Addressing SO_x, NO_x, ballast water and energy efficiency requirements more or less in the same time frame requires a careful balancing act where care must be taken so that the technology solution to one issue does not unduly constrain the choices for the others. A fine balancing act is required, in particular, when one factors in generally increasing fuel prices, high investment costs and potential lack of financing, and the likelihood of soft charter rates.

In the longer run, the ability to navigate these treacherous waters may be a key commercial differentiator where companies with the necessary analytic capabilities, the strategic vision and implementation resources are likely to outperform those trying to do business "the way it used to be done."

Eirik Nyhus
Det Norske Veritas

CO_2 emissions from ships

The impact of EEDI and SEEMP

TORE LONGVA – The first formal CO_2 control regulations were adopted by the International Maritime Organization (IMO) at the 62nd session of the Marine Environment Protection Committee (MEPC) in July 2011. These comprise the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), both of which will enter into force on Jan. 1, 2013.

A new International Energy Efficiency Certificate (IEEC) will be introduced for all vessels. This includes a supplement recording particulars related to the ship's energy efficiency, such as the propulsion system, the attained EEDI for newbuildings and the presence of a SEEMP.

Energy Efficiency Design Index

The EEDI requirements will apply to new ships above 400 gross metric tons only, where "new ship" means a ship:

- for which the building contract is placed on or after Jan. 1, 2013 or
- in the absence of a building contract, the keel of which is laid or which is at a similar stage of construction on or after Jan. 1, 2013 or
- the delivery of which is on or after Jan. 1, 2015

The EEDI is measured in the mass of CO_2 emitted per unit of transport work (gCO_2/ton-nm). The yard, designer or a consultant will have to develop an EEDI technical file containing the necessary documentation and calculations. Verification will be done in two stages, a preliminary verification at the design stage based on tank tests, manufacturers' data and design particulars and final verification at the sea trial. During the sea trial the speed will be measured and the technical file will be updated together with engine certificates and other necessary documentation. The EEDI technical file will then be verified by a flag administration or a recognized organization, and the IEEC will be issued.

The regulation differentiates between ship types which are required to calculate an attained EEDI and those that must have an attained EEDI below a certain required EEDI. Ship types needing to comply with a specific required EEDI level to obtain the IEEC are defined in the table below, which also indicates the timeline for the tightening of the requirement levels.

The reference line value of a ship is calculated based on the following formula: a · capacity-c, where the *a* and *c* parameters are given in the following table:

Ship type	Capacity	a	c
Bulk carrier	DWT	961.79	0.477
Gas tanker	DWT	1120.00	0.456
Tanker	DWT	1218.80	0.488
Container	70% · DWT	174.22	0.201
General cargo	DWT	107.48	0.216
Reefer	DWT	227.01	0.244
Combination	DWT	1218.80	0.488

The reference lines are shown in Figure 2. The lines stop at the lower cut-off lines for the ship types, below which the required EEDI does not apply.

In order to address concerns raised by developing countries, the regulations include a clause allowing any administration to waive the EEDI requirements for ships flying its flag for a period of up to four years (linked to the contract date), or six years and six months (linked to the delivery date) after Jan. 1, 2013. However, the preliminary indications are that the major flag states will be reluctant to invoke the waiver clause.

1 Reduction factors (in percentage) for the EEDI relative to the reference line for each ship type

	Size	Phase 0 Jan. 1, 2013 – Dec. 31, 2014	Phase 1 Jan. 1, 2011 – Dec. 31, 2019	Phase 2 Jan. 1, 2020 – Dec. 31, 2024	Phase 3 Jan. 1, 2025 onwards
Bulk Carriers	>20,000 DWT 10-20,000 DWT	0% n/a	10% 0-10%*	20% 0-20%*	30% 0-30%*
Gas tankers	>10,000 DWT 2-10,000 DWT	0% n/a	10% 0-10%*	20% 0-20%*	30% 0-30%*
Tanker and combination carriers	>20,000 DWT 4-20,000 DWT	0% n/a	10% 0-10%*	20% 0-20%*	30% 0-30%*
Container ships	>15,000 DWT 10-15,000 DWT	0% n/a	10% 0-10%*	20% 0-20%*	30% 0-30%*
General cargo ships	>15,000 DWT 3-15,000 DWT	0% n/a	10% 0-10%*	20% 0-20%*	30% 0-30%*
Refrigerated cargo tankers	>5,000 DWT 3-5,000 DWT	0% n/a	10% 0-10%*	20% 0-20%*	30% 0-30%*

* The reduction factor is to be linearly interpolated between the two values depending on the vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

The EEDI will, as new ships are built, gradually reduce the emissions from the world fleet with 3 percent in 2020, 13 percent in 2030, and 30 percent in 2050.

Complying to the requirements in Phases 0 and 1 is expected to come at a low cost. There is no commercial reason to order a ship without a calculated EEDI as the second-hand value may be lower and the ability to get a charter may be reduced as charterers will prefer ships with low (and thus calculated) EEDI.

Ship Energy Efficiency Management Plan

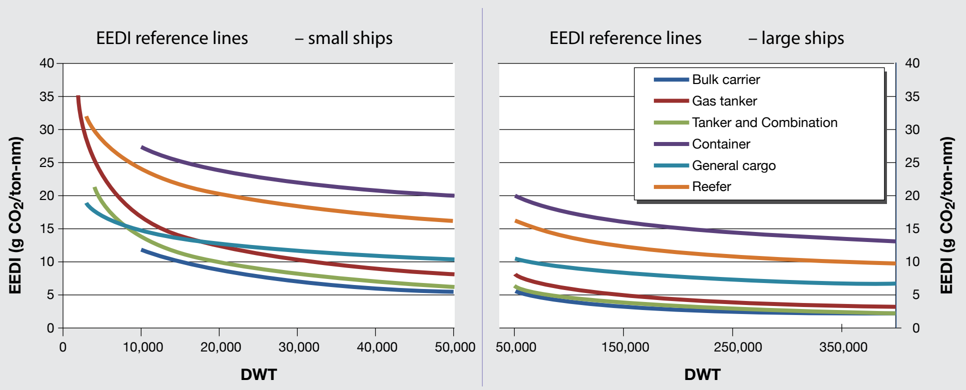
No changes were made to the SEEMP at MEPC 62, but the inclusion of SEEMP in the Annex VI amendments makes it mandatory for all ships – both new and existing – after it enters into force. The presence of a SEEMP will be checked during the first intermediate or renewal survey for the IAPP certificate, at which point the IEEC will be issued. The EEDI will not be calculated for existing vessels and thus not included in the IEEC.

Future CO_2 regulations

The adoption of the amendments is a significant step towards the regulation of greenhouse gas emissions by the IMO. Nevertheless, the EU is likely to consider it insufficient in light of its own ambitions. The EU process for establishing a regional CO_2 emission reduction mechanism for shipping is therefore expected to continue. Other parts of the international community also consider these regulations insufficient.

There is therefore a strong political drive to regulate shipping further, eg, through regional or international Market Based Measures (MBMs). Proposals under review range from a contribution or levy on CO_2 emissions from shipping via emission trading systems to schemes based on ship efficiency. If agreed, MBMs may appear towards the end of this decade.

2 The reference lines of a ship



Commercial energy efficiency requirements are becoming increasingly important. The creation of various voluntary schemes for rating environmental performance, including CO_2 performance, provides tools that allow charterers and cargo owners to use only ships that satisfy their environmental requirements. These rating schemes must be based on robust methods and verifiable data in order to create a level playing field for the shipowner.

Reducing the EEDI

Any measure considered for reducing the EEDI must affect one or more of the parameters in the EEDI equation.

3 The EEDI equation

Main engine — Auxiliary engine — Shaft motor — Energy efficient technology (electrical) — Energy efficient technology (mechanical)

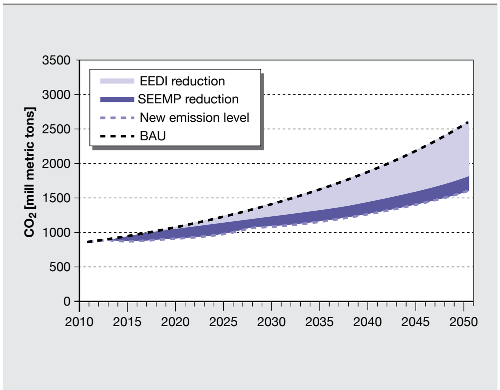
$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + (P_{AE} \cdot C_{FAE} \cdot SFC_{AE^*}) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE^*}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

Correction factors

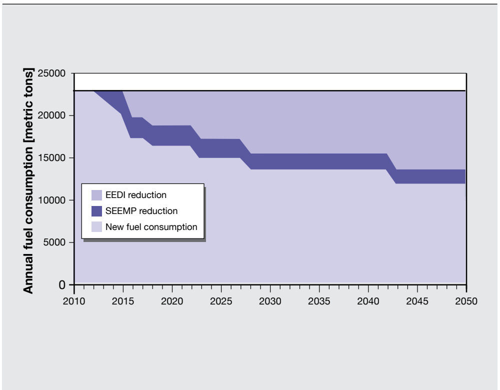
Transport work

Method	Measures	Parameter affected
Reduce the main engine installed power	Improved hull and propeller efficiency Speed reduction or de-rate engine	P_{ME}
Lower the specific fuel consumption	Switch to a more efficient engine Engine control tuning	SFC_{ME}, SFC_{AE}
Increase the speed (without increasing the installed power)	Improved hull and propeller efficiency (ie, Mewis duct, propeller boss cap fin or other flow devices)	V_{ref}
Use fuel/energy source with a lower carbon content	Ie, LNG, biofuel (no guideline yet)	C_{FME}, C_{FAE}
Innovative mechanical energy-efficient technology	Ie, kites (no guideline yet)	P_{eff}
Innovative electrical energy-efficient technology	Ie, waste heat recovery	P_{AEeff}
Increase the capacity	Larger ships	Capacity

4 World fleet - average scenario: A1B-4 and B2-1



5 Ship type: very large crude carrier (VLCC) - scenario: A1B-4
Fuel: high, SEEMP uptake: high, no waiver



The sulfur regulation coming into force in 2020 will significantly increase the fuel prices, but the increase energy efficiency will reduce the expected cost from 50 million to 30 million dollars per year.

In addition, there will be compensation when using shaft generators (PPTO) and applying ice strengthening (fj). Other correction factors, for example for voluntary structural enhancement, are under development.

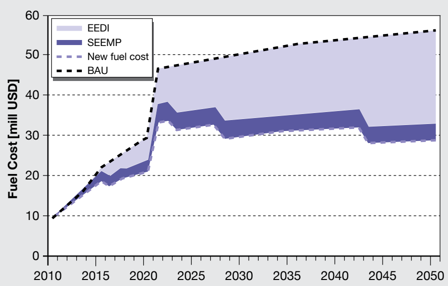
Some proposed measures, such as kites or solar panels, cannot provide power all the time and will not enable the main engine power and thus the EEDI to be reduced. At the moment, there are no guidelines for how such measures can be applied to reduce the EEDI, but these are expected to be developed at a later stage, most likely through the Peff parameter. Propulsion efficiency devices, such as Mewis ducts or propeller boss cap fins, can either reduce the main engine power (Pme) or enable the ship to obtain a higher speed (Vref).

Further, the use of biofuels is not covered by the current framework as the carbon content cannot easily be determined. There are no indications regarding if and when this will be developed.

Further regulatory work

A number of guidelines will be developed during the next few years, with the most important being issued before entry into force in 2013:
- February 2012 – MEPC 63: guidelines for minimum propulsion power
- October 2012 – MEPC 64: guidelines on voluntary structural enhancement
- July 2013 – MEPC 65: guidelines for CO_2 abatement technologies
- March 2014 – MEPC 66: guidelines for calculation of EEDI for RoRo, passenger, diesel-electric and hybrid propulsion ships

6 Annual fuel cost for newbuild VLCC - scenario: A1B-4
Fuel: high, SEEMP uptake: high, no waiver



The requirements and dates are subject to two reviews. The first is on the requirements for small ships and large bulkers and tankers and is due in July 2013. The second review allows for a discussion of both the requirements and the timeline for when Phases 2 and 3 are to enter into force, and is due in January 2015.

Impact of EEDI and SEEMP

The IMO commissioned a study by Lloyd's Register and Det Norske Veritas to estimate the impact of the new requirements. The results from the study show that the EEDI will, as new ships are built, gradually reduce the emissions from the world fleet with 3 percent in 2020, 13 percent in 2030, and 30 percent in 2050. The SEEMP will not directly mandate an emission reduction, but by increased awareness of costs and reduction potentials, the study estimated the reduction to between 5-10 percent from 2015 onwards.

Effect of SEEMP

The EEDI will mandate improvements in hull design and machinery, while the SEEMP will require ship-owners to develop a plan for their ships. There are significant potentials for reduction by operational measure, and with the current fuel prices, most are also cost-effective. However, there appears to be a limited uptake of these measures caused by non-financial barriers, such as lack of capital, lack of competence, lack of cooperation between actor and split incentives. Higher fuel prices will lead only to a limited extra implementation of measures, but over time will drive technology development and innovation. Other incentives will have to be in place to implement the existing set of measures. The SEEMP will initiate monitoring and target setting and look at concrete measure to be implemented for each vessel. Awareness of the potential savings is expected to increase the uptake of measures.

Very large crude carrier (VLCC) case

The effect of the new regulations was applied on a VLCC to see how the fuel consumption and cost would develop. The baseline case was a tanker using 23,000 metric tons of fuel per year, which at current fuel prices would cost around $10 million. The first figure shows how a newbuild vessel would perform year by year towards 2050.

A ship built according to the requirements in 2030 would use about 14,000 metric tons per year in 2030. The fuel cost calculations in the second chart are based on a scenario where the sulfur regulation coming into force in 2020 will significantly increase the fuel prices, but the increase energy efficiency will reduce the expected cost from $50 million to $30 million per year.

Tore Longva
Det Norske Veritas

EMMA™ Ship Energy Manager

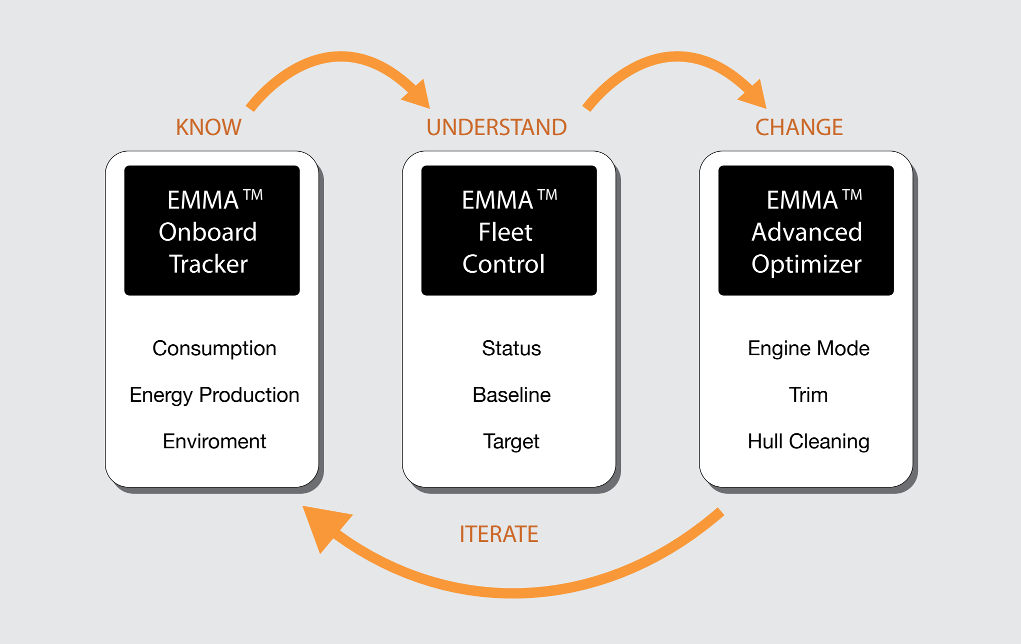
Know, understand and change

JUKKA IGNATIUS, JAN-ERIK RÄSÄNEN, KALEVI TERVO, OLLI HUTTUNEN – There is considerable potential for today's vessels to improve overall energy consumption. This can be done by, for instance, changing the engine configuration, operating profiles or the fuel used; or by recovering waste heat or optimizing trim. EMMA™ offers integrated solutions for decision support in the search for optimal energy management.

To improve operations, owners need to identify and understand the weakest parts of their existing performance. Understanding is developed by measuring the key performance indicators (KPIs) of each and every vessel in the fleet.

With such progressive improvement in mind, ABB has developed the EMMA Advisory Suite, which offers a range of products designed to take an iterative approach to ship performance benchmarking.

1 Benchmarking process with EMMA Advisory Suite



The EMMA product portfolio consists of onboard modules for energy monitoring and optimization and office tools for fleet-wide data analysis (Figure 1). The EMMA Suite aims to look at the vessel as a whole, instead of providing separate decision support tools for different problem areas.

Relationship to SEEMP

The International Maritime Organization's Marine Environment Protection Committee (MEPC) describes the Ship Energy Efficiency Management Plan (SEEMP) as a four-step cycle of planning, implementation, monitoring, self-evaluation and improvement. In combination with EMMA and energy coaching services, a shipping company can implement a full SEEMP which will be mandatory as of Jan. 1, 2013.

The SEEMP requires ship and company-specific measurements to be determined. EMMA has a good set of proposed KPIs including the Energy Efficiency Operational Indicator (EEOI). Using ABB's energy coaches, the most appropriate KPIs can be selected to fit the operations in question.

Voluntary goal setting for the selected measures is also part of the process. The MEPC states that the goal may take any form, fitting well with the various KPIs that EMMA presents. Depending on the operational profile, a suitable target can be set either qualitatively or quantitatively.

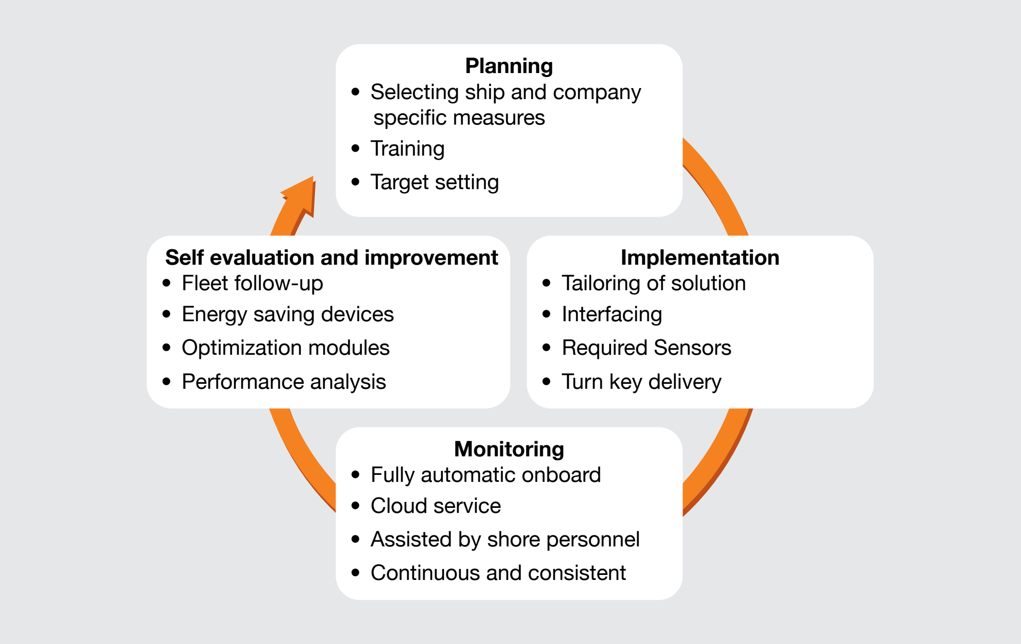
Measures that can be taken towards better energy management practices depend on vessel type. ABB offers the following as a turnkey delivery:
– Optimum trim
– Hull and propeller condition maintenance
– Energy management and waste heat recovery
– Propulsion system optimization
– Pump and fan operation

Planning – optimum trim

The EMMA solution is based on the principle of easy-to-use optimization modules for even the most complex onboard processes. This principle requires smart algorithms and the latest available design and operating guidelines. Trim optimization is a good example of this. The operator can see from a distance of about 3 meters a clear presentation of the current trim of the vessel, the optimum trim and the potential savings available.

The algorithm used is based on effective machine learning methods and real-time sensor fusion algorithms of real, full scale, measurements instead of

2 SEEMP process



merely being inferred from computed fluid dynamics (CFD) or towing tank tests. The model can also include prior information based, for example, on the propeller's properties, and certain key variables that affect the vessel's resistance and propulsion power loss.

This type of approach will find the optimum trim for any given operating condition. The model uses data collected from several sources on board, such as an integrated automation system, an integrated navigation system and ABB's attitude sensors that measure ship movements.

Typically, after installing the system on board, measurements are recorded over a 1-2 month period to ensure that the parameters of the trim optimization model are supported by sufficient statistical data drawn from normal operational conditions. In addition, trim sweep tests are performed with the help of ABB's Energy Coach to complete model construction.

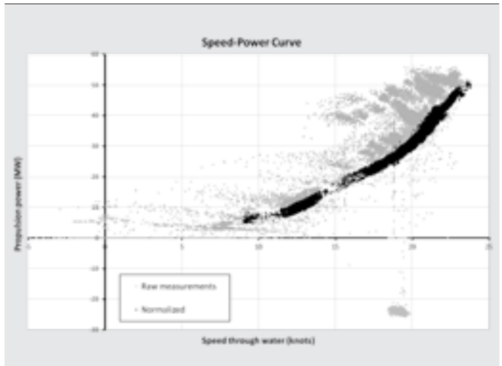
Planning – hull and propeller condition maintenance

The EMMA optimizer gives accurate predictions of the propulsion power required, taking into account operating conditions such as wind, sea state, speed,

The EMMA solution is based on the principle of easy-to-use optimization modules for even the most complex onboard processes.

3 Example of EMMA Advanced Optimizer Trim

4 Speed-power curve as raw data, and filtered and normalized (except the trim)



Typical sensors required in SEEMP implementation

Torductor: shaft torque meter - a proven product for shaft torque measurement for any size of propeller shaft. The technology used is based on measurement of the magnetic characteristics of the shaft.

CoriolisMaster: mass flow meter operating on the Coriolis principle - included in the ABB portfolio. It can measure mass flow, volume flow, density, temperature and concentration simultaneously without moving parts.

Attitude sensors: needed for accurate dynamic trim measurements. ABB uses military grade attitude sensors. Depending on the size of the vessel, two to three sensors are installed to measure the attitude.

currents, etc. Therefore the model gives a benchmark for the propulsion system's performance and the hull condition. One interesting by-product that can be built on these measurements is a hull maintenance planning aid.

The typical problem in interpreting full-scale speed-power measurements is visible in Figure 4. The grey dots indicate raw data, as received from the automation and navigation systems. This raw data includes approximately 112,000 measurements. The black dots represent the measurement set once the obviously erroneous and low speed values are removed and the data is normalized for weather and floating positions effects using the EMMA method. Curve fitting using raw data results in 0.706 as the coefficient of determination. The filtered and normalized values put this at 0.992, which is a remarkable improvement (see Figure 4).

Calculating these normalized figures over time shows the hydrodynamic performance of the vessel. The effect of hull and propeller conditions is evident from these figures, and the shipping company can use this data in correctly scheduling hull cleaning or even dry-docking.

Planning: energy management and waste recovery

The EMMA power plant optimizer employs a physical model (including, for example, specific fuel oil consumption curves) that is adjusted using statistical data from real-life measurements. This combination gives a definite advantage to plain power plant physical modeling, since any energy producer will not be the same throughout its life cycle.

5 Example of EMMA Advanced Optimizer Power Plant

6 Example of EMMA Onboard Tracker main dashboard

Decision support for the user is given in a simple way, observing the power plant as a whole. This is important, especially with more complex configurations. The example in Figure 5 is from a large container vessel with two main engines, two shaft generators/motors, four auxiliary engines and a large 20 MW waste heat recovery (WHR) unit.

Optimizing such power plant requires extensive knowledge, and the number of permutations is beyond possible real-time human interpretation. The EMMA user interface (UI) clearly indicates the overall status, as can be seen from Figure 5. Each energy producer is listed, and the UI uses color codes to indicate the running status, current and optimum load and the advice for the user.

The optimizer allows the user to determine and change the necessary spinning reserve, as well as the operating limits for each power producer. Moreover, the user can exclude some of the power producers from the optimization model in real time. The model is also able to take into account the maintenance cycles of power producers.

The optimization model can also easily be enhanced if a forecast for power demand can be added. This will allow the system to use the model predictive control (MPC) philosophy. The MPC is based on the idea that the optimization algorithm uses the existing model of the system and forecast inputs to simulate the consequences of actions taken now.

Planning - propulsion system

If the vessel is equipped with two or more Azipod® propulsion units, ABB offers an Azipod Dynamic Optimization (ADO) tool addressing the towing angle of the Azipods. This is a problem of a dynamic nature and requires constant measurement of real conditions. The system does not require any user interference and is totally automatic, providing continuous optimum vessel thrust.

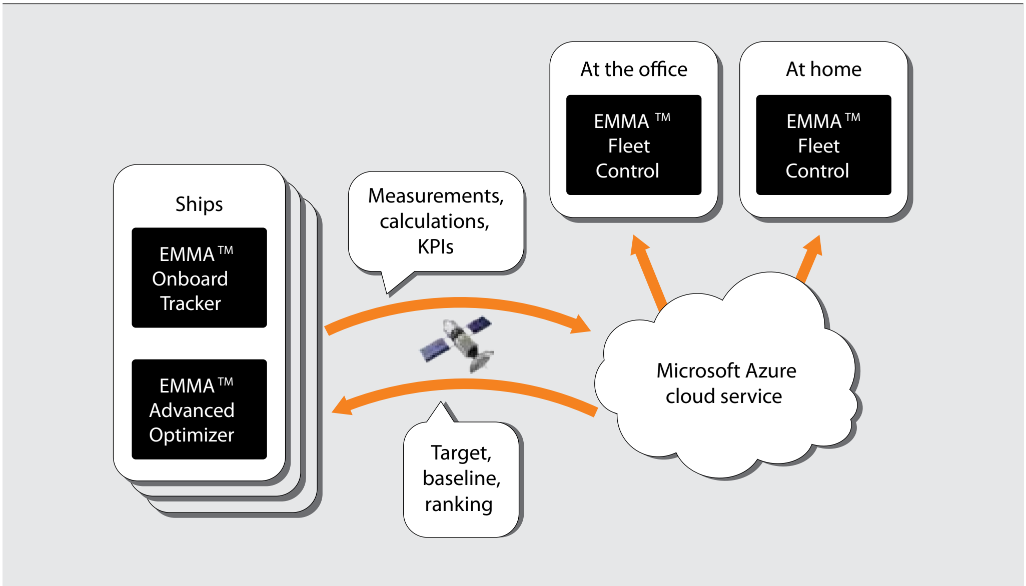
Planning – pump and fan operation

Until recently, energy efficiency in auxiliary systems was not taken into account during the design process or construction of marine vessels. For this reason, systems on existing ships are not energy efficient and have not been fully optimized in terms of overall fuel consumption. The onboard ship systems most suitable for improving energy efficiency are those with large pumps and fans, which are not required to run continuously and at full capacity. When applicable, electric motors can be fitted with variable frequency drives (VFD) to operate pumps and fans more efficiently under partial loads during slower sailing speeds or when ventilation requirements are reduced. The electric power consumption of a pump is related to its volumetric flow. As an example, a reduction of the pump speed by 10 percent will save 27 percent of the power consumed.

Implementation

The MEPC guidelines state that the selected measures for energy management have to be implemented by defining tasks and assigning them to qualified personnel. ABB can implement a project as a complete turnkey delivery, thus minimizing the shipping company's risk and involvement in possible installations and modifications. Naturally, tasks are assigned to the personnel operating the vessel.

7 EMMA data transfer principles



Depending on the measures selected, installation of sensors might be required. For example, dynamic trim optimization requires attitude sensors and propeller shaft torque measurement. Power plant optimization requires power measurements and fuel flow meters that are as accurate as possible. If these are required but not available, ABB offers a package including all required hardware in the same turnkey project.

Monitoring

SEEMP guidelines state that onboard monitoring should be quantitative, assisted by shore personnel, consistent and continuous, and should involve the crew as little as possible. The EMMA Advisory Suite handles the monitoring automatically on two levels - on board the vessel with the EMMA Onboard Tracker and for the office personnel with EMMA Fleet Control.

Monitoring – EMMA Onboard Tracker

The EMMA Onboard Tracker is a fully automatic tool for onboard KPI calculation, display and recording purposes. The user interface is heavily implemented on the "3-meter-screen" ideology, which simply means that the overall status is visible from a distance without the need for making a detailed study. Figure 6 shows an example of the main dashboard.

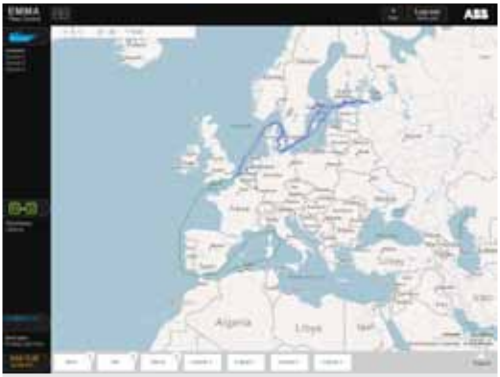
The UI in this example is divided into four segments presenting different type of KPIs:

- Upper left: cost of operation
- Upper right: energy production/consumption
- Lower left: navigational aspect, in this case consumption per nautical mile
- Lower right: overall optimization status

The large dials are visible from a long distance. If all of the segments are lit up, the vessel is performing well in the specific area, taking into account prevailing environmental conditions. The more segments are missing, the greater the potential for improvement. Trend presentation of history data is also available.
It is typical for marine applications that the performance of some equipment varies more as a result of operating conditions than it does as a result of substandard operation. For example, in deep sea operations, the variation in the vessel's propulsion power is set by the desired speed in the context of wind, weather and waves. These operating conditions need to be taken into account when evaluating performance.

The EMMA Onboard Tracker addresses this issue by employing the ABB self-learning model to provide adaptive dynamic targets for each power producer. The model can learn the interdependence in play between a consumer and the operating conditions automatically without any human effort.

8 Example of EMMA Fleet Control view



Once the model can predict behaviour of the consumer to the required level, it starts to provide the adaptive dynamic KPI value for the consumer. By normalizing the effect of operating conditions generated by the consumer measurements, performance degradation that is directly due to equipment wear or poor operation can be spotted easily.

Monitoring – EMMA Fleet Control

All of the data collected and calculated on board is automatically transferred to EMMA Fleet Control, which is a modern business intelligence data analysis tool. EMMA Fleet Control operates within the high cyber security Microsoft Azure cloud service. This enables secure data access from any location. This centralized EMMA database is used to form the baseline and ranking of fleet performance. The benchmarking data is replicated back to the vessels so that the fleet-wide performance is visible for users on board without a broadband connection. See Figure 7 for data transfer principles.

All collected and calculated figures are available for access in graphical and numerical forms. EMMA Fleet Control uses predefined views for ease of use. As an example, weekly fuel oil consumption is visualized using bar charts, fleet positions on an interactive map (Figure 8), and the speed-power curve as a scatter chart with curve fitting. The user can benchmark and rank data collected from the fleet.

As in any benchmarking process, the MEPC describes the last step of SEEMP as the one that should produce “meaningful feedback for the coming first stage, ie, planning stage, of the next improvement cycle.” All of the measures documented in the SEEMP are documented and quantitatively recorded using the onboard and office tools. It is even advisable that all the possible measures are not included in the first implementation of SEEMP. Having the EMMA system implemented for a couple of months provides excellent information on current vessel status and additional measures can be chosen more wisely using this baseline.

Unleash the power of integration

As described, the existing fleet can easily be retrofitted with a custom EMMA Advisory Suite, thus significantly improving the performance. However, the full power of the approach is only unleashed when a complete ABB solution is implemented. Such an integrated approach would see the ship equipped with an ABB automation system, power management and decision support tools so that the information flow is not only enabled but significantly simplified. The more the system “knows,” the more it is able to offer advice on optimizing operations.

ABB believes that an integrated solution is not only preferable, but critical in ensuring an efficient and eco-friendly fleet. Only through integrated approach can an owner harmonize what may be conflicting advice affecting different parameters. For instance, a voyage optimization tool should be connected to live data drawn from power plant performance. ABB’s integrated solution makes sure that the vessel is observed as a whole.

As well as heightening awareness of decision support tools themselves, an integrated solution minimizes hardware and the number of interfaces. This naturally increases the system’s availability and robustness. Again, the integrated approach should mean that software tools are more easily updated throughout the ship’s life cycle.

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Onboard DC Grid

The newest design for marine power and propulsion systems

JAN FREDRIK HANSEN, JOHN OLAV LINDTJØRN, TOR-ARNE MYKLEBUST, KLAUS VÄNSKÄ – Think of a Mac from Apple, a Le Corbusier chair, a Frank Lloyd Wright house. All are designs that are clean, elegant, streamlined. All are also designs that took an existing element and created something innovative. ABB has done just that with its Onboard DC Grid for electric power distribution, creating the most flexible marine power and propulsion system to date. The system merges the various DC links throughout the vessel and distributes power through a single 1,000 V DC circuit, thereby eliminating the need for main AC switchboards, distributed rectifiers and converter transformers. The Onboard DC Grid combines the best of both AC and DC components and systems, is fully compliant with rules and regulations for selectivity and equipment protection, can be used for any electrical marine application up to 20 MW, and operates at a nominal voltage of 1,000 V DC. The best part: ABB's Onboard DC Grid increases a vessel's energy efficiency by up to 20 percent and reduces the electrical equipment footprint and weight by up to 30 percent.

In designing the new system, ABB looked at the entire power delivery chain of energy conversions on marine vessels and identified a case for using DC distribution rather than the traditional AC system.

Two longstanding and crucial principles have been carried over from the traditional AC distribution system to form the framework of the Onboard DC Grid philosophy: equipment shall be protected in case of failures and proper selectivity[1] shall be ensured in such a way that safe operation is maintained after any single failure.

Advantages of DC distribution in certain cases include lower overall losses and fewer problems with harmonic distortion. Yet historically there have been challenges with DC distribution, primarily revolving around how full selectivity and equipment protection can be achieved in ways that are similar to AC distribution. AC currents are by nature simpler to interrupt because of their natural zero crossing every half cycle. DC circuit breakers exist but are more complex, larger and more expensive than comparable AC circuit breakers.

ABB overcame these challenges by breaking with the classic protection philosophy, where selectivity is achieved through an arrangement of coordinated circuit breakers, and instead capitalizing on the opportunities afforded by power electronic components in the Onboard DC Grid system.

Power distribution and configurations

In traditional electrical propulsion systems, variable frequency drives typically account for more than 80 percent of the installed power. At its simplest level, the Onboard DC Grid concept is a reworked and distributed multidrive system where distributed rectifiers are eliminated (Figure 1).

The new system merges the various DC links around the vessel and distributes power through a single 1,000 V DC circuit, thereby eliminating the need for main AC switchboards, distributed rectifiers and converter transformers (Figure 2). All electric power generated is fed either directly or via a rectifier into a common DC bus that distributes the electrical energy

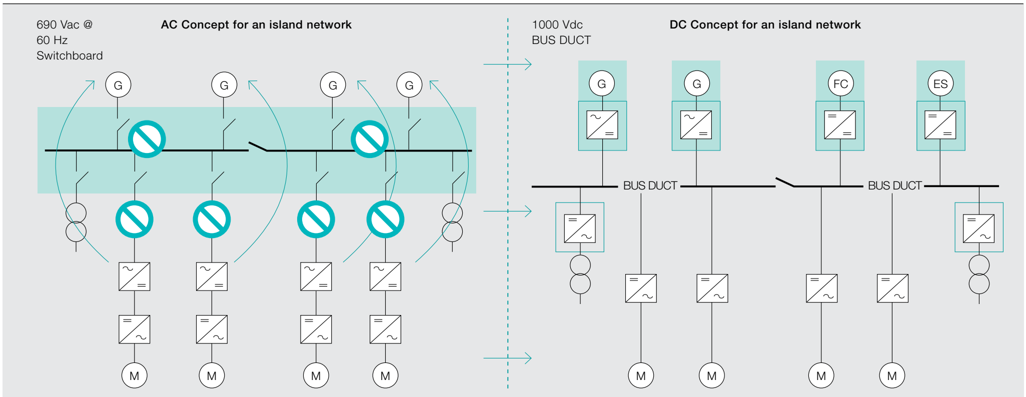
Title picture
Marine offshore support vessels are excellent candidates for the Onboard DC Grid

1a Platform supply vessel witn Onboard DC Grid

1b AC to DC transformation of a generic electric propulsion system

The new system merges the various DC links around the vessel and distributes powers through a single 1,000 V DC circuit.

2 AC to DC transformation of a generic electric propulsion system



Proper protection of the Onboard DC Grid is achieved through a combination of fuses, isolating switches and controlled turn-off semiconductor power devices.

to the onboard consumers. Each main consumer is then fed by a separate inverter unit. When an AC distribution network is still needed, for example with a 230 V hotel load, it is fed using island converters, developed by ABB to feed clean power to these more sensitive circuits. Additional converters for energy storage in the form of batteries or super capacitors for leveling out power variations can be added to the DC Grid.

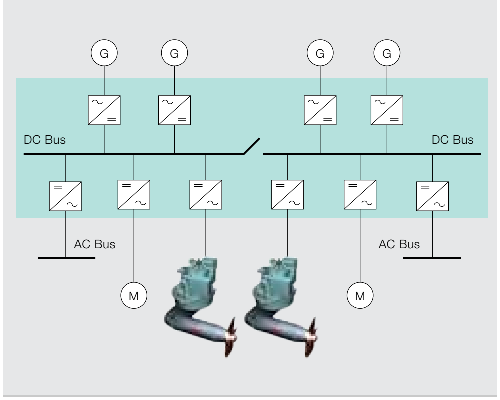
The system has been remodeled in such a way that most of the well-proven products used in today's electric ships such as AC generators, inverter modules and AC motors can still be used.

The Onboard DC Grid can be configured in several different ways. With a centralized approach all converter modules are located in one or multiple lineups within the same space that the main AC switchboards used to occupy (Figure 3).

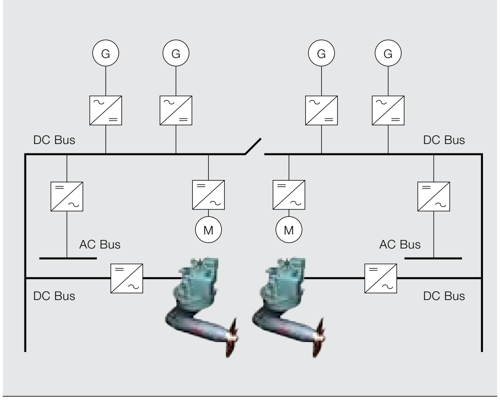
With a distributed approach, the various converters can be placed where it suits the vessel operation or design best (Figure 4). The AC generators can have either integrated or stand-alone rectifiers installed in cabinets. As a result of the novel approach to protection, the volume of components that, by law, must be installed in the main switchboard room is drastically reduced. This affords the vessel designer a new level of freedom in designing the electrical power system around the vessel function, increasing the vessel functionality and value.

Protection and safety

With the main AC switchboard, AC circuit breakers and protection relays omitted from the new design, 3 Onboard DC Grid, multidrive approach



4 Onboard DC Grid, distributed approach



a new protection philosophy that fulfills regulatory requirements for selectivity and equipment protection is essential. Proper protection of the Onboard DC Grid is achieved through a combination of fuses, isolating switches and controlled turn-off of semiconductor power devices. Since all energy-producing components have controllable switching devices, the fault current can be interrupted much faster than would be possible with traditional circuit breakers and their associated protection relays.

In case of a serious fault in a module, fuses are used to protect and isolate inverter modules just as with current LV frequency converters. In addition, input circuits separate the inverter modules from the main DC bus and afford full control of reverse power, both in fault and normal conditions (as, for example, in propeller braking mode). This means that faults on a single consumer will not affect other consumers on the main DC distribution system. In the event of severe faults on the distributed DC bus, the system is protected with generators by means of a controllable thyristor rectifier, which also doubles as a protection device for the generator. Isolator switches are installed in each circuit branch in order to isolate faulty sections automatically from the healthy system.

In close cooperation with Det Norske Veritas, a global organization that provides classification and risk assessment services to the maritime industry, ABB has ensured that the Onboard DC Grid system philosophy meets or exceeds the demands of current rules and regulations. Fault currents can be controlled in as little as 10 ms to 20 ms, resulting in a drastic reduction in the DC Grid's fault energy levels when compared with traditional AC protection circuits where fault durations can reach up to 1 s. This low-energy fault protection scheme, combined with the new flexibility in designing generator parameters, allows the Onboard DC Grid system to be used for installed power up to 20 MW.

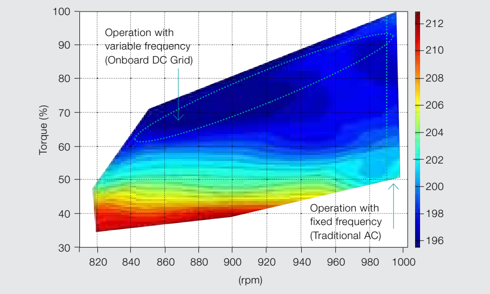
Efficiency with fuel and space

The DC Grid concept utilizes well-proven AC generators and motors, but allows for increased efficiency because the system is no longer locked to a specific frequency (usually 60 Hz on ships), even though any 60 Hz power source may still be used. The new freedom of controlling each power consumer independently opens up numerous ways of optimizing fuel consumption.

When operating marine combustion engines at constant speed, the fuel consumption is lowest in a very small operating window, typically around 85 percent of rated load. With the introduction of variable-speed operation of the engine, this window of optimal efficiency can be extended as far down as 5 percent, depending on the engine (Figure 5). If the engine is operated at loads below this, the engine efficiency remains significantly higher than that of the traditional fixed-speed equivalent. The end result is that a typical offshore support vessel can achieve fuel savings of up to 20 percent (Figure 6).

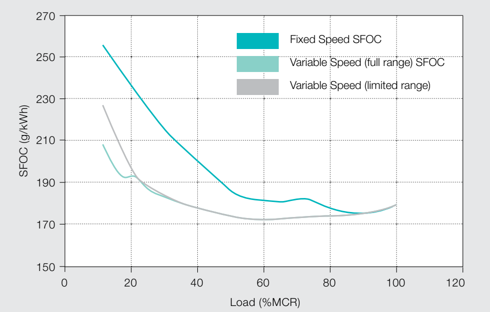
By eliminating the bulky converter transformers and main switchboards previously needed with the traditional AC system, the Onboard DC Grid also reduces the footprint of the electrical equipment used (Figure 7). This creates more space and provides greater flexibility in the positioning of system components in the vessel. In addition, the system enables simpler

5 Engine fuel tests at variable speed (color scheme indicates specific fuel oil consumption (8FOC) in g/kWh. University test engine



Test results are of fuel consumption as a function of applied torque and RPM for a small test engine at Helsinki University. Results show that it is possible to run this type of engine with the lowest possible fuel comsumtion at least down to 50 percent leading.

6 Engine fuel characteristics at variable speed (color scheme indicates specific fuel oil consumption (SFOC) in g/kWh



Further analysis has been done, in cooperation with an independent engine manufacturer, on a medium speed engine range typically used in OSV vessel powerplants.

7 Benefits of the Onboard DC Grid

- More functional vessel layout through more flexible placement of electrical components
- Reduced maintenance of engines by more efficient operation
- Improved dynamic response and maneuverability
- Increased space for payload through lower electrical footprint and more flexible placement of electrical components
- A system platform that allows “plug and play” retrofitting possibilities to adapt to future energy sources
- Up to 20 percent fuel savings

integration of supplementary DC energy sources such as solar panels, fuel cells or batteries into the ship’s DC electric systems, creating scope for further fuel savings.

The reduced weight and footprint of the installed electrical equipment will vary depending on the ship type and application. One comparison using a distributed variant of the Onboard DC Grid system instead of the traditional AC system for a platform supply vessel (PSV) reduced the weight of the electric system components by 25 percent from 115 to 86 metric tons.

Dynamic positioning vessels

The variable power consumption of anchor handling vessels and offshore support vessels make them very good candidates for the Onboard DC Grid system (Figure 8). The new concept helps solve the traditional fuel efficiency challenge faced in dynamic positioning (DP) operations. DP vessels often need to run several diesel generators in parallel due to redundancy considerations. This means that the connected diesel engines spend most of their running hours at relatively low loads, where fuel efficiency is significantly lower than at the optimal load, which is typically at 85 to 90 percent load.

DP is when the propellers (thrusters or main propulsion or both) are used to stay at a given position (+/- a few meters) and heading (to minimize the impact of wind, current and wave action on the vessel hull). It is sometimes used for work orders close to a drillship or when performing operations like loading/unloading close to an installation (eg, a drillship or platform). In severe DP operations — for example, in extreme weather or in critical operations where loss of propulsion power could cause significant damage to the vessel, other installations or personnel — the electrical plant is split into a minimum of two separate sections to achieve a higher level of redundancy in the power system.

By doing so, the vessel can maintain its position even if one side of the power plant fails. However, running in split mode generally does not utilize the full benefits of electric propulsion because total optimization of running engines is not possible. Fuel efficiency has therefore often been sacrificed in favor of safety. With the Onboard DC Grid the split mode operation can run more efficiently as the engine speed can be adjusted and optimized to the required load without the need for changing the number of generators online.

In particular, when considering the DP operation, integration of energy storage to the Onboard DC Grid, will set a new standard for response time of the thrust and station keeping accuracy. The energy storage allows main engines to run with a relatively constant power load by charging and discharging the energy storage device depending on the needed thrust to keep vessels position. Thus, the vessel's ability to keep its position will be less dependent on the engines' response time for load transients. Positioning performance can be improved, and the engines can operate even closer to their optimal load conditions. Also, as the throttling of the engine is more constant, tear and wear of the mechanical actuators could also be reduced.

Yachts

One day, a yacht may be transferred to a new port at its maximum speed to be ready to welcome quests, while next day, it is quietly sailing while there is party on board. Whatever the propulsion need should be, the Onboard DC Grid helps to provide the best efficiency and comfort with a reduced use of valuable space.

Ferries

Some ferries carry trains; others carry cars, trucks or passengers. What is common for almost all ferries is that they operate on scheduled routes between two or more terminals. Most of the terminals are located in densly populated areas and even in the middle of cities. The visibility of these ships and their direct effect to the quality of life for so many people create a strengthened awareness and attention to the environmental emissions by ferry owners and operators.

Certain new technologies, such as liquefied natural gas (LNG) engines are being introduced in ferries, and the Onboard DC Grid is particularly well-suited for integrating the LNG power plant with the propulsion, as it gives the possibility to operate the engines at more stable loads with higher efficiency and less methane slip.

The Onboard DC Grid is easily compatible with energy storage devices such as batteries either as a source of energy that is supplementary to the combustion engines or even as the only source if adequate charging can be supplied at the terminal.

8 New order

ABB will equip a newbuild platform support vessel (PSV), owned by Myklebusthaug and located at the Klevan shipyard in Ulsteinvik, Norway, with a full Onboard DC Grid system, including all power, propulsion and automation systems.

The 93 meters long, 4,800 GT type MT 6015 PSV, a multipurpose oil field supply and construction vessel designed by the Norwegian company Marin Teknikk, is due for delivery in the first quarter of 2013. The vessel has five variable-speed diesel generators, four rated at 2,300 kW and one at 920 kW, two 2,200 kW main propulsion units and three additional thrusters for DP operation.

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Footnotes

1 In the event of a fault on a component or subsystem, selectivity means (on a functional level) that only the faulty component or subsystem is affected and taken out of operation.

2 The term "hotel load" is used with respect to ships to describe their non-propulsion energy requirements, such as lights, air conditioning, computers, water purifiers, radios, etc..

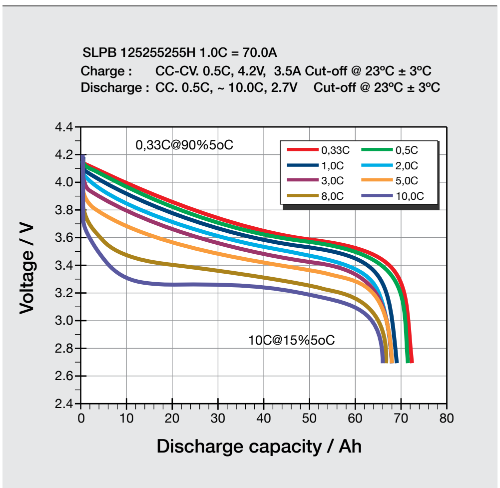
Further reading

Hansen, J. F., Lindtjørn, J. O., Vanska, K. (October 2011). *Onboard DC Grid for enhanced DP operation in ships*. Paper presented at the Dynamic Positioning Conference, Houston, TX, United States.

Batteries installation and load sharing in hybrid power plants

FRANK WENDT – Facing a growing demand for higher power plant efficiency, reduced fuel consumption and lower emission levels, the marine market is evaluating concepts based on the use of hybrid power plant with energy storage systems. Given the availability of high power and energy dense batteries, such systems are now being considered as a possible additional and/or alternative power source to diesel generator sets for shipboard electrical power plant. Load sharing has to be controlled, especially when the battery system is operating in parallel with other power sources, and this article describes a load sharing method which allows a direct connection of the battery with a DC-link system.

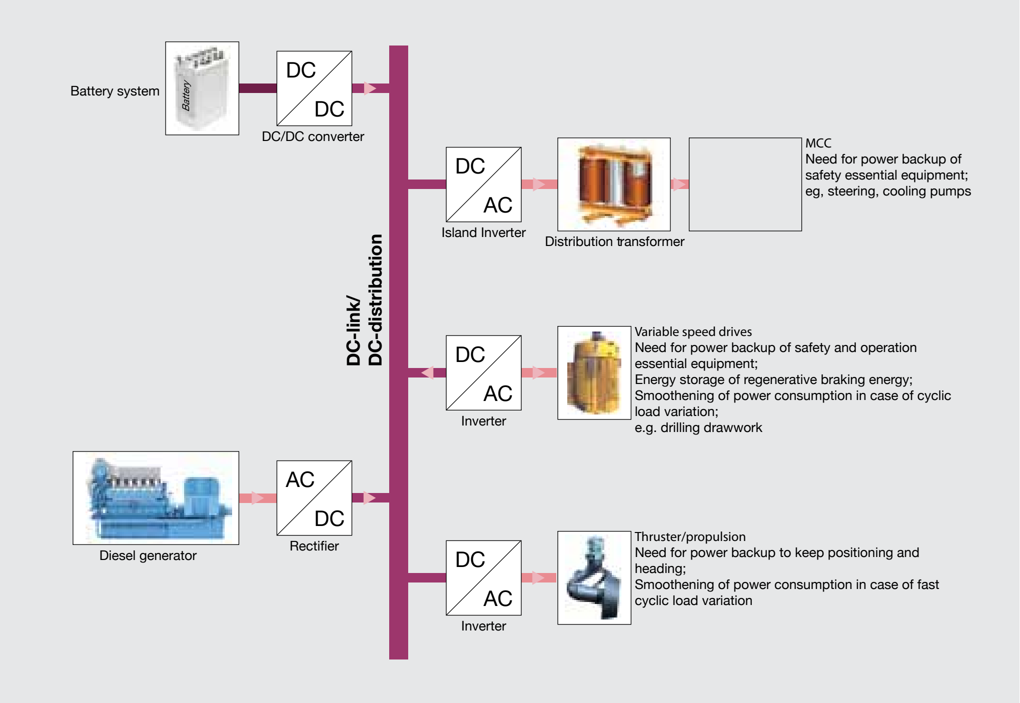
1 Cell performance of lithium Ion battery (Corvus Energy)



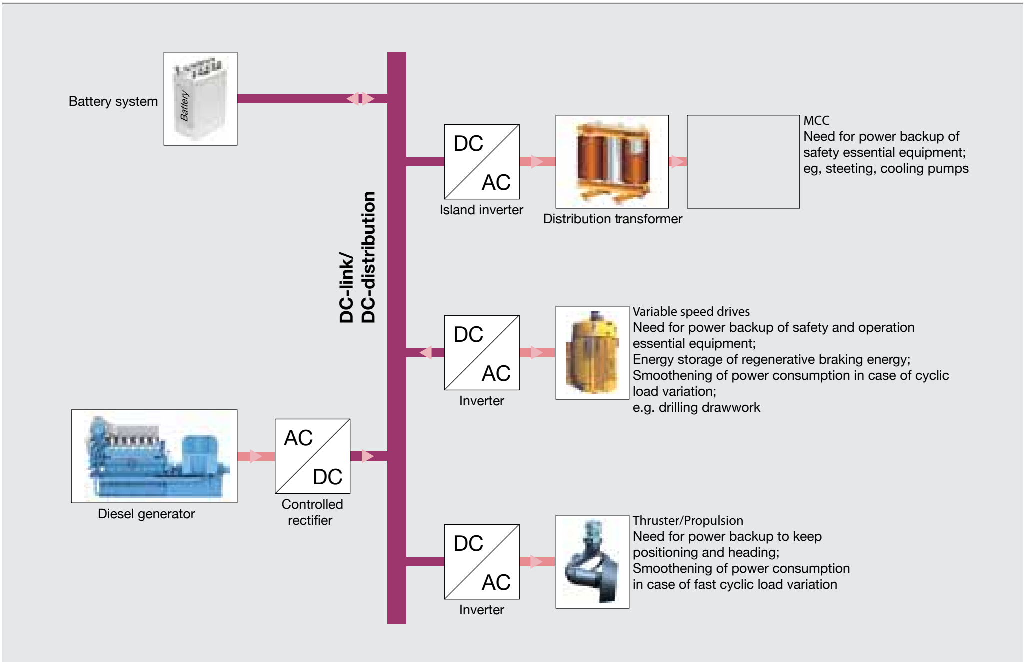
When using a battery-based energy storage system in a diesel-electric power plant, load sharing between the battery system and diesel generator(s) has to be controllable. The battery system can be connected either to the common DC bus in a multi-drive variable speed drive system or directly into a DC grid power distribution system.

The voltage at the batteries' terminals varies with their state of charge (SoC) and the charge or discharge current. The variation in voltage depends on the battery chemistry and, for a lithium ion cell, can be up to 20-25 percent between a typical operation point 0.33C@90 percent SoC and 10C@15 percent SoC, C being the rated discharge current (Figure 1). Furthermore, unlike other power sources such as diesel generators, there is no way of controlling a battery that enables direct power sharing.

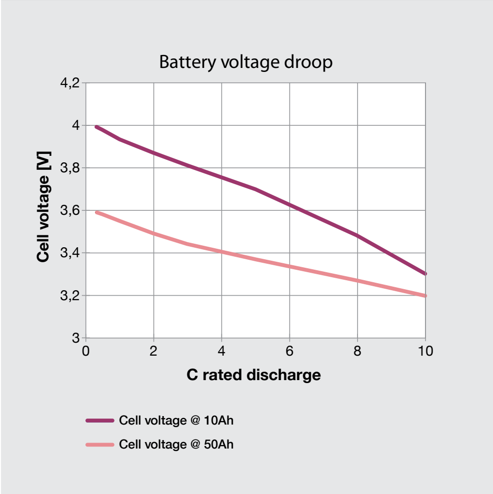
2 Battery system connected through a DC/DC converter to DC-link)



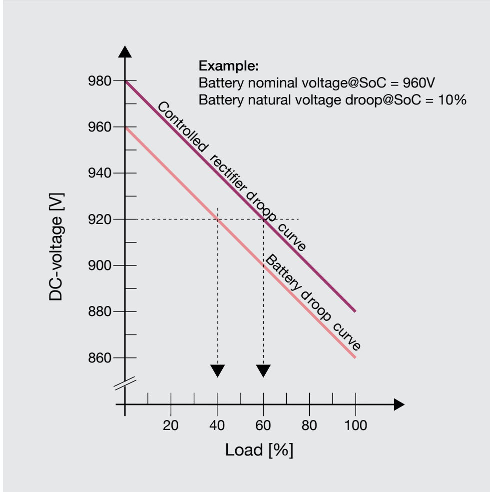
3 Battery system directly connected to DC-link



4 Battery voltage droop



5 Voltage droop based load sharing



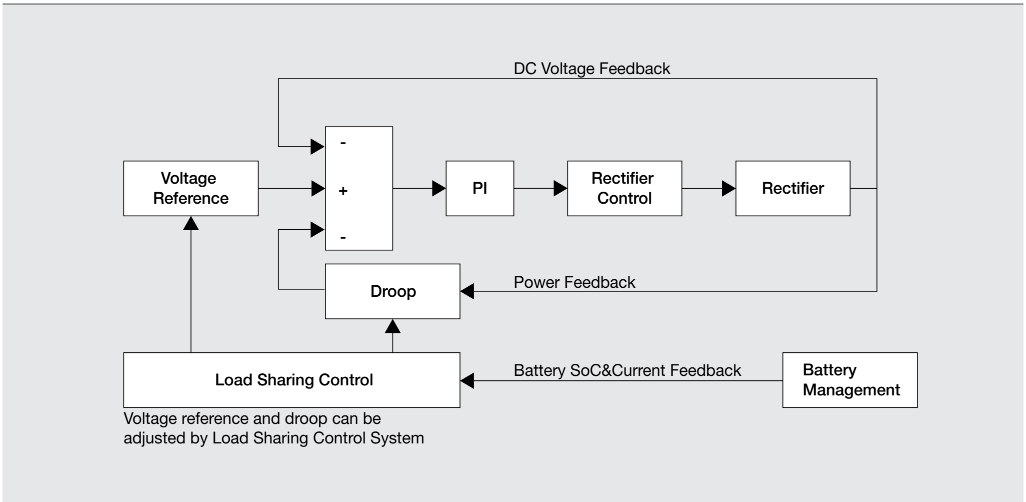
The marine market is evaluating concepts based on the use of hybrid power plant with energy storage systems.

The main power consumers in a diesel-electric power plant are usually variable speed drive (VSD) systems, including, for example, propulsion thrusters and cargo and drilling drives. Modern VSDs are based on voltage source converter technology which uses a relatively constant DC voltage intermediate circuit. To guarantee full performance of the VSD, the DC link voltage has to stay above certain defined levels.

When using batteries as part of the power source for VSD systems, the voltage variation of the battery can be compensated for through the use of DC/DC converters, which boost the changing battery voltage level up to the required DC link voltage. The DC/DC converter also enables the control of direct power load sharing between the battery system and diesel generator (Figure 2). In high power battery energy storage systems, however, the DC/DC converter contributes significantly to the size and cost of the overall battery energy storage system and can cause additional losses.

An alternative configuration is to connect the battery directly to the DC link (Figure 3). In such a system the battery voltage determines the DC-link voltage and all power consumers have to be rated according to the variation of the DC link voltage. This mainly affects the current and voltage rating of the power components in the system, as these must be able to convert or produce the required power at both maximum and minimum voltage levels. Load sharing between the battery system and the diesel generator(s), as well

6 Controlled rectifier voltage droop control



as battery charging/discharging, has to be controlled by the AC/DC rectifier unit(s), which feed power into the DC link system. In applications with a high C-rate discharge current, the natural droop of the battery voltage can be used for load sharing between a diesel generator set and the battery. The voltage droop (cell voltage versus discharge current) is relatively linear, but changes with the SoC of the battery (Figure 4). Voltage droop based load sharing is an effective and robust method for parallel operating power sources. With the DC voltage common for both the battery and rectifier, each unit supplies the amount of power, which corresponds to its applied droop curve. As the load on the DC link increases, the DC-voltage drops.

By implementing a voltage droop control algorithm in the rectifier control system, the output voltage of the rectifier can be adjusted to control both the power flow in the battery and the AC/DC rectifier and consequently between the battery and diesel-generator (Figure 5). The natural droop curve of the battery is only quasi-static and changes with the SoC. With current and SoC feedback from the battery management controller, a load sharing controller can adjust the voltage reference and droop curve settings of the droop controller in the controlled rectifier. By adjusting the voltage reference and droop curve setting in the droop controller, not only can the load sharing between the battery and diesel generator be controlled, but also the battery charging.

Frank Wendt

ABB AS, Marine CoE O&G Vessels

High capacity battery packs

BRENT PERRY – Energy storage and battery technologies are developing rapidly. There is a clear trend of integrating batteries in marine electric systems due to the additional benefits of energy storage for electric propulsion.

Energy storage will typically provide a supplementary source of energy in the electric plant that can enhance energy efficiency when used together with diesel engine sets and offer backup power supply for increased safety, although designs are also being developed that use batteries as the main or sole energy source. It is expected that greater attention to fuel efficiency and fault tolerance in design and operation will create an increasing demand for battery use in marine electric propulsion systems in the years to come.

Generations invited Corvus Energy, a company specializing in designing and manufacturing high capacity battery packs, to show their recent developments in battery technologies and battery management and to share their experiences on marine applications.

Introduction

Battery technology is taking a new place in industrial applications, with the focus on increased performance, cost, safety and quality. What was once a promising technology has become a working product that can both optimize and in some cases replace fuel-driven engines, while expanding operational flexibility for operators. Today, it is possible to build successful battery systems that scale from 2.5 kWh to multi MWh.

Applications include hybrid and electric drive lines, dynamic positioning systems, large-scale uninterruptable power supply (UPS), emergency generators and multisized house systems; all engineered to meet the physical needs of some of the most rugged applications in the most challenging environments. This article is intended to follow the path, which led Corvus Energy to choose nickel manganese cobalt (NMC) chemistry as ideal for use in marine applications.

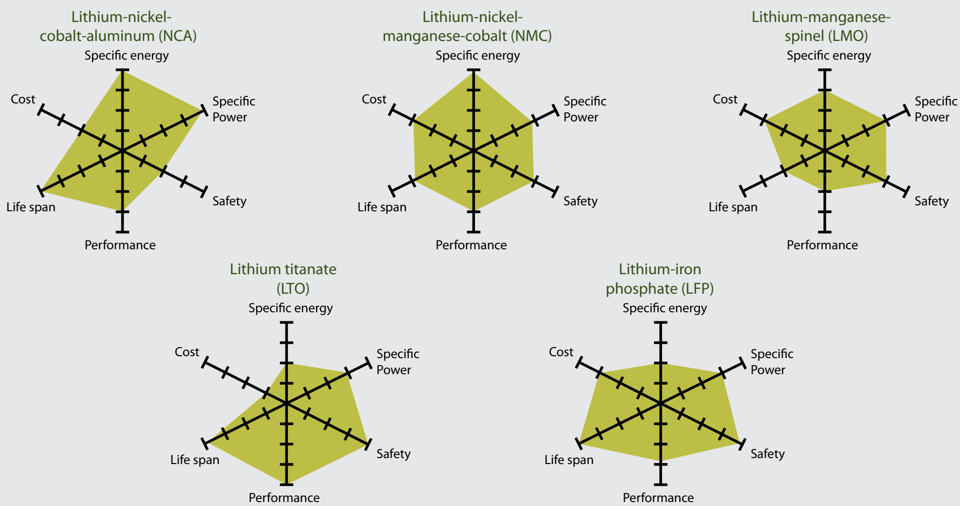
Corvus Energy's story is different from most battery companies today with background from boat building and marine engineering. The company's goal is to integrate actual energy-based products into systems and to deliver turnkey, "killer performance" solutions that exceed customer expectations and offer payback within one to five years, with up to 20 years of operational savings available to the clients.

Product overview

The marine industry is unique in its demands when it comes to an efficient battery system. The battery system has to:

- Be independent of any supporting systems, such as active cooling or heating, ventilation and air conditioning (HVAC)
- Deliver high output power and energy without developing high temperatures
- Offer very long life
- Offset the cost of the system in no longer than five years through reduction of fuel cost, maintenance, and service savings, compared with existing choices
- Maintenance free, IP67 rated enclosure
- Meet the demands of rugged environments, specifically those involving exposure to salt, temperature and humidity

1 There are trade-offs among the five principal lithium-ion battery technologies



Source: BCG research.
Note: The farther the colored shape extends along a given axis, the better the performance along that dimension.

– Interact with ship systems as today a smart battery must communicate and function in a fully integrated way to achieve best value performance.

The battery

There are four basic principles involved in delivering a successful battery, with each element needing to focus on safety, reliability, and quality.

1. Cell chemistry and construction
2. Battery management system
3. Battery engineering
4. Service and support

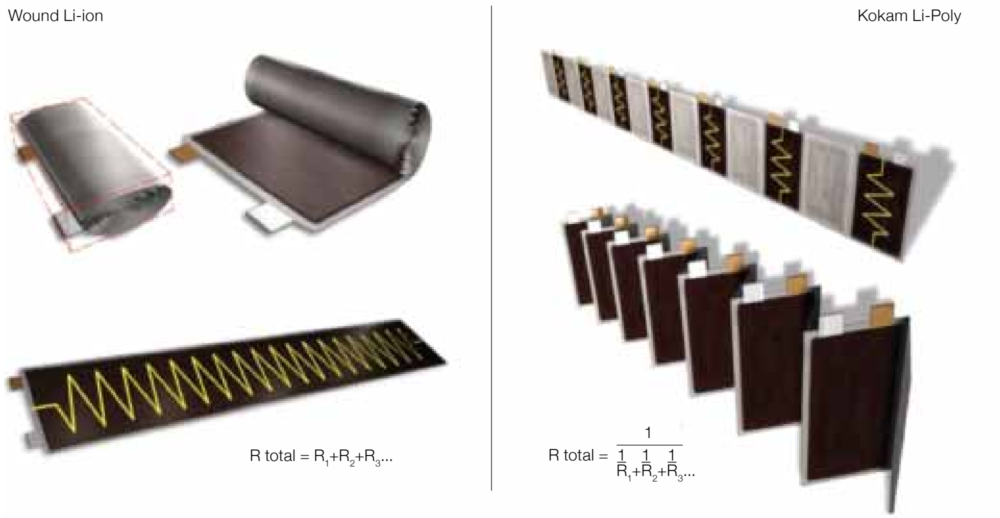
Cell chemistries

Chemistry is the bedrock of the new battery age. After years of testing, Corvus Energy focused on the impact that lithium brings to the market. The company chose lithium NMC as the underlying chemistry due to its superior performance and life, where it has proven to be the best overall choice for large-scale marine applications.

There are several lithium chemistries that are usable in commercial industrial applications, and each has specific benefits and uses, different life characteristics and safety features. In the journey to select the best lithium for the marine industry, Corvus Energy chose from those in Figure 1.

It is expected that greater attention to fuel efficiency and fault tolerance in design and operation will create an increasing demand for battery use in marine electric propulsion systems.

2 Wound (rolled), prismatic and Z-fold Li battery cells



The NMC cells produced by Dow Kokam demonstrated the best of all characteristics.

Of the choices available, NCA was deemed unstable or not safe enough. LMO did not offer enough life span. LTO did not meet Corvus Energy's energy/power density criteria, and LFP involved too much manufacturing risk to be incorporated into big pack technologies, which have scalable risk factors.

NMC met the energy/density requirements (the highest energy/power density commercially available), safety requirements and manufacturing risk requirements. The NMC cells produced by Dow Kokam demonstrated the best of all characteristics: a reliable cell-to-cell manufacturing process that demonstrated consistent performance matching technical data sheets, the fewest connections required, the highest charge/discharge efficiency in existence today, excellent energy density, very safe chemistry (that is, if the chemistry fails it will be a benign failure) and very repeatable manufactured quality.

Cell types

There are three principal types of cells: wound, prismatic (formed wound into rectangular shapes) and Z fold (layered by use of aligning film).

Wound cells (the most common cells, principally LFP or iron phosphate) are typical cylindrical cells that come in the shape similar to an "AA" battery (18650) or a "D" cell (26650). The cylinder "can" is made up of nickel-plated steel with positive and negative electrode connections at either end. These cells are interconnected within a pack by welding nickel-plated tabs to either the positive or negative electrode connections of the cell. For higher current applications, the nickel electrode connections and tabs show much larger impedance than aluminum or copper.

These cells are excellent for use in small scale applications, where they are manufactured in a cost-effective way to a high level of quality, such as laptops, typically with lower continuous discharge/charge rates.

The weakness of this fundamental design is the drop in charge/discharge efficiency (increased impedance) as pack size grows, tied to thermal management risks/added costs where high power and fast charge are critical. They will be dependent on active cooling and heating systems and require environmental controls when in use in the marine industry, raising service issues and associated capital/maintenance costs.

These cells are best used in applications characterized by low energy need (best under 3 kWh capacity) and where small overall capacity is required.

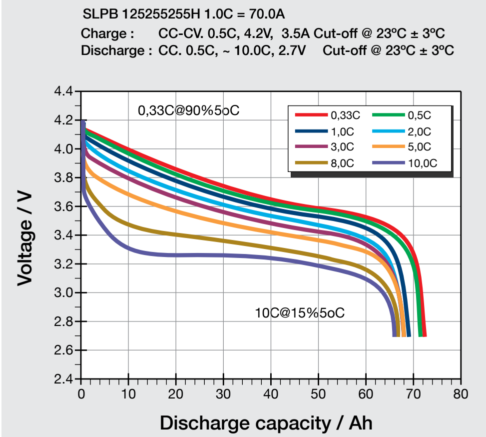
Prismatic cells are wound cells that are formed into rectangular or square cells, such as cell phone batteries. These cells have the same effective performance characteristics as wound cells, with the added issue that the forming process produces a strain on the anode and cathode at the rolled ends, which leads to uneven cooling/aging of the battery itself.

The thickness of the cells also means that they will store heat more effectively and take longer to cool/reduce the heat generated when configured in a pack. Corvus Energy determined that limitations on discharge and charge, and heat management, coupled with the risk of having so many cells in use, meant there were too many factors ranged against achieving successful integration into large-scale packs.

When it comes to Z fold cells, NMC cells are assembled using “Z fold” technology, where the cells are layered until the energy capacity has been met. The cells are then bonded to the master anode and cathode, which means that there are only single anode and cathode connectors at the summary point of the cell.

The advantage of this, beyond reducing connections (two versus as many as 80 using small independent cells), is that Corvus Energy has also developed a

3 Discharge characteristics for NMC cells



Chemistry	Lead acid (AGM)	Sodium nickel chloride	Lithium iron phosphate	Corvus lithium NMC
Nominal voltage	2.0V	2.58V	3.20V	3.70V
Maximum voltage	2.60V	2.9V	3.60V	4.20V
Minimum voltage	1.50V	2.0V	2.30V	2.75V
Energy vensity	20 Wh/kg	100 Wh/kg	129 Wh/kg	163 Wh/kg
Power density	75 Wh/l	150 Wh/l	255 Wh/l	320 Wh/l
Cycle life (80% DOD)	200	1000	>1500	>4000
Internal impedance	>20 ohms	150 milliohms	3 milliohms	0.5 milliohms
Initial cost1	$200/kWh	$800/kWh	$1,000/kWh	$1,100/kWh
5 Yr cost2	$1,750/kWh	$1,400/kWh	$1,166/kWh	$1,100/kWh
10 Yr cost2	$3,500/kWh	$2,800/kWh	$2,333/kWh	$1,100/kWh

thermal fuse at the anode, a safety feature not available when using wound or prismatic cells. From the thermal point of view, the Z fold is superior to all other forms of manufacture because instead of increasing resistance and impedance through an increase in capacity, it is actually reducing it, leading to a critical efficiency gain in terms of charge and discharge and consequent heat reductions. Because it is possible to clamp these tabs, there is also no risk of weld shear at the point of contact. Overall, Z fold cells are the best product available worldwide for use in large-scale packs and are ideal for our architecture.

A Corvus Energy's module has a capacity of 6.5 kWh and uses 24 cells. Using wound cells, more than 750 cells would be needed to develop the same capacity. Taking into account all chemical, software and manufacturing considerations, NMC cells have proved to be the safest and most reliable ones and are ideal for use in the marine industry. The fact that they are designed to incorporate up to 10C discharges (that is, 10 times the battery capacity) and can charge at 2C (30 minutes maximum to full charge) means that it is possible to deliver power that is equal to fuel driven motors and starts any machinery.

Key fundamental considerations after determining chemistry and manufacturing method are:
Voltage – The lower the operating voltage of the cell, the more cells are required to attain the necessary pack voltage. For example, a 320 volt pack will require 160 lead acid cells in series or 124 sodium cells in series or 100 iron phosphate cells in series. Corvus Energy's NMC cells will require only 86. The lower number of cells means lower interconnections between cells and less potential for failures.

Energy density – a higher energy density cell will yield longer running times than a lower energy density cell or the same running time with a smaller pack (this has an impact on the size, weight and cost of the pack).

Power density – a higher power density will mean that it is acceptable to receive and deliver higher current surges. This has an impact on size, weight and the cost of the pack.

Cycle life – There is a direct relationship to the overall cost, including cell costs and battery replacement costs.

Internal impedance – Directly related to cell chemistry and to the quality of manufacture. Lower cell impedance permits the cell to be safely operated at higher charge/discharge rates.

Lower Cost –The technologies with the lowest initial costs do not necessarily offer the best through-life economy.

The battery management system (BMS)

The battery management system is the "brains" when it comes to the performance and the life span of any technology based battery.

Typically, a BMS is developed to meet a single need, such as a laptop or a phone. In the marine industry, a multiple platform solution that is flexible but delivers industrial level consistency and performance was needed. This has been delivered by developing best in industry measurement and control tools that are specifically focused on safety, quality, reliability and lifetime performance. Using active monitoring, the battery management system reports both performance and out of parameter performance. Data is immediately directed "up the line" in the communications chain to all in the system.

Safety

Safety is the most important requirement in a battery pack. The BMS is responsible for ensuring that all operating functions of the pack are maintained within a safe window. This is demonstrated by the amount of redundancy that is available to the operator within the system. Each segment is isolated from one function to the other, with redundant processors in place to prevent an immediate failure taking the BMS down.

Even in the case of a dead short the BMS is robust enough to maintain shutdown functionality and communications to the ship.

Another safety feature of the Corvus Energy's system is its redundancy. Because uptime is critical, the design works in the following way:

– Voltage is determined in series, up to 1058 VDC (string)
– Energy is determined by how many strings are in parallel

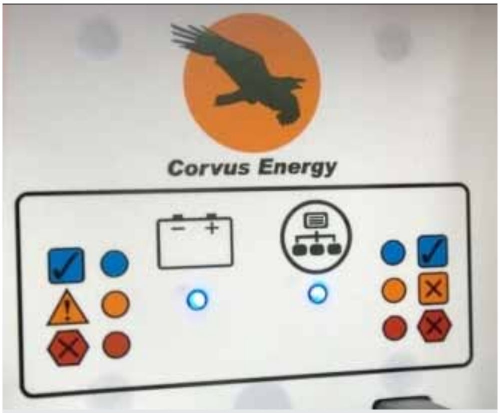
The architecture ensures a high level of redundancy, while allowing the shutdown of a single pack (in the case of module failure) without removing the balance of the system from the DC bus so that the system stays live and functional while the malfunctioning pack is "hot-swapped" out of the application.

Service and support

Uptime in any Industrial application is critical, and Corvus Energy ensures through training, monitoring and on-site support that the customer is working at peak efficiency.

A battery pack can be supported over its lifetime (up to about 20 years) to ensure that it matches the requirements for the original application and any changes to use of the vessel.

4 Battery On Board physical status panel

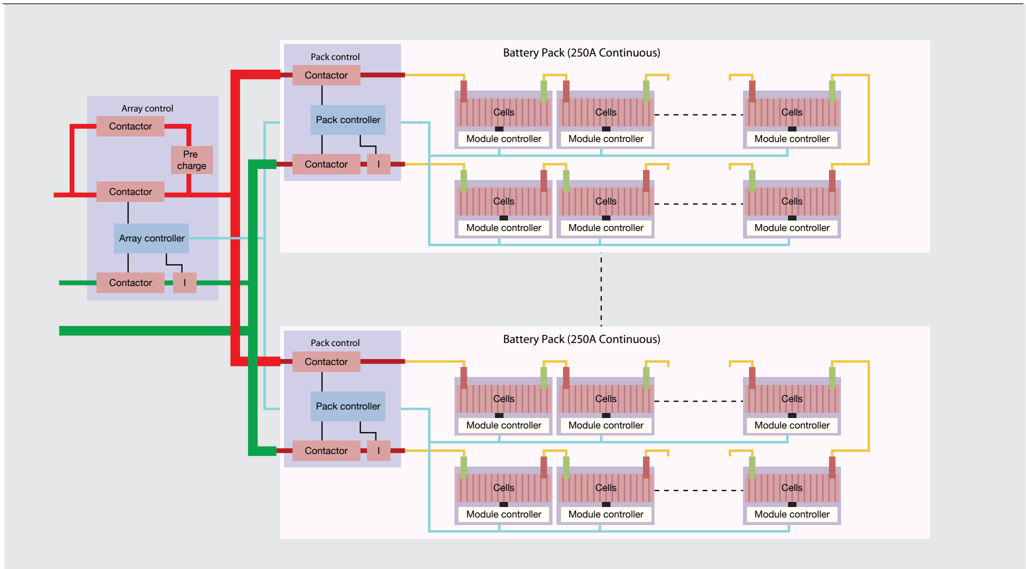


BMS

The term BMS encompasses both hardware and software and effectively manages the following features:

– Operating and storage temperature
– Operating cell and pack voltage
– Charge and discharge
– Depth of discharge
– Accurate energy gauging
– Effective communication of data inside or outside the pack
– Safety parameters and alarms
– Duty Cycle Programming
– Scalability in voltages from 12 to 1058 VDC
– Scalability of energy, from 2.5 kWh to multi-MWh
– Remote monitoring and programming
– Prevention of over and under voltage of every cell
– Prevention of overcurrent in the pack
– Prevention of over and under temperature of every cell

5 Redundant architecture



Recyclability

Today, being accountable for one's lifestyle is becoming more and more important. Customers can count on the fact that Corvus Energy's batteries are 99 percent recyclable; the company will take the batteries back on completion of life to perform this service.

Conclusion

In a high capacity battery pack (≥ 1 kWh), the pack is only as good as its weakest part. A weak cell, a malfunctioning BMS or a poor interconnection will cause a premature fault within the pack. In the case of a cell phone or a laptop computer, a premature fault will cause, at the most, brief inconvenience and a small replacement cost. In the case of a battery pack ≥1 kWh, the replacement cost will be quite high and the downtime of the battery-powered equipment can be significant.

Cell, BMS and manufacturing quality, as well as a commitment of service, are essential for high capacity battery packs. All of these components must work together so that the engineering solution specific to the marine industry delivers a long-term, reliable contribution to the success of Corvus Energy's customers. Externally, this demands that outside bodies such as Lloyd's Register, CE, Det Norske Veritas, ABS, GL, RINA, UNT, ATEX, etc.. give formal approval of the technology in order to validate the product, the process and the performance.

Brent Perry
Corvus Energy

Hybrid marine electric propulsion system

With super-capacitors energy storage

JESSIE WENJIE CHEN, JOHN OLAV LINDTJØRN, FRANK WENDT – In order to reduce the effects of system load fluctuations on the power plant, a hybrid converter based on super-capacitors is considered for fast-acting energy storage for marine vessels. The super-capacitors work as energy buffers, reducing the load variations as seen by the system generators, thereby improving system stability and under certain conditions allowing for a more fuel-efficient operation of available diesel gensets.

The use of electric propulsion in certain vessel types is well-known. In marine applications, nearly all the energy is produced by diesel engines. Using an electric propulsion system, where the energy transmission is electrical and the propulsion and thruster are variable speed electrically driven, fuel consumption can be reduced significantly for many vessel types with environmental benefits. But in some special working conditions, such as dynamic positioning (DP) operation, the load varies substantially, for instance with wave disturbance and weather influence. The sudden load variation is a continuous disturbance of the electric system and the prime movers. Furthermore, to keep to the safety margins of the power generation plants, the average loading of running engines has to be reduced, which increases fuel consumption and environmental emissions.

Nomenclature

DP: Dynamic positioning

SC: Super-capacitor

OSV: Offshore support vessels (general term for a range of vessel types for offshore operation)

DCU: Drive control unit

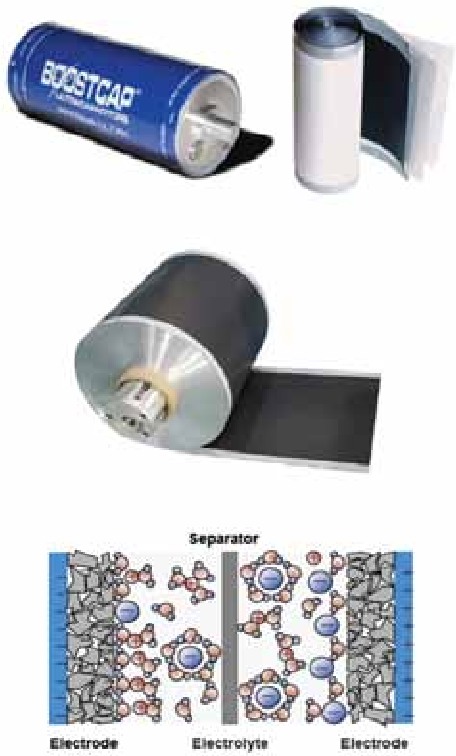
PMS: Power management system

MCR: Max continuous rating

ECR: Engine control room

1 **Propulsion and control system layout for a DC grid vessel**

2 **Structure and outlook of the super-capacitors by Maxell**



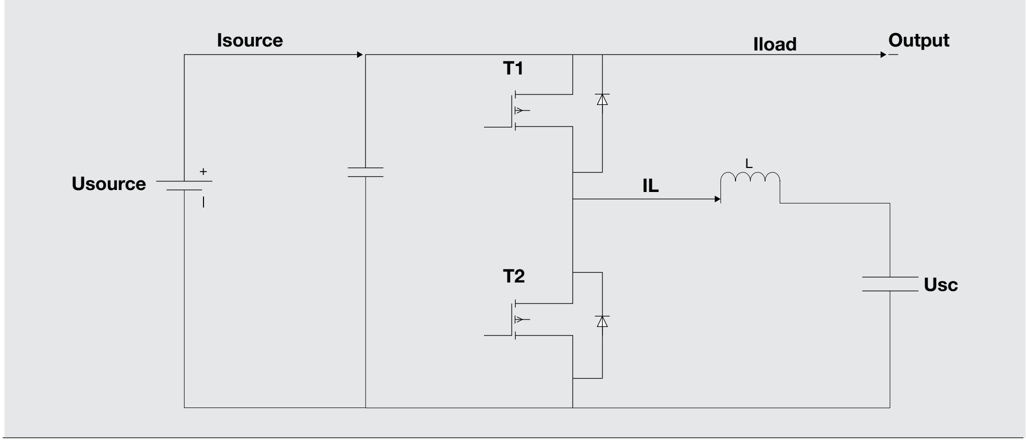
Fast-acting energy storage systems can solve these problems by effectively reducing load power fluctuations in a power system, due to their energy storage capacity. This will smooth sudden changes in power demand, improve the system's stability and possibly increase the average loading with fewer running engines and thus reduce fuel consumption and maintenance. Super-capacitor technology is one among other solutions, such as batteries, flywheels or possibly in the future superconductors. In this paper, an offshore support vessel (OSV) is chosen as the target vessel. A hybrid converter incorporating super-capacitors will be modeled and simulated in Matlab/Simulink simulation environment.

An OSV with electric propulsion is equipped with an electric power plant with variable speed drives to control the main propulsion and thrusters. ABB recently released the Onboard DC Grid solution. It adds to the full freedom for integrating and combining different engery sources, including renewables, gas and diesel, and a greater flexibility in placing system components in the vessel design. The main electric propulsion system topology for DC Grid system is shown in Figure 1. The super-capacitor can be used both in AC and DC Grid system to realise the energy storage function and increase the efficiency up to 20 percent.

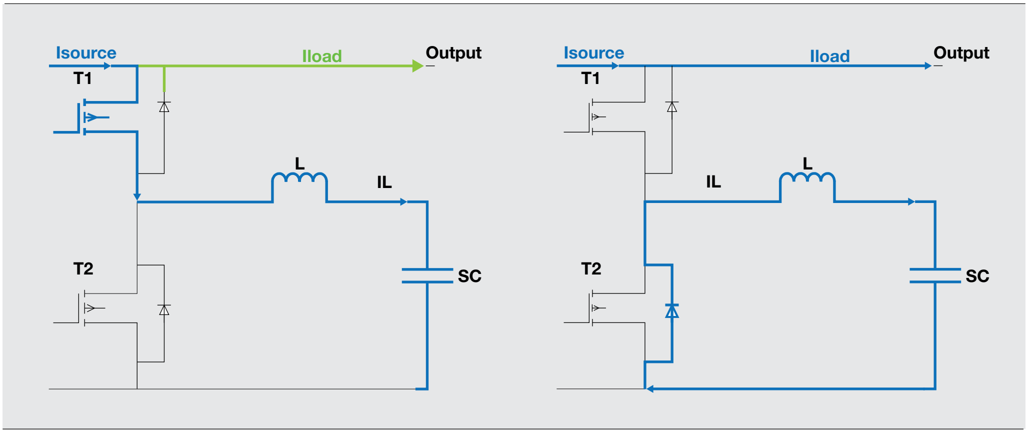
Super-capacitors technology is a new type of energy storage device used increasingly in industry and automotive applications, such as cars, buses and high-speed trains. Unlike conventional capacitors, super-capacitors have a larger area for storing the charge and closer distance between the electrodes, which is why they achieve much greater capacitance within the same volume.

Compared with the batteries, super-capacitors have several advantages: super-capacitors can be charged extremely quickly, while many battery technologies are damaged by fast charging; super-capacitors can be cycled several hundred thousands of times whereas batteries are capable of only a few hundred cycles. They can deliver frequent pulses of energy without any detrimental effects while batteries experience reduced life-time if exposed to frequent huge power pulses. Super-capacitors can also be charged to any voltage within their voltage rating while batteries operate within a narrow voltage range. On the other hand, batteries can store much more energy than the same size of super-capacitors.

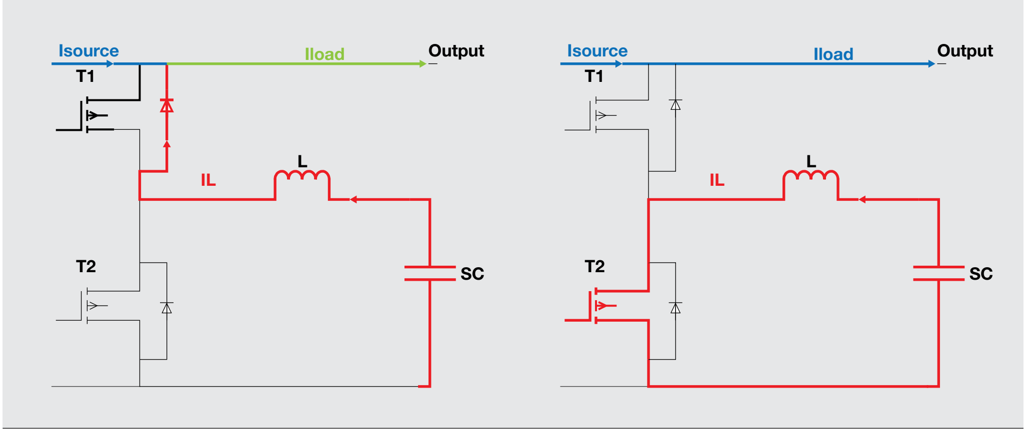
3 Basic structure of super-capacitor system



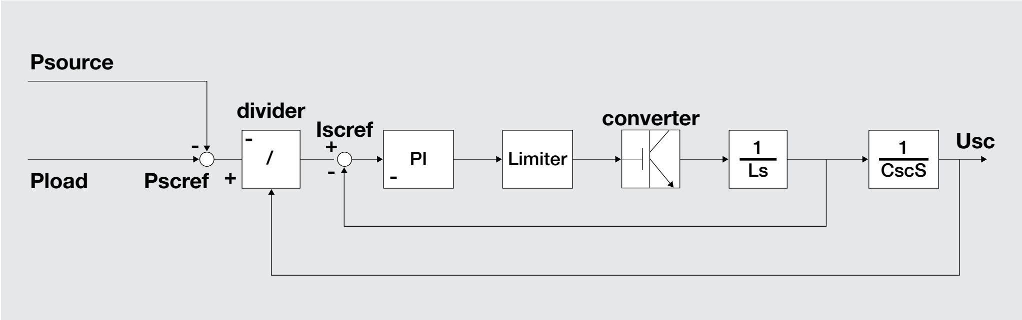
4 Buck converter mode



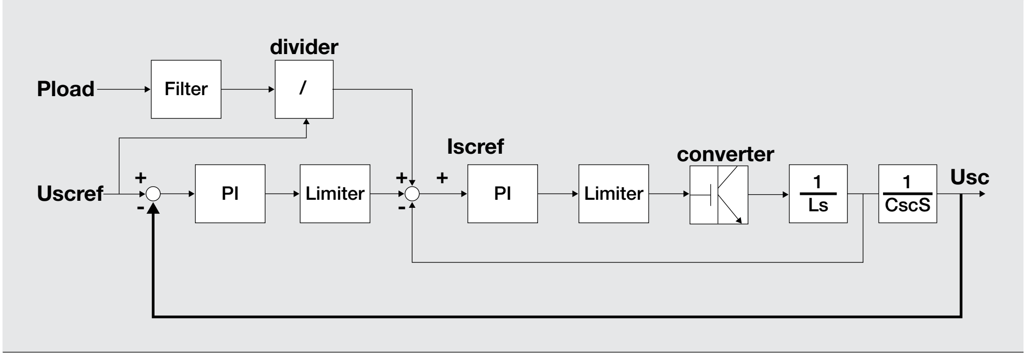
5 Boost converter mode



6 Power control method



7 Improved power control method



Super-capacitors have a high power density, long lifetime, high efficiency, and low cost device, but their energy density is still limited.

Figure 2 shows the basic structure of super-capacitors, whose electrode film consists of the highly porous carbon particles that are compacted and bounded together into a matrix and in electrical contact with aluminum foil.

Design for DC-DC converter

The most typical structure for controlling the power flow for a super-capacitor is shown in Figure 3.

The DC-DC converter that controls the energy flow to the super-capacitor is connected directly to the DC bus of the frequency converters. This configuration permits its power transfer in both directions. The DC-DC converter is a combination of a buck and a boost converter. This converter operates in buck mode while charging the super-capacitor and in boost mode while discharging it. The direction and value of the super-capacitor current is controlled by the duty cycle D of the semiconductor bridge.

Buck mode

In buck mode, which works as in Figure 4, energy flows from the network to the super-capacitor. The super-capacitor is charged.

$$\frac{U_{sc}}{U_{source}} = D_1$$

D1 is the duty cycle of the buck mode.

Boost mode

In boost mode, as shown in Figure 5, the energy flows from the super-capacitor to the network. Super-capacitor discharges to release energy.

$$\frac{U_{source}}{U_{sc}} = \frac{1}{1 - D_2}$$

D2 is the duty cycle of the buck mode.

It is clear that here D1=1-D2. The controlled trigger signal for T1 and T2 will always be opposite each other.

$$\frac{U_{sc}}{U_{source}} = D_1 = D$$

Design for control method

There are several classical control methods, such as traction control strategy, current flow control, fuzzy logic control and power flow control. Here the power flow control is chosen as it is more practical to implement in both control and simulation systems, compared with traction control and fuzzy logic control and it is more accurate than current flow control.

The power flow control method

The power flow of the system follows the energy conservation law. The power value of the source, the load and the super-capacitor can be represented as in the following equation.

$$P_{source} = P_{load} + P_{sc}$$

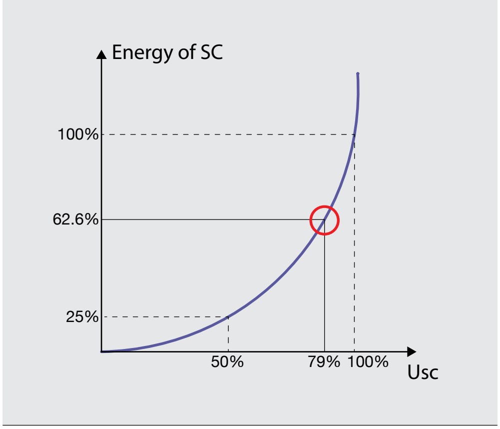
The sum of the super-capacitor power and the load power should be equal to the power drawn from the source. The reference super-capacitor current can be calculated as super-capacitor power divided by the super-capacitor voltage. Figure 6 shows the control flow chart.

There are several problems coming from this control diagram. First, it is a single closed loop control with one PI controller. super-capacitor current is the control variable, while super-capacitor voltage will not be regulated and may drift. Second, Usc that is used as a variable to calculate the current reference is a measurement with high noise level that will prompt disturbances in the regulator.

The improved average power control method

The voltage of the super-capacitor is a crucial variable and relates directly to how much energy the super capacitor cell stores. To ensure that the power supply system is under control and prevent the super-capacitor voltage from drifting excessively causing it to be over or undercharged, Usc must be regulated. An improved average power control method is therefore designed.

8 Reference voltage value setting



The control flow chart is shown as Figure 7. Compared with the traditional power flow control, the improved average power control method will regulate the average super-capacitor voltage.

In order to regulate the working voltage to be in the range of the rated value, a voltage balancing circuit is used as the outer loop in this case. Super-capacitor releases 75 percent of its energy when the voltage reduces to 50 percent. The energy ranks from 25 percent to 100 percent, as shown in this equation.

$$Q = \frac{1}{2} \cdot C_{sc} U_{sc}^2$$

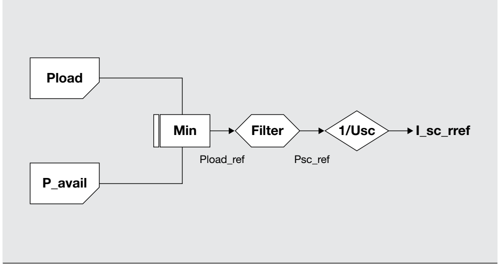
If the level of 62,5 percent is assumed as the normal value of the energy storage, the average voltage of the super-capacitor should be kept close to 79 percent. So here 79 percent is chosen as the setting point value of the super-capacitor voltage, as shown in Figure 8.

A double-closed loop control method is designed. The outer loop controls the average voltage while the inner loop is the current control loop that controls the instantaneous power flow. The two PI controllers must be tuned in a way that the inner loop will be capable to fulfill the instantaneous power control requirements while the outer loop avoids drifting of the voltage to over or under voltage.

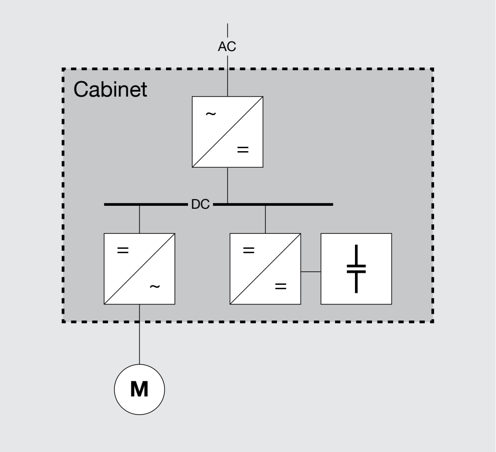
Modifications design for DCU system

Drive control unit (DCU) is the ABB application control system/product for a thruster drive. The main purpose

9 Rules of new DCU system



10 Topology of VFD with SC



is RPM control based on references received from the DP control system or the speed levers from the bridge/engine control room (ECR). The original DCU could not give attention to both the variation of the load and the super-capacitor. Modifications have been designed specifically for the super-capacitors electric converter to ensure that the average load power consumption is not higher than the available power from the online generators. The power available signal would normally be received from a power management system.

Figure 9 shows the basic principle of the supplementary function of the DCU. The power of the load demand should not be higher than the source capacity. Pavail is the capacity of the plant.

This DCU modification helps the system to:
– Regulate the controlled signal to the load according to the capability of the source
– Regulate the power delivery of the super-capacitor, and prevent it from overloading

Modeling and simulation

The structure of the electric propulsion system with a DC distribution and super-capacitor is shown in Figure 10.

Introduction of super-capacitors as energy storage will not imply major changes of the original frequency converter hardware layout. The super-capacitor converter is connected between the rectifier and the inverter, directly on the existing DC bus.

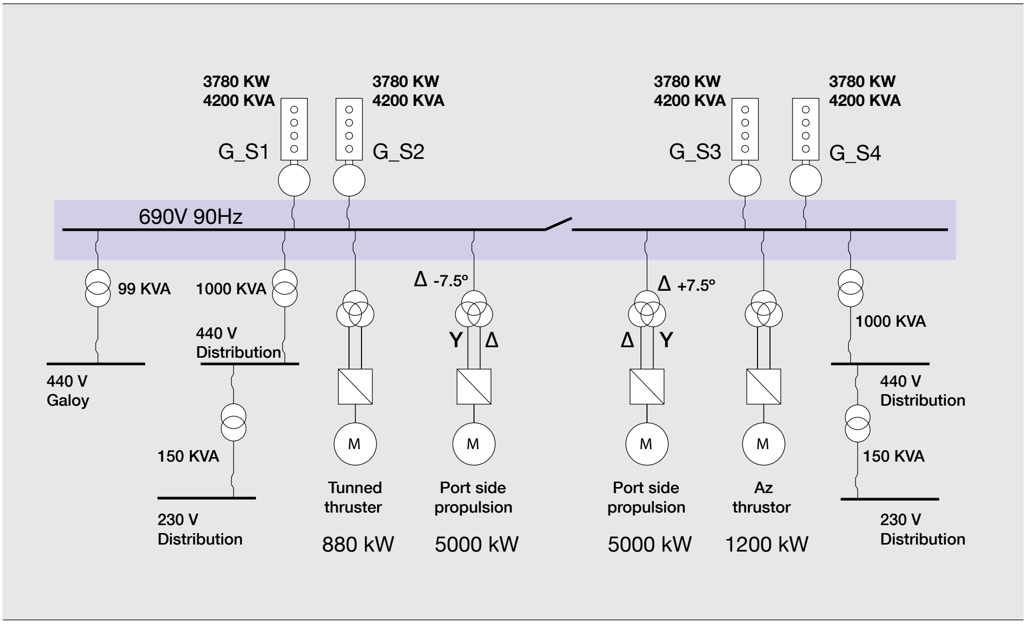
In Figure 11, the OSV chosen as the target vessel is shown to be equipped with electric propulsion, where the main propulsors and station keeping thruster are driven by variable speed electric motor drives, supplied from the common ship electric power plant with constant frequency and voltage.

Model establishment

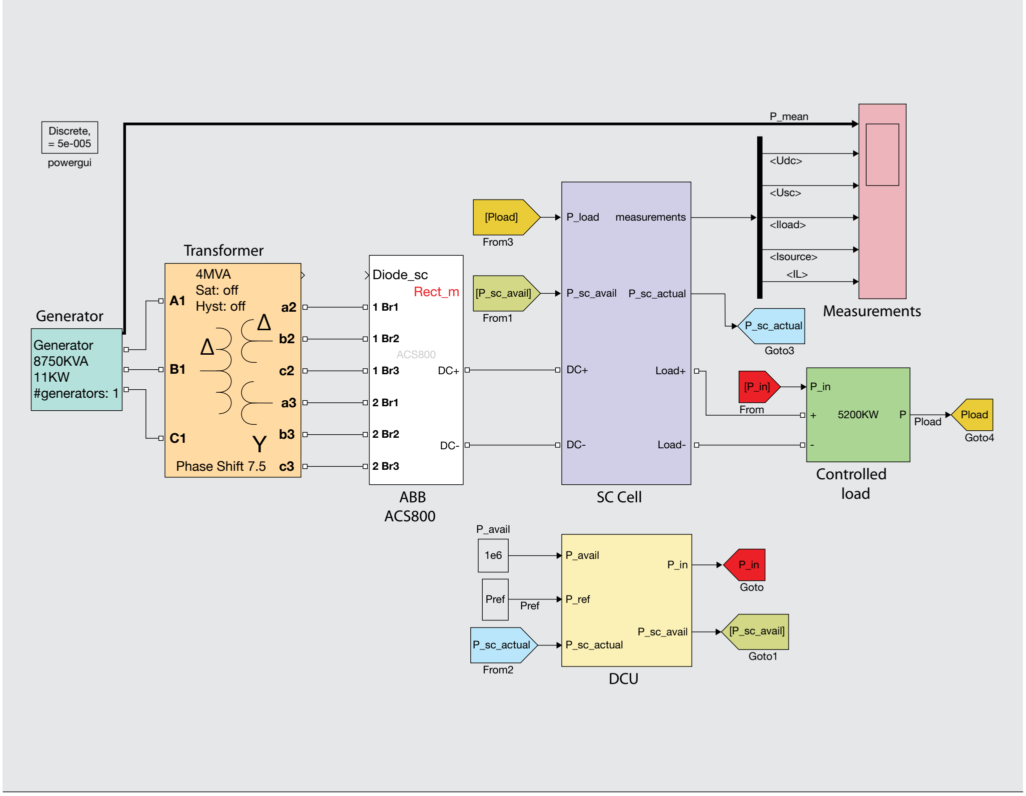
The system was modeled in MATLAB/Simulink environment using the ABB library. A typical thruster system was constructed as shown in Figure 12.

The electric propulsion system consists of a generator, transformer, rectifier (ACS800) and a controlled load. To simplify the simulation models, different types of loads such as inverter, motor, and pumps are be modeled as a controlled current sources. The super-capacitor block consists of two parts: DC-DC converter and control loop part.

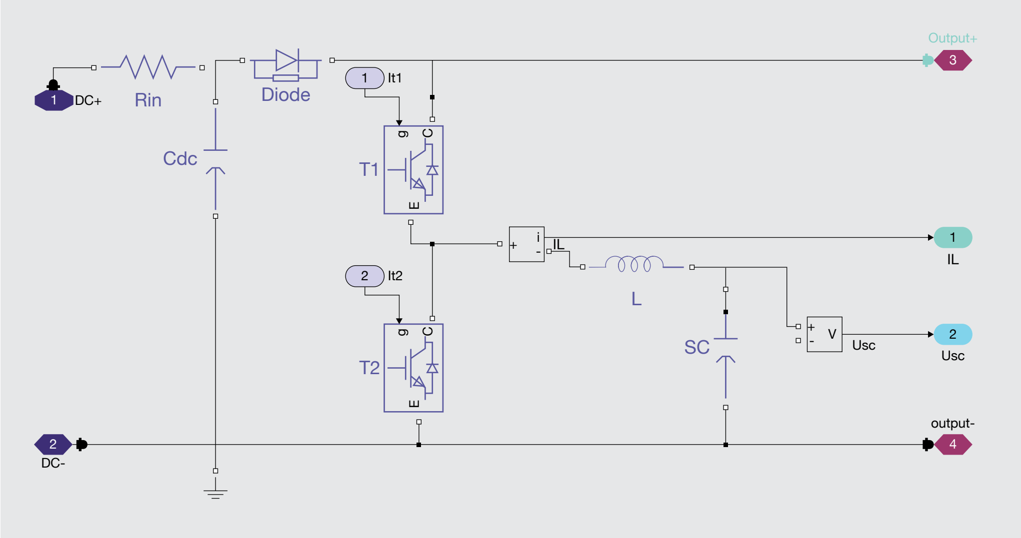
11 Configuration for diesel electrical OSV



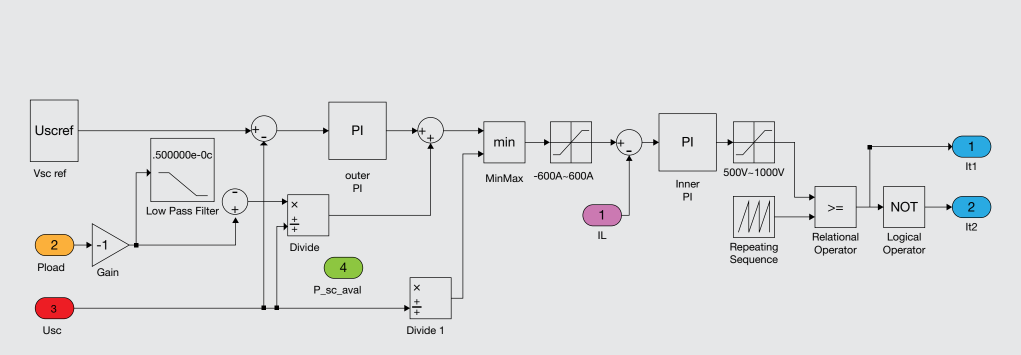
12 Electric propulsion system modeling



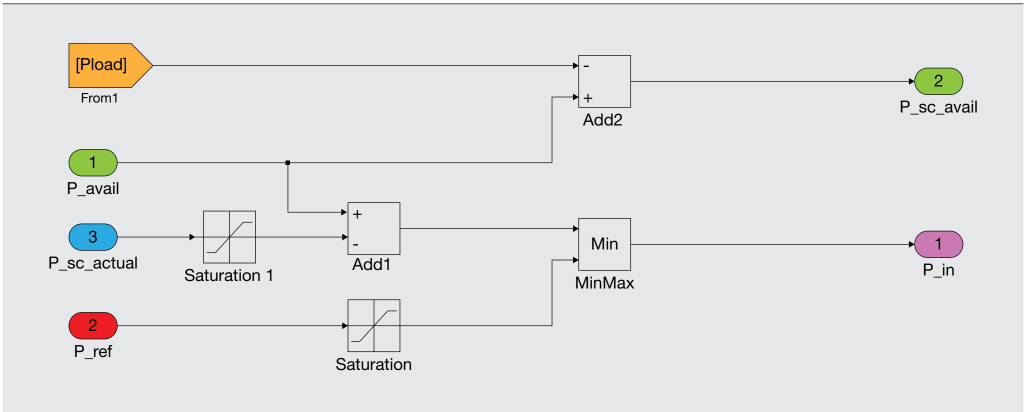
13 Super-capacitor DC-DC converter model



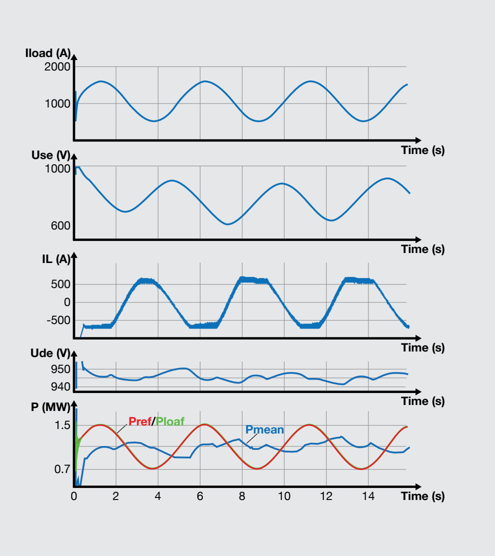
14 Improved control method block



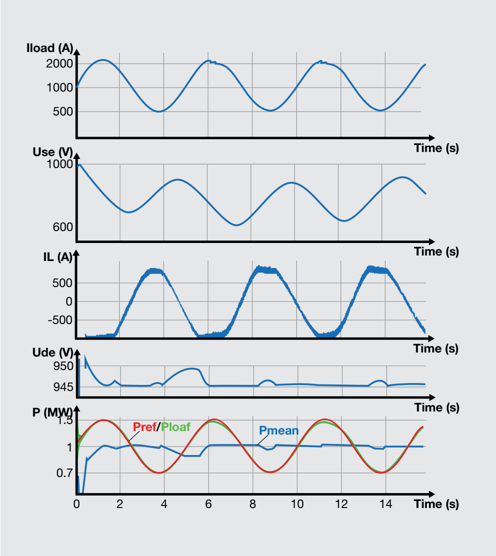
15 Power available control block in Simulink



16 Simulation results (1)



17 Simulation results (2)



A current and voltage limiter is added to the controlled block, as shown in Figure 14, to protect the system from overloading. Two PI controllers have to be tuned during the simulation. Figure 15 shows the power available control model in Matlab.

Results analysis

For this analysis the dynamic load variation for the thruster was assumed to be from 0.5 MW to 1.5 MW with a period of 5s.

Case one

The thruster system is not limited by the power available signal from the PMS.

The simulation results in Figure 16 show that during low load conditions the super-capacitor is charged, super-capacitor voltage rises and the current to the super-capacitors is positive. When the load increases, the super-capacitor is subsequently discharged; the super-capacitor current becomes negative and the voltage decreases.

The voltage stabiliser and power limitation functionality works as expected. This control method also reduces the load disturbances of the power plant.

Case two

The thruster system is limited by power avialable signal from PMS at Pavail = 1 MW.

As shown in Figure 17, the power drawn from the network remains almost constant at 1 MW, even with the varying thruster load. The thruster, on the other hand, operates virtually unimpeded by the applied power available signal, which also works as a power protect function, to always limit the power of the source under the safety margin.

Therefore, the available power in the electrical plant at any given time must be greater than the sum of anticipated loads in the system, otherwise the target vessel could not keep the position during the DP operations.

The super-capacitor system could achieve the improved performance with less number of running engines and lower fuel consumption with less environmental emissions.

Fuel consumption savings calculation

The optimum operation point of a diesel engine will typically be around a load of 85 percent of the Max continuous rating (MCR). Moreover, the efficiency level drops quickly as the load becomes lower than 50 percent of MCR, as shown in Figure 18.

With the help of the electric system, the mechanical propulsion primer mover is replaced by diesel-electric prime movers that will automatically start and stop as load demand varies. In comparison to a conventional vessel with mechanical propulsion, this enhances the efficiency of the energy usage and reduces the fuel consumption by keeping the average loading of each running diesel engine close to its optimum load point. However, in DP vessel applications, the load variations can be large and rapid. It is impossible to make the generators switch on and off every five seconds as would be the case in the examples above. By using super-capacitors to supply the load variations, and hence let the diesel engines provide the average load, the peak power of the power plant will be reduced, allowing the average loading of the engines to increase to a more optimal point with lower specific fuel oil consumption.

The savings in fuel consumption will depend on many parameters such as actual variations in the load, the average load and the number of prime movers. For example, if one could increase the average loading of the running engines from, for instance, 40 percent to 60 percent, fuel oil consumption would be reduced by more than 10 percent.

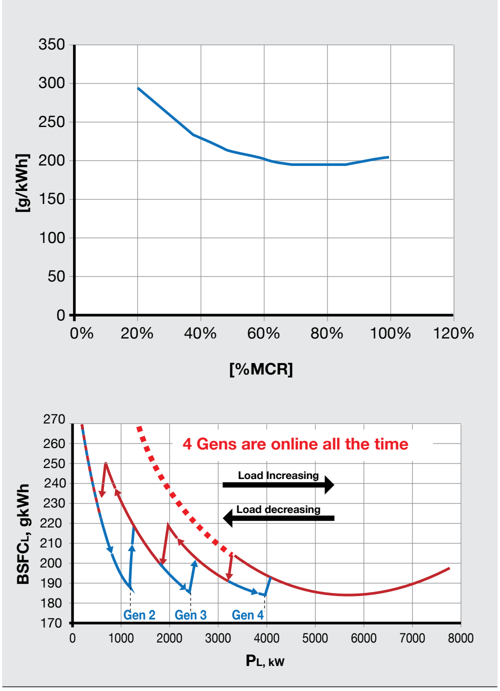
Conclusion and further works

In the case studies above it has been shown that the use of super-capacitor for short-term energy storage in a thruster system can effectively limit the power fluctuations seen by the supplying network.

The advantages of this are twofold. First, this reduction in power peaks can offset the need for bringing additional diesel engines online, thereby increasing the average loading of each diesel and improving diesel fuel efficiencies. Second, when a diesel engine is loaded and unloaded quickly, the combustion process in the diesel engines is adversely affected. A reduction in rate at which they are loaded and unloaded will also reduce their fuel consumption significantly.

For further work, it is important to quantify possible fuel savings and lifetime costs for larger systems. Investigation into other frequency converter applications found on board ships should also be performed.

17 Simulation results (2)



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[2] Jan Fredrik Hansen, John Olav Lindtjørn, Klaus Vänskä, "Onboard DC Grid for enhanced DP operation in ships," Dynamic Positioning Donference, Houston, Oct. 11-12, 2011
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Parallel hybrid propulsion for AHTS

A compromise between performance, energy efficiency, and investment

TOR ARNE MYKLEBUST, ALF KÅRE ÅDNANES - Electric propulsion in platform or offshore supply vessels (OSV) has been used since the early 1990s. Advances in technology mean that today there are several optimal propulsion systems that reduce fuel consumption and environmental impact, simplify design and construction, better utilize onboard space and create an improved working environment for the crew.

One of the reasons for the suitability of electric propulsion for OSVs is the large variations in the load profile of propulsors and thrusters. Total engine capacity has to be dimensioned to achieve the design speed of the vessel, or the dynamic positioning (DP) capability in the worst weather situations. As most newbuild vessels are classified as DP 2, with redundancy requirements, the total installed power might be much higher than that required for average loads.

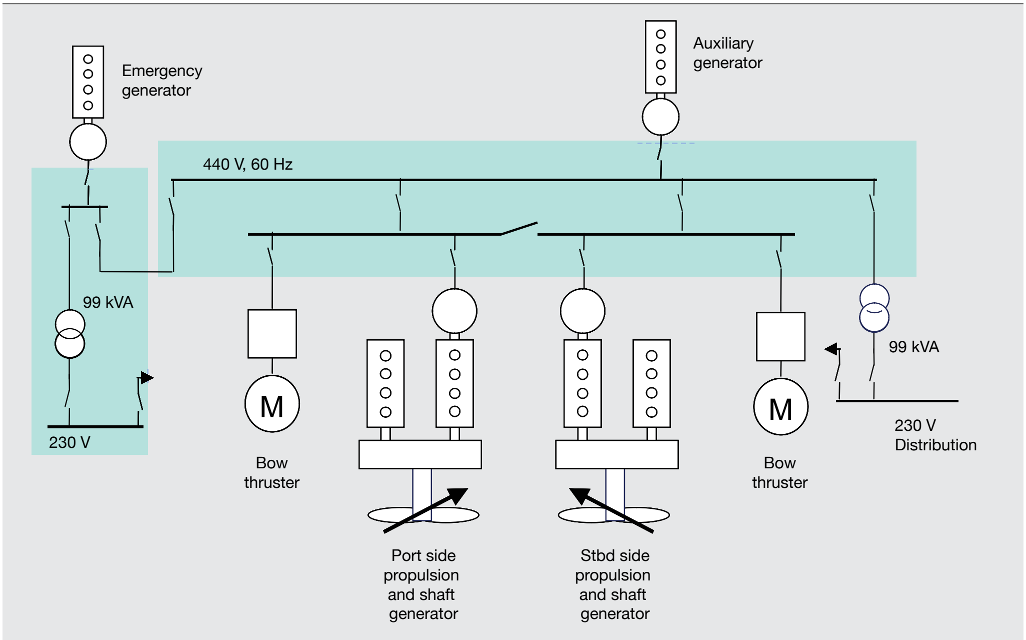
Electric propulsion makes it possible to increase energy efficiency by running the propellers at variable speeds to reduce hydrodynamic losses, as well as optimizing the power plant configuration and operation to ensure a closer to the best possible working condition for the diesel engine prime movers.

Until recently, nearly all anchor handling tug supply (AHTS) vessels were built with diesel-mechanical propulsion due to an overriding focus on bollard pull requirements, even though their operational profile made them even more suitable candidates for electric propulsion, compared with OSVs. For smaller AHTS vessels, there are few reasons for not selecting electric propulsion. However, higher investments demanded by this solution make such a commitment more challenging for shipowners. A parallel hybrid solution may then be a good trade-off, where additional building costs are lower, while some of the important fuel-saving characteristics of diesel electric propulsion are accrued.

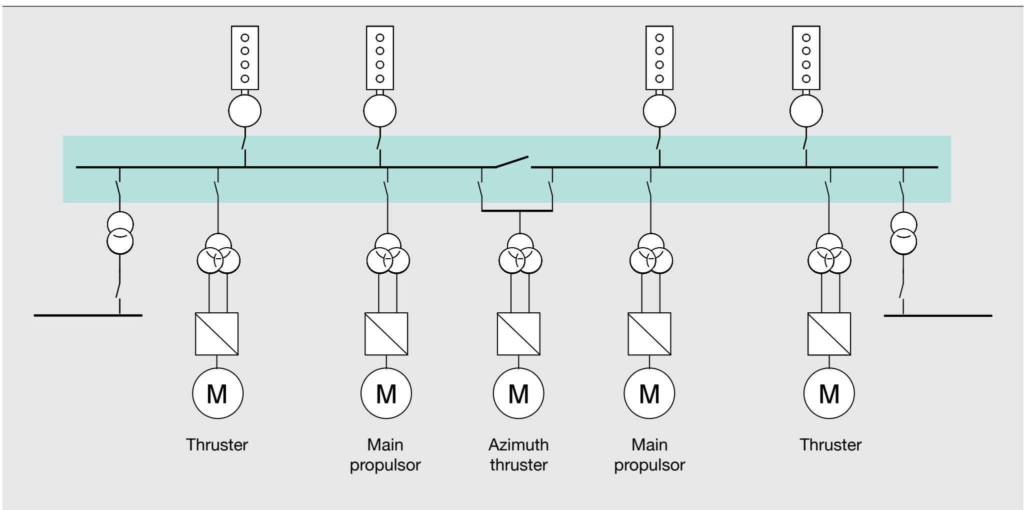
Energy efficiency of electric propulsion

Electric propulsion has demonstrated substantial fuel reduction, compared with direct mechanical propulsion in OSVs (Figure 1). The fuel savings will often reach 15- 25 percent in typical operating profiles and as much as 40-50 percent in pure DP operations. As a result of this, together with an increasing awareness on operational costs and environmental emissions, a large part of the OSV fleet is now specified by the oil companies and charterers to be equipped with electric propulsion.

1a Conventional direct mechanical propulsion



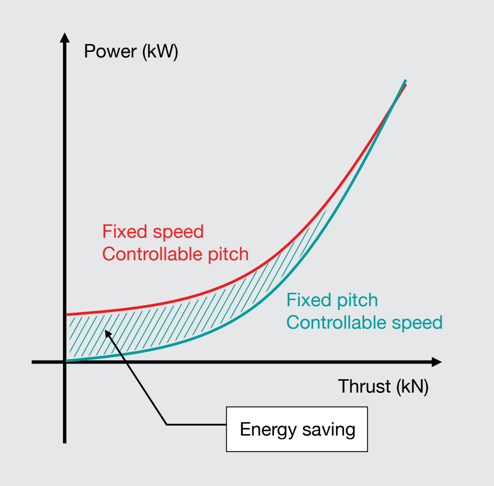
1b Electric propulsion



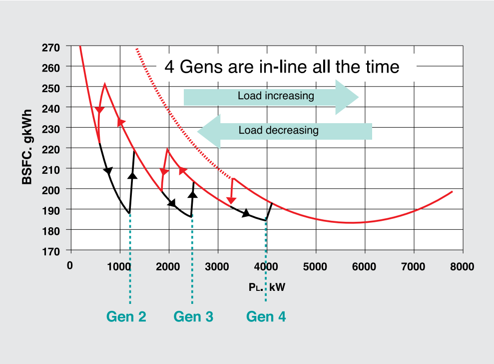
Reduced fuel consumption in an electric propulsion system can be attributed to two key elements. The first is the variable speed control of the propeller, which reduces the "no-load" losses of the propellers to a minimum compared with classical fixed-speed controllable-pitch propellers. The second element is the automatic start and stop of the diesel engines, which ensures that the engine load is kept as close to its optimum operating point as possible, within the limits of operation.

The classical design of an offshore support vessel, including an AHTS vessel, uses fixed-speed propellers with controllable pitch. Compared with

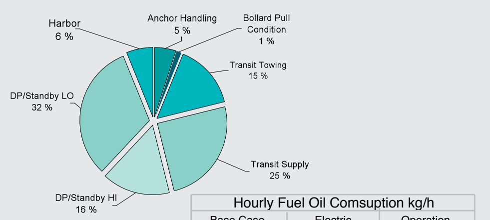
2 Comparison of shaft power versus provided thrust from a fixed-speed controllable pitch propeller (CPP) and a variable speed fixed-pitch propeller (FPP)



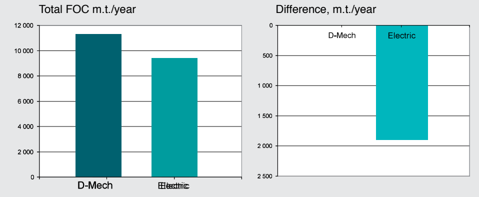
3 Fuel consumption per kWh of produced energy



4 Impact of ratio of station keeping mode versus transit mode in fuel saving of diesel electric systems, this is for illustration and not calculated for a particular case



	Hourly Fuel Oil Comsuption kg/h		
	Base Case D-Mech	Electric Propulsion	Operation Profile
Anchor handling	2280	2295	438
Bollard Pull Condition	2451	2795	88
Transit Towing	1898	2053	1314
Transit Supply	1276	1036	2190
DP/Standby HI	1377	1020	1402
DP/Standby LO	1015	620	2803
Harbor	26	25	526
Total FOC kr//year	11 293 005	9 396 661	
Total FOC m.t./year	11293	9 397	
Difference, m.t./year	0	1896	



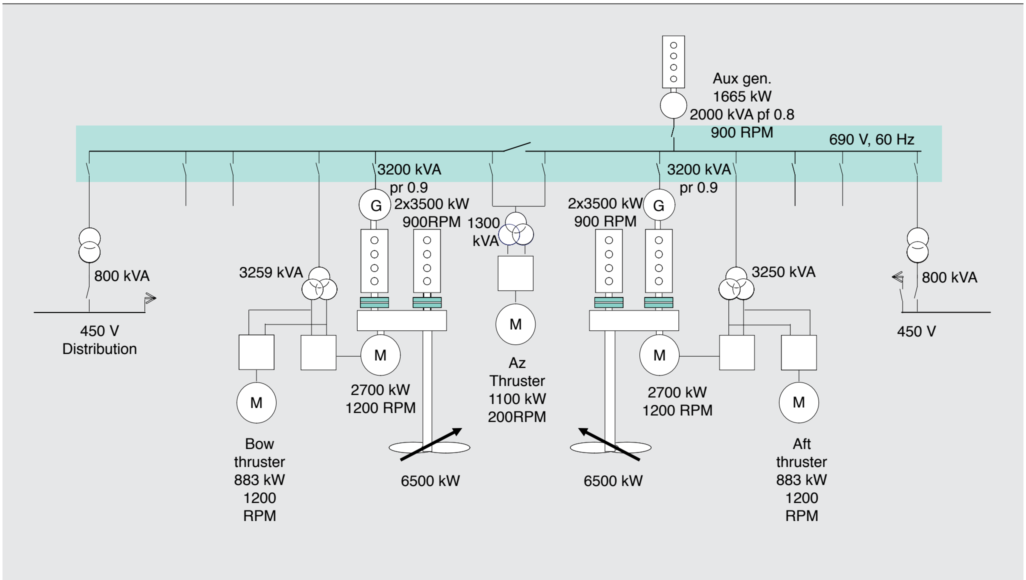
variable-speed control of the propeller, this is a very inefficient way of controlling the thrust due to the high "no-load" losses of the fixed speed propellers (Figure 2). This alone contributes to most of the savings in electric propulsion when applied to offshore vessels. In addition, the utilization of the thruster capacity in DP operations is very low for most of the days operational in, for example, the North Sea, even though this is regarded as a harsh environment.

Electric propulsion also offers the potential for the optimal loading of the diesel engines by using a number of smaller engines, compared with using a smaller number of larger units. Depending on the load, the automatic start and stop of the engines yields better loading and thus reduces fuel consumption (Figure 3).

This reduction in fuel consumption is to some extent counteracted by the higher losses in the transmission system between the diesel engines and the propellers. While losses in the shaft line and gear box of a conventional design are of the order of a few percent, transmission losses in a diesel electric system are in the range of 8-11 percent depending on the concept and efficiency of the components in the drive train. Hence, the potential for fuel savings is highest for vessels with an operational profile where much of the time is spent in DP, standby or manoeuvring, while the benefits are less obvious, absent, or even negative where transit at high speed is the dominating operational mode (Figure 4).

The same mechanisms for energy efficiency and fuel savings that are proven in the OSV segment are available for AHTS vessels; in fact, they are more compelling. In an anchor handler, the peak power is determined by the bollard pull requirement for the vessel, which in most cases will be further from the average load point the higher the bollard pull is. A calculated case study shows that for a 200+ metric ton bollard pull AHTS vessel, fuel consumption will be 1,900 metric tons lower when electric propulsion is used (Figure 5).

5 Electric propulsion and direct mechanical propulsion for a 200+ metric ton bollard pull AHTS



Although there is an increasing interest in using electric propulsion for AHTS vessels, most anchor handlers are today built with conventional diesel-mechanic solutions in spite of the obvious fuel saving potential. Contributory may be that charterers awareness of the fuel costs is lower in this segment, and the focus on fulfilling the bollard pull requirement is higher. In addition, as propulsion power increases, so do extra investment costs, which may prevent designers and owners from promoting electric propulsion if they do not get their rightful portion of savings available.

An alternative to the full electric solution is the combination of mechanical and electric propulsion systems – the so-called hybrid propulsion system (Figure 6). As the electric and mechanical propulsion systems work in parallel through the gear box, this is also called “parallel hybrid.”

In terms of installation costs, hybrid solutions are more economical than pure electric solutions. In principle, the hybrid solution will gain most of the same benefits in energy efficiency in low load operations, due to the variable speed thrusters and optimal diesel engine operations and at the same time reduce the transmission losses at peak propulsion loads. For these reasons, several new AHTS vessel designs have been based on such hybrid solutions, especially those with high bollard pull.

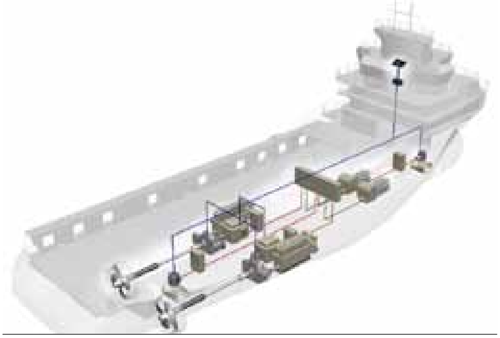
However, the increased mechanical complexity of such hybrid systems – where the crew must be more active and manually select the optimum operational modes for the prevailing conditions – should not be disregarded. In pure electric propulsion systems, it is much easier for the power management system to optimize the configuration of the power automatically and gain a reduction in consumption of fuel and lower environmental emissions, especially NO_x and CO_2. With the adoption of electric propulsion by OSVs and now also by AHTS vessels, fuel consumption, emissions and operational costs are being drastically reduced.

Electric propulsion systems make fuel savings possible through the flexible operation of the vessel, even though the system itself introduces new losses in the energy chain. Efforts can, of course, be made to reduce these new losses, but in order to maximize the benefits of electric propulsion, the focus should primarily be on designing a simple, reliable and flexible system.

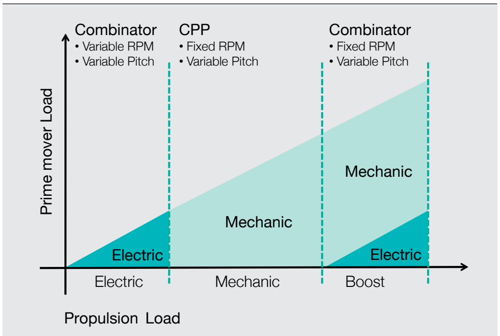
Control of parallel hybrid propulsion

As the design is optimized for the ship’s operationing profiles and owner’s requests, the control of the parallel hybrid propulsion must also be considered case by case. But in principle, the vessel can be operated in three ways:

6 Hybrid electric and mechanical propulsion for an AHTS



7 One approach to control a parallel hybrid propulsion system



8 The 423 metric ton bollard pull vessel *Far Samson* with hybrid propulsion system; diesel mech: 4 x 6000 kW (4 x 8160 BHP) and diesel electrical 4 x 2755 kW. Total propulsion power: 35900 BHP on main propellers

– Pure electric propulsion for low-speed manoeuvring, transit and DP
– Pure mechanical propulsion for tug operations and high-speed transit
– Hybrid electric and mechanical propulsion, where electrical equipment can be used as a booster for the mechanical propulsion system to maximize bollard pull

One approach, which utilizes all three modes, is shown in Figure 7.

ABB's electric propulsion offerings

As the leading supplier of electric propulsion, ABB designs and offers a wide range of electric or hybrid solutions, with or without energy storage. The concepts shown above feature classical fixed-system frequency AC distribution. However, the concept of Onboard DC Grid is well suited both in the pure diesel electric configuration, as well as in parallel hybrid solutions.

From 2077 onwards and as per May 2012, ABB has supplied electrical solutions for 26 vessels with hybrid propulsion, including 24 anchor handling vessels. The total installed propulsion power in each of these ranges from 14 to 24 MW.

The largest hybrid propulsion power delivered so far has been for Farstad Shipping ASA, for the vessel *Far Samson*, delivered in 2009.

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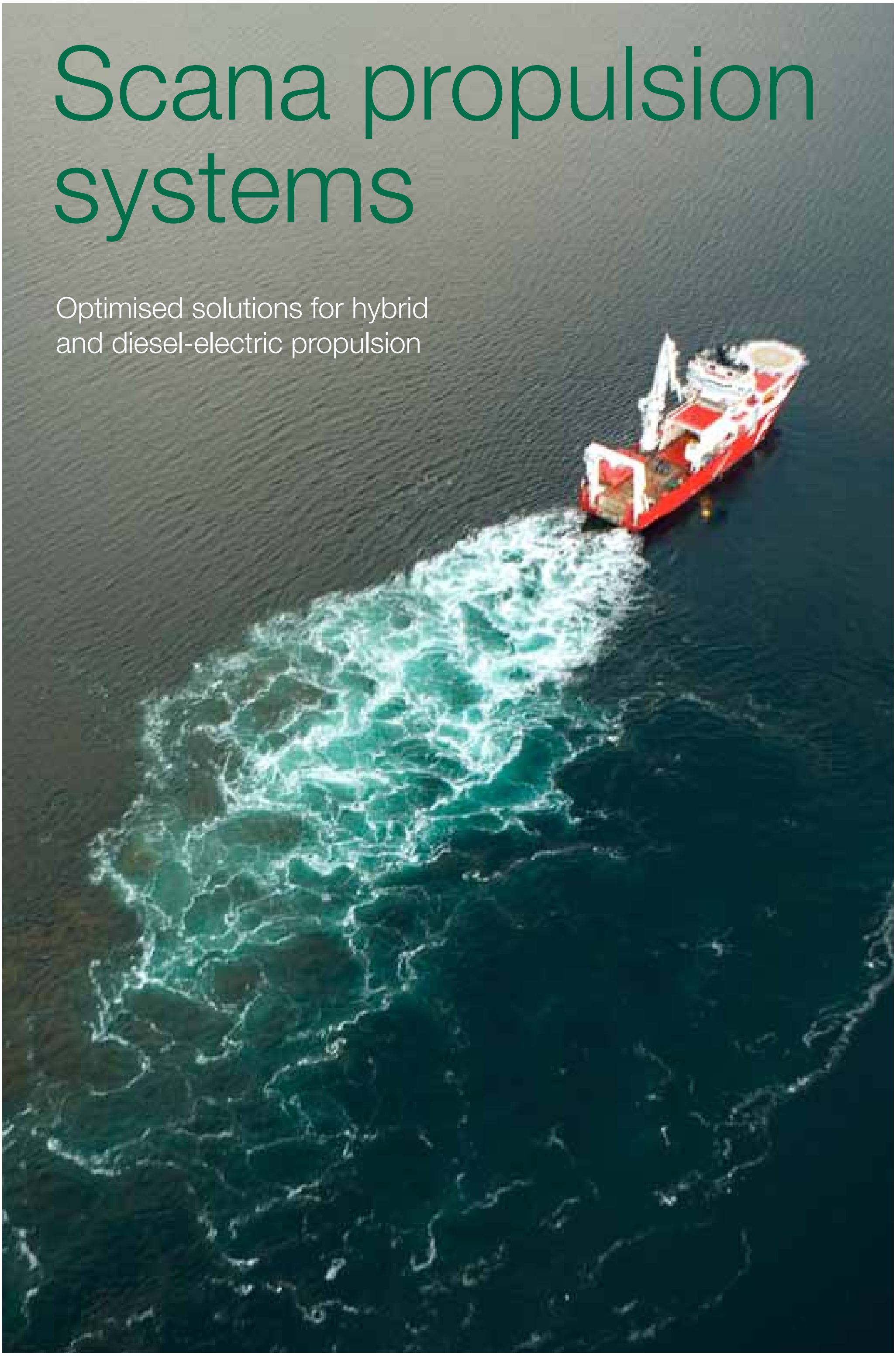
Scana propulsion systems

Optimised solutions for hybrid and diesel-electric propulsion



SVERRE TONHEIM, KENNETH SEKKINGSTAD - In order to build a vessel with optimal performance, good cooperation has to be in place between all stakeholders in the design and building process. Suppliers working with a shipyard interact with each other, and it is invaluable for the cluster of marine industries to be able to share experiences, discuss improvements and test new ideas beyond company and competition borders.

G*enerations* invited Scana Propulsion to contribute an article about the developments in gear box technologies applied in shaft line propulsion with CP or FP propellers. These solutions are used widely in the maritime industries. Recent years have seen increasing interest in the use of geared shaft line propulsion in hybrid diesel-mechanical and electrical propulsion. In such parallel hybrid designs, the ship gains the advantage of energy-efficient diesel-electric propulsion that is dimensioned for the lower transit and station keeping loads of the propellers, while the highest peak loads used for tugging and anchor handing, plowing, etc.etera are achieved with direct mechanical propulsion.

The electric propulsion part may also be used to add to the shaft torque to reach peak thrust demand. This solution is of particular interest to operators of anchor handling tug supply (AHTS) vessels where hybrid propulsion may form the optimal compromise between vessel performance, energy efficiency and CAPEX.

Scana Propulsion has for decades supplied gearboxes and CP propellers to the global shipbuilding industry. Thanks to its location in the middle of the Norwegian maritime cluster, the company, established in 1913, has interacted closely with Norwegian shipowners and designers in the fishing and offshore sectors. Offshore activity in the North Sea has led the way for sophisticated systems operating in harsh weather conditions.

Scana Propulsion has, through its engineering competence, played a major role in the development of today's sophisticated vessels, with tailor-made propulsion systems suited for any operation to meet customer, market and regulatory demands. Total propulsion efficiency forms the basis for the selection of system configuration for the particular vessel, whether the answer is diesel-mechanical, diesel-electric or hybrid propulsion. Scana Propulsion reduction gearboxes are an integral part of this system.

Over the course of the last decade, diesel-electric and parallel hybrid propulsion systems have become more visible on many types of ships. Such innovative propulsion is a blueprint for the future and may offer great advantages, both economically and environmentally.

The goal for using diesel-electric or hybrid propulsion instead of diesel-mechanical systems is to improve the efficiency and flexibility of the ship. In diesel-electric systems, the propeller is driven by one or several electric motors, while in parallel hybrid systems the propeller can be driven by a diesel engine, an electric motor or by both types of motor at the same time. However, electric or hybrid propulsion will not be the most economical solution for all types of ships and ship service profiles.

Ships with a uniform service profile will normally use a conventional diesel-mechanical propulsion system because of its simplicity, low investment cost and small transformation and transmission losses. However, there may be other reasons for using electric propulsion on such ships.

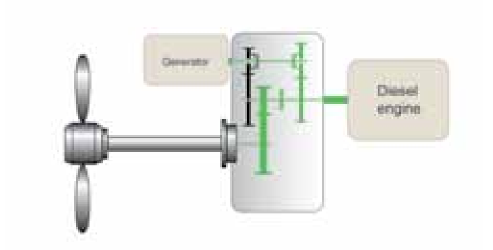
Ships with large variations in service conditions will gain advantages by using diesel-electric or hybrid solutions. The larger the variation in service conditions, ie, the ratio of peak power demand and actual power usage, the larger the potential benefit for energy efficiency and fuel saving.

Propulsion efficiency - the basis for defining the optimum propulsion system

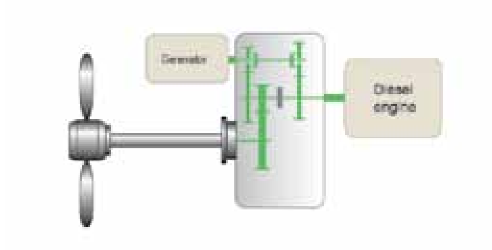
Total propulsion efficiency is a product of the efficiency in all parts of the propulsion train: main diesel engines, auxiliary diesel engines, generators, electric distribution systems and transformers, frequency converters, electric motors, reduction gearbox, shaft line, hull and propeller. The power consumption of the auxiliary systems should also be considered in overall energy efficiency.

Title picture
The 423 metric ton bollard pull vessel *Far Samson* with hybrid propulsion system

1 **The two-speed reduction gear run as a standard diesel-mechanical plant with a PTO**



2 **All main engine power is taken over the PTO shaft for optimum distribution between propeller and PTO/shaft generator**



All these factors will vary with the type of ship, equipment type and arrangement and with different ship service profiles. In order to make a correct comparison between diesel-mechanical and diesel-electric propulsion, each of these factors should be estimated for every service condition so that the total overall efficiency for the ship's particular service profile can be calculated accordingly.

As a simple comparison of running costs for a given ship/propeller arrangement, it can be assumed that the specific fuel consumption of the power sources and the propeller efficiency are the only influencing factors. The other efficiencies and propulsion factors are unchanged. The question then is whether the gain in propeller efficiency and in specific fuel consumption is big enough to compensate for additional losses caused by the energy transformation introduced by the electric system.

Propeller efficiency

Propeller efficiency is defined as:

$$\eta_0 = \frac{T \cdot V_a}{P}$$

T = thrust, V_a = speed of advance and P = power delivered to the propeller.

According to this definition, η_0 is zero when T or V_a is zero. It is also clear that is high when T and V_a are high.

From this simple equation it can be seen that the propeller efficiency per definition is zero in a bollard pull condition, even if this is the condition of maximum propeller thrust. It is also seen that fast vessels have potential for high propeller efficiency. From this it is noted that propeller efficiency depends not only on propeller design, but more on its working condition.

Another simple but informative expression for propeller efficiency can be developed from the momentum theory:

$$\eta_0 = \frac{1}{1 + 0.5 \cdot \frac{U_a}{V_a}}$$

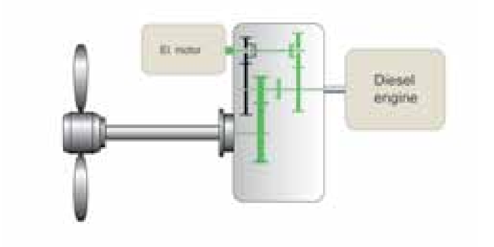
V_a = the flow speed far upstream, U_a = induced flow speed by the propeller action.

From this equation it can be seen that η_0 increases when U_a decreases. To obtain a low induced speed U_a, the thrust per unit disc area must be low, meaning that for a given thrust the propeller disc area must be large.

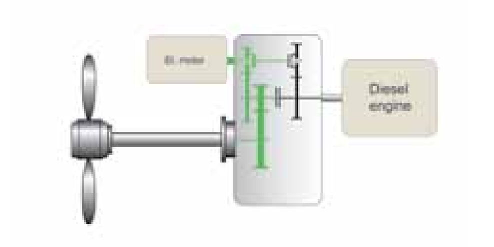
A certain momentum or propeller thrust can be created either by high velocity U_a of a small mass, or by low velocity of a large mass. However, it should be noted that the alternative with the small acceleration and largest mass is the most efficient.

The conclusion is that the propeller diameter should be as large as possible with all consideration given to the necessary clearances to avoid vibration and noise. This is a general rule for all propellers, though there is an exception. Nozzle propellers at high ship speed will have a certain upper limit where a further increase in diameter will result in a reduction in thrust. In all propulsion conditions with high power and low ship speed, typical for tugs, trawlers and seismic vessels, the larger nozzle propeller will be superior. Accordingly, the first criterion for highest possible propeller thrust and efficiency is a large propeller.

3 Propulsion condition in boost mode to give the maximum power needed in heavy operations



4 Low propulsion power mode run by the electrical motor only and shutdown of the main engine



The second criterion is to establish the best possible working conditions for the propeller, through the optimum constellation between the primary design parameters – power, ship speed and wake, propeller diameter and propeller RPM. With a given engine and propeller speed, the optimum gear ratio is given. Further detailed optimisation of gear and propeller is carried out on the basis of these established optimum primary parameters.

Selection of reduction gearbox in the total system configuration

Scana Propulsion has a wide configuration range from single-mode transmission to advanced systems customised for specialised vessels with a high number of operational modes. A wide range of power output (PTO) and power input (PTI) solutions are available for the optimisation of the gearbox system according to each customer's requirements. Stringent safety regulations and environmental concerns are addressed when designing a system for any type of ship to ensure cost efficiency and reliability. The right configuration may give the possibility to make extensive savings such as through reduced fuel consumption.

For vessels spending most of their operational time in low propulsion power conditions below 40 to 50 percent of the total available power there is significant potential for power saving if the zero pitch loss can be reduced or eliminated. There are a number of solutions on the market that reflect this, ranging from diesel-electric configurations, sliding frequency run shaft generators to different low-loss propulsion concepts. All these have advantages and limitations, and the operational profile of the vessel has to be considered in order to determine which solution fits a particular vessel.

The advantages of two-speed reduction gearboxes

Scana Propulsion's solution is a two-speed reduction gear combined with diesel-electric features to create a flexible and redundant hybrid configuration. The Scana Propulsion two-speed reduction gear is a fully integrated solution to provide the option for two "steps" of different propeller speeds with the same input speed from the main engine, still allowing the integrated PTO shaft to run at the required speed.

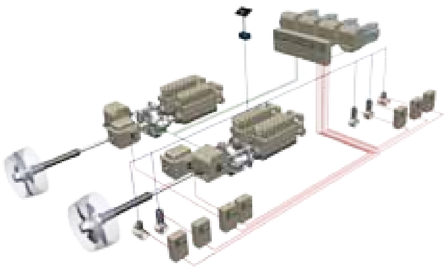
The most important feature is that the reduction gear can transfer all the main engine power over the PTO shaft. In medium-low propulsion power this enables the reduction gear to run a low step propeller RPM in combination with the rated speed PTO/shaft generator, reducing the zero pitch loss of the propulsion plant (Figure 2). It can also be combined with sliding frequency 50-60 Hz.

For high propulsion power the reduction gear can combine the main engine power with the input power of the shaft generator acting as a motor and creating a boost mode. The benefit of using a boost mode is that the size of the main engine can be reduced while maintaining the required maximum power needed for certain operations such as anchor handling or trawling (Figure 3).

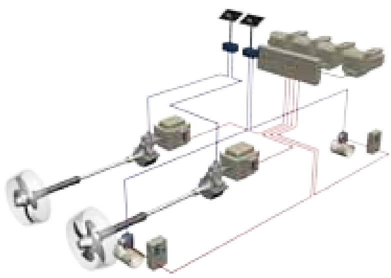
In a low propulsion power condition the propeller can be driven by the electrical motor (shaft generator in reverse power) at rated speed (50-60 Hz) with the reduced propeller RPM. The main engine can be shut down when running in this mode. Alternatively, the electrical motor can be driven with variable speed by a frequency converter (VFD), that gives additional fuel saving (Figure 4).

The above illustrations are principle sketches of the

5 **Hybrid propulsion system suitable for a 300 T+ AHTS**



6 **Diesel electric twin screw system suitable for a 120 T AHTS**



two-speed gearbox, which is available as single-in single-out and twin-in single-out versions. In an offshore vessel configuration where the twin-screw systems are most common, these systems offer a huge flexibility with numerous operational modes.

Hybrid and diesel-electric propulsion systems for offshore vessels

Hybrid propulsion combines the better of two systems. It ensures optimum operational efficiency at both low and high power ranges through a combination of electric propulsion at variable RPM and diesel drive at fixed RPM.

On twin screw ships it is often desirable to use one of the main diesel engines as the power source for electric propulsion. This should be arranged in such a way as to ensure that both propellers are driven electrically. This can be arranged with a PTO and a generator in front of the main engine. The power is converted and distributed to each of the propellers via the PTI on the gearboxes. If it is not possible to position a PTO in the front of the diesel engine, the same function can be obtained by arranging a PTO on the main gearbox primary side.

Diesel-electric propulsion

The arrangement can be similar to that described for hybrid system though the diesel engine is changed by an electric motor. There may be one, two or several electric motors coupled to the same main gearbox. These systems can be arranged for a combination of fixed and variable frequency on the different motors or with variable frequency on all. Such systems will have considerable flexibility and high efficiency in variable service conditions as the propeller has optimised working conditions in the entire power range.

Scana Propulsion gearboxes are available in vertical, horizontal and as twin-in, single-out versions with a wide range of PTO/PTI solutions and in single or two step power transmission.

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Improvements in Azipod® design

Efficiency and availability

JUKKA VARIS - Technical developments and improvements have been achieved over the years to improve energy efficiency and availability of Azipod propulsion based on experiences gained from vessel operations.

Azipod technology was introduced in 1990 on a pilot installation for a Finnish fairway maintenance vessel and later installed in some ice-going vessels and ice breakers. It took seven more years to make a breakthrough in wider markets. The first cruise vessel installation on the Fantasy-class vessel *Elation* in 1998 showed remarkably positive results with high efficiency and excellent maneuverability.

The technology also provided ship designers with greater freedom to optimize the ship's general arrangement. After gaining initial operational experience it was noted that further development of some critical components was needed.

Improvements were initially focused on components and systems like bearings, seals and lube oil systems. After processing further knowledge from experience and getting a better understanding of the system's behavior in operation, the scope of development was widened to cover larger systems and then, finally, by combining customer feedback and all knowledge gathered, complete redesigns and the development of completely new products were undertaken.

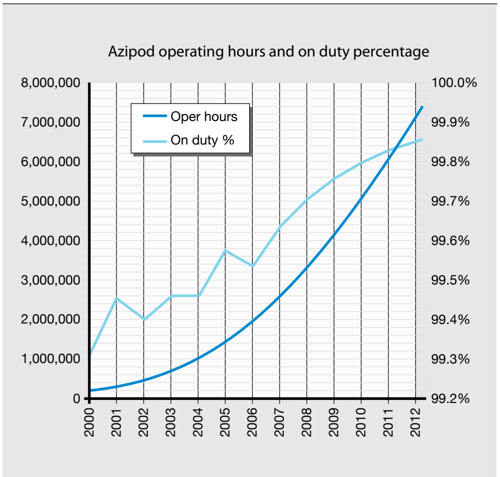
Design improvements

The load conditions on an operating Azipod unit are continuously changing. The propeller generates dynamic forces and torques, which are dependent on propulsion power, vessel speed, steering angle and vessel motions that depend on the weather conditions. There may be rapid changes in the load direction to all three directions and there will also be additional impacts loads when operating in ice.

At first the improvements were mainly concentrated on shaft bearings and seals. While the basic mechanical design remained the same, the focus was to provide improved lubrication conditions to maintain proper oil films between rolling surfaces in different conditions and to improve seals to prevent any leakages into the lube oil or into the sea.

System reliability and availability was improved by promoting both internal changes in the bearing housing and external changes in the lube oil system, with more redundant seal designs that had improved lip materials also introduced. Lube oil monitoring and vibration monitoring systems were brought in to provide better knowledge of system status and

1 **Azipod operating hours and on duty percentage**



The target was to improve the control of the whole process from development and component supply to unit transportation, installation, commissioning, and finally operation and maintenance.

to perform necessary maintenance actions in time. These improvements were performed in a very close cooperation with customers and follow-up was done together to share experience and validate the design changes.

After collecting several years of operational experience with wider knowledge and deeper understanding of system behavior, improvements were broadened to include processes like better control of manufacturing, delivery and operational processes, and general quality control. All of this was improved further through the adoption of strict manufacturing procedures and general requirement specification updates. The target was to improve the control of the whole process from development and component supply to unit transportation, installation, commissioning, and finally operation and maintenance.

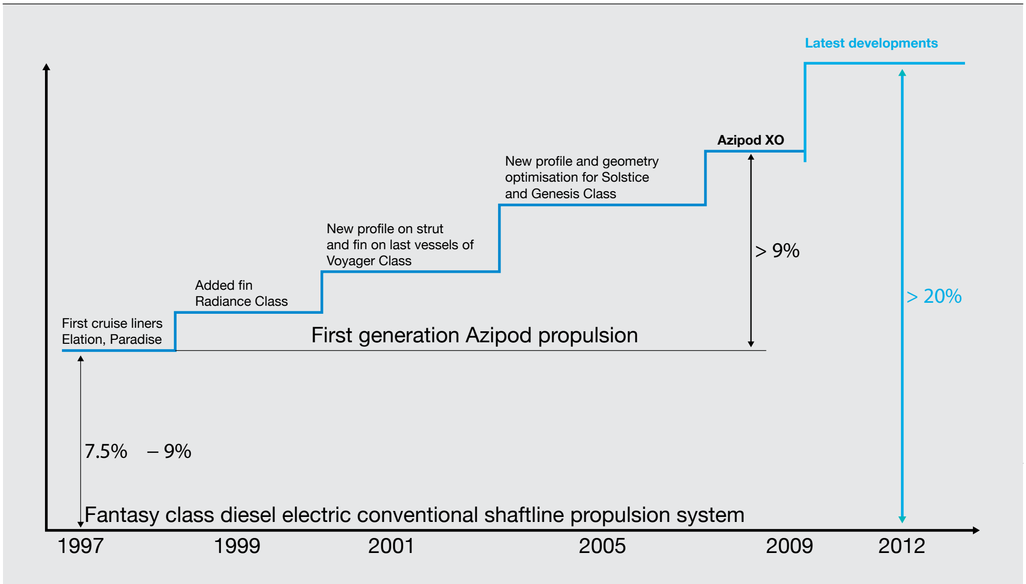
After several generations of updates from the original design, it was seen that a concurrent redesign would be necessary to be able to combine all identified improvement ideas. The first such development project addressed the larger open water unit series, which was subsequently given the identifying type code Azipod XO where X stands for "next generation Azipod" and O means that it is mainly made for vessels that will operate in open water conditions.

In this research and development project ABB Marine decided to utilize well-known, proven technologies for components and design, with the components either proven reliable in the previous Azipod units, or brought in from other marine operation applications where good references had been secured. As an example of the latter, sliding bearings were selected for thrust bearings.

This made it possible to maintain this aspect of operations without dry-docking the vessel. However, because Azipod propulsion generates totally different loads in the shaft system, a thorough full-scale testing was performed to guarantee suitability for the unit. According to tests, the bearing met the requirements and in many cases even exceeded them by a good margin.

The outer shaft seal was also completely redesigned to provide similar benefits: reliability and maintainability. The new seal design consists of four different lip seals against water and two against the bearing oil chamber to provide redundancy. The new seal arrangement separates the seal packages for water

2 Propulsion efficiency has been improved by several steps in design optimization



and bearing oil seals, meaning that there is only a theoretical possibility of water leaking into the bearing or into the sea.

The seal system enables advanced condition monitoring to a degree not seen elsewhere in the market. It controls the seal's operational environment, and the balance between pressure and heat, for example, is automatically optimized.

For larger models the seal can be changed from inside the pod through an ingenious design, arranged by using a temporary inflatable seal placed around the hub during the seal change operation. The seal is designed for a five-year lifetime and to be replaced during normal dry-dockings, but in case of an emergency situation this can also be done with the vessel afloat.

The fully electric steering gear was originally designed for smaller Azipod sizes, but it was the right time to introduce it for larger open water unit sizes to replace conventional electro-hydraulic steering gear. The main reasons for this step were that it reduced energy consumption and noise, as well as cutting the amount of oil in the installation, in order to make it more environmentally friendly. Electric steering gear is now installed on recent Azipod deliveries for open water conditions and first factory tests have been completed to verify its operation.

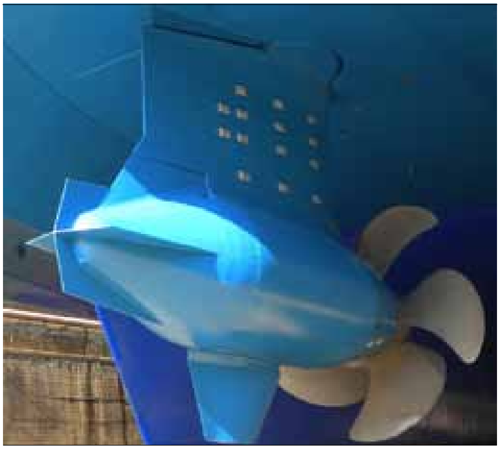
Testing

To reach the high reliability achieved today, ABB has added to its knowledge through undertaking more measurements, tests and research on podded propulsion and its critical components than anyone with comparable products. Very thorough data collection and analysis has been undertaken within various areas to increase the understanding of the design loads and conditions experienced, in order to offer systems that meet both ship design and operational requirements. This also includes long-term measurements from operating units in both open water and ice-going units.

These installations have been fitted with strain-gauges at different locations in the propulsion unit frame to measure stresses and also with vibration sensors, and in some cases proximity sensors to follow-up shaft dynamics. ABB has also invested in a full-size bearing test setup to provide test capacity exceeding normal operational bearing loads and also to simulate extreme situations like major angular misalignment. The test setup has also been used to recreate undesirable operating conditions, such as when high metal particle content is found in oil to verify internal flow and particle removal process.

New systems are also tested during the ship delivery process and during operation to verify that they work according to design criteria. The first installations with

3 Azipod with X-tale



The propulsion motor technology in Azipod units is selected so that it will achieve high efficiency throughout the entire propeller speed range.

the new Azipod X will be thoroughly tested and monitored to confirm that their performance is consistent with laboratory tests. For example, the wear of thrust pads will be checked regularly to ensure that the slide type bearing is functioning as expected. Lessons learned to date suggest that caution is a prerequisite and ABB wants to ensure that the design works as promised in real operating conditions.

Availability

The Azipod's availability has been monitored throughout the years by collecting unplanned off-hire time data and comparing this with the total planned operational hours (Figure 1). Off-hire time that is due to Azipod units but not due to external reasons like ground contact etc.., is measured directly. This number gives indicative feedback on the level of success achieved by design improvements.

The figures show that availability has increased to over 99.8 percent. The increasing availability Figure is an indication of the design and process improvements, but is also a result of improvements in the way the propulsion is used and of the greater awareness of maintenance issues. The relation and cooperation between suppliers and operators is a key factor here.

Improved fuel efficiency

The propulsion efficiency of Azipod propulsion, when originally installed on cruise ship *Elation* back in 1997, improved by some 9 percent, when comparing full scale measurements to measurements from earlier identical sisterships with traditional shaftlines. Since then, the propulsion efficiency has been improved by several steps in design optimization (Figure 2).

One major hydrodynamic improvement was gained early by installing a fin under the Azipod to reduce rotational flow losses generated by the propeller. The lower fin was also an efficient means of reducing steering system loads by reducing the azimuthing counter torque. In the next steps, the Azipod strut design was modified by making it slimmer and more optimal for operation in the propulsion environment. Finally, with the Azipod XO, the propeller hub and motor module diameters were reduced and the unlt is entire hull was optimized with the help of CFD and model testing. All in all Azipod hydrodynamic improvements from the first units to Azipod XO have been improved by 9 percent when compared to the *Elation* results.

During 2011, ABB introduced an additional package to improve Azipod propulsion efficiency further. This package consists of an asymmetric lower fin and crossed plates (X-tail) that are integrated in the aft cone.

The asymmetric lower fin will improve efficiency up to 1 percent by reducing the losses from the propulsion system and the X-tail will further increase efficiency by up to 1.5 percent by reducing the rotational flow losses at the aft cone section. These changes can also be made as a retrofit installation on open water units. Due to different design and load conditions these modifications are not applicable to ice-going vessels.

The first retrofit work with asymmetric fin and X-tail was done in 2011 during the vessel's normal dry-docking. To verify the results, the same measurements were taken for two similar vessels before and after dry-docking. The first vessel did not feature the modifications and the second one did. Both vessels benefited from the same scope of hull cleaning and painting during dry-docking. Finally the numbers were verified and approved together with the customer and a third party. The results showed a 2.8 percent reduction in fuel consumption for the propulsion.

Also in 2011, ABB launched a method of optimizing the energy efficiency of Azipod installations on board vessels. This was based on the finding that further fuel consumption savings can be reached by optimizing the toe (steering) angle of the Azipod units dynamically, in addition to the angle optimization already undertaken at the vessel design stage. This package has the acronym ADO from the words "Azipod Dynamic Optimizer." Fuel consumption is estimated to be reduced further by up to 1.5 percent using ADO.

Although the propulsion efficiency of the Azipod has already reached a high value, one should never stop looking for opportunities to improve it. The propulsion efficiency for operating units can be further improved by applying optimized propeller geometry to meet current design criteria. For a retrofit installation, it is possible to reduce blade thicknesses to provide lower losses. By applying stainless steel materials that are common in ice-classed Azipod units, the thicknesses can be further reduced and efficiency further improved. The estimated reduction on fuel consumption on such vessels may reach up to 4 percent.

The overall improvement in propulsion efficiency has been above 10 percent over the course of the existence of the Azipod, with a more than 20 percent gain when compared to the shaftlines being used back in the mid 1990s. However, it is fair to acknowledge that there have also been improvements in shaftline propulsion during this time. Even so, a recent comparison test at Marin showed that Azipod propulsion compared to a fixed shaftline propulsion design still had a 6-8 percent lead what regards to propulsion efficiency. Furthermore, these tests were made before the introduction of asymmetric fin, X-tail and ADO, which can improve the efficiency of the Azipod system overall by up to four percent.

To support high propulsion efficiency and to provide best overall system efficiency, the propulsion motor technology in Azipod units is selected so that it will achieve high efficiency throughout the entire propeller speed range. As an example, on a typical dynamically positioned drill ship, the required thruster power will be below 15 percent for over 90 percent of the time. Azipod C, with its permanent magnet motor compared to a similar thruster unit provided with an induction motor, will have over 10 percent higher efficiency at low power loads, providing savings on fuel consumption and emissions. Similar effects will apply to larger units with synchronous motors that also have high efficiency with very low loads.

Operation experience

With regards to fuel savings and ship maneuverability, the expectations set by ship operators have typically been fulfilled or exceeded by the Azipod. Ship captains in particular have expressed satisfaction with the ease of operation and the maneuverability of their ships. Concerning energy efficiency, some operators have claimed fuel savings of more than 20 percent, compared with their vessels operating with conventional propulsion. The Azipod concept is established and recognized to be the preferred solution for ice going ships and icebreakers. The thrust and power efficiency makes it also very suitable for DP operations.

Dedicated ship operation simulation facilities have been set up to provide training in how to operate ships optimally with Azipod propulsion and take full advantage of its characteristics. It is greatly satisfying to see that the continuous efforts to meet customers' expectations have resulted in the major cruise ship operators choosing Azipod propulsion for their latest vessels ordered.

Seven million operating hours with Azipod propulsion over a time span of two decades have resulted in the largest pool of experience in how podded propulsion systems should be designed, used and maintained for trouble-free reliable operation.

During the Azipod's existence, components and systems that are critical for undisturbed ship operation have been identified. These have needed special attention during design and the selection of components, as well as for their operation and maintenance phases. Technical issues have been approached through systematic analysis and root causes for unwanted behavior have been identified. New solutions have been developed over the years, when necessary.

ABB has established a unique position being the only company that has in-depth and in-house product and integration knowledge, with a responsibility covering the whole concept from hydrodynamics, mechanics, electronics, cooling to operating, maintenance and services, as well as the integration of the complete electrical and control system. The advantage of having data available from a large number of operating units, as well as a wide range of test results from models and full size units, has been essential for continuous development. Close cooperation with a large group of ship operators and shipyards on a variety of Azipod applications and ship designs for various demanding operating environments have complemented our understanding of the Azipod concept.

The maintainability of the propulsion unit has shown itself to be one of the more important factors in providing reliable operation of the critical components of the system, which are the shaft seals, shaft-line bearings, steering system, slewing seals, slewing bearings and the propulsion motor itself.

Nowadays, Azipod propulsion and thruster units are designed for five years dry-docking and maintenance intervals. For some applications a longer maintenance interval of even up to 10 years has proven supportable. This conclusion is based on results drawn from a well-documented operational and maintenance history.

Today, there are some 100 vessels using Azipod propulsion. It has been selected for a wide range of ship types and operations; such as cruise ships, icebreakers and ice-going cargo vessels, ferries, megayachts, offshore supply vessels, research vessels, wind turbine installation vessels and drilling rigs.

The advantage of having data available from a large number of operating units as well as a wide range of test results from models and full size units has been essential for continuous development.

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Simplifying energy efficiency

Azipod® CZ advantages for drilling vessels

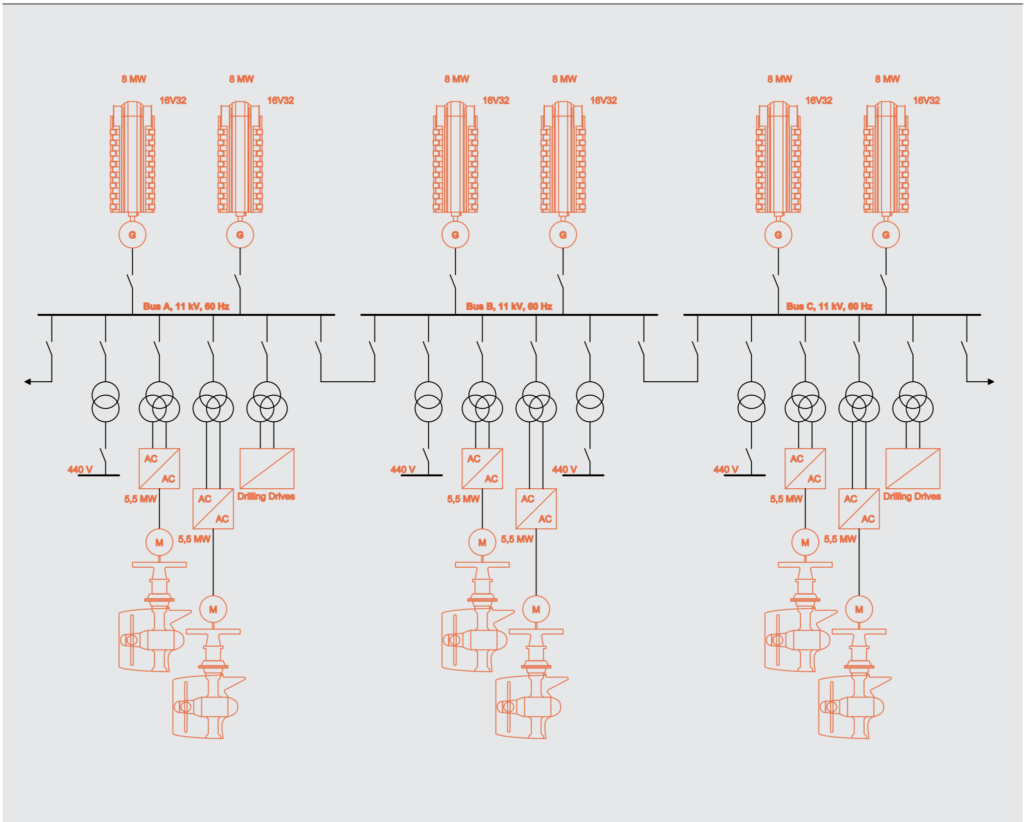
LAURI TIAINEN, TEEMU JEHKONEN, JAN FREDRIK HANSEN - Drilling vessels such as semi-submersible drilling rigs and drillships are characterized by a high amount of installed electrical power for two main processes; drilling operations and dynamic positioning (DP). Both processes consume power of the order of several MWs and are powered from a common power supply consisting of multiple diesel generators in a redundant configuration. The total installed power is of around 50 MVA and is configured in several split subsystems, which can be interconnected when required. A variety of configurations exists; however, typically a semi submersible has a four-split arrangement with eight generators and eight thrusters, while a drill ship has a three-split arrangement with six generators and six thrusters.

The drilling operation can consume as much as 10-15 MW and the dynamic positioning operation as much as 30 MW in the most extreme weather conditions. Both processes may be subject to large transient variations in their loads. Other loads on these vessels, such as accommodation and other auxiliaries, are minor when compared to these two largest processes. This article will focus on the thruster system used for dynamic positioning and its effects to the main power plant.

The availability to dynamic positioning is essential for operation of the vessel, as keeping position in all conditions is a prerequisite for drilling operations and also affects the safety of the vessel and persons on board, as well as the environmental emissions and risk for spill. For these reasons, thruster units are powered to keep the vessel in position considering also the most extreme weather conditions permissible for safe operation. Furthermore, rules and regulations are developed so that failures of components or subsystems shall not affect station keeping capabilities. For example, for DP classes 2 and 3, which apply to deepwater drilling units, the requirement is that the vessel maintains essential operations and keeps its position in the case of any single electrical failure (failures from fire and flooding are only covered by class 3). This means that the total rated power of all thrusters and power plant must be overdimensioned when compared to the actual loads experienced most of the time in operation. Simplified, a three-split system will be 3/2 or 150 percent rated, while a four-split system is 4/3 or 133 percent rated against power required after a single failure.

Vessel safety is, naturally, paramount and overrides efficiency and fuel oil consumption considerations. However, there remains potential to achieve energy savings and reduce installed power without compromising safety margins in any way, through introducing equipment such as the ABB's Azipod CZ, which has been specially developed to maximize the output thrust force with minimum consumption of electric power.

1 Single line of a typical drillship with traditional mechanical thrusters



With a more efficient thruster system, not only the thrusters, but the whole power plant could be adjusted.

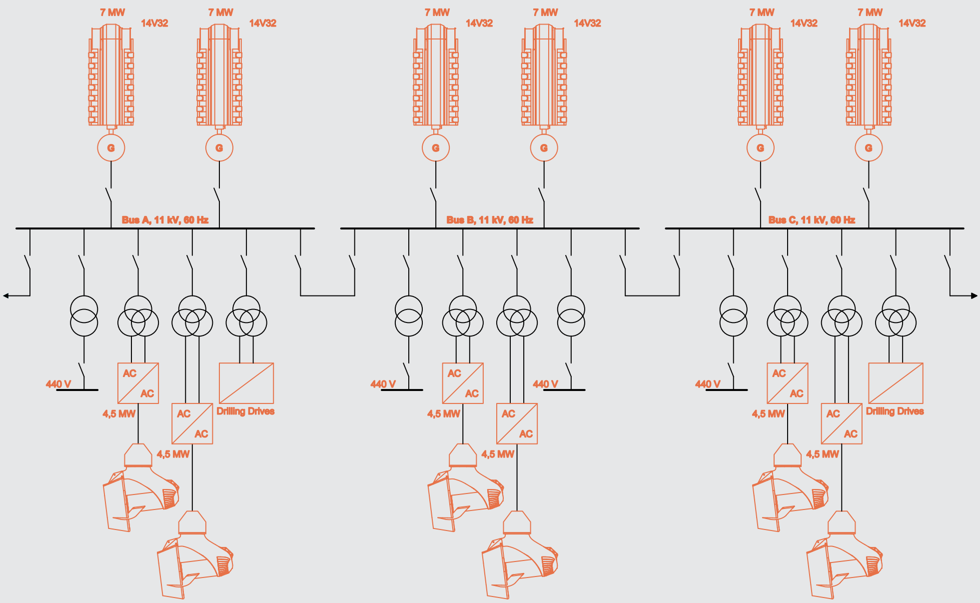
Drill ship configuration: typical example

There are two possible operational criteria for dimensioning main power plant and thrusters: transit and DP operation.

If DP operation is the main criterion, the size of the diesel engines selected will be determined by the power required for station-keeping and the required power for drilling operations. Here, the bollard pull capability of the thruster will be the decisive factor.

If the transit speed is the dimensioning criterion, then it is the required power at the design speed (typically, this could be 10-12 knots) that sets the criteria, with the only addition being hotel and auxiliary loads. This would mean that the power requirement in bollard pull conditions is lower, as could be the case if the vessel is designed for DP operation in calmer waters. It is the designed permissible weather window and the consequence of single failure that decides the power requirements for DP operation.

2 Single line of a typical drillship with traditional Azipod CZ thrusters and suitable power plant



In Figure 1, a typical single line for a drillship is shown. The thruster motors consume 5.5 MW of power from the converters and the main engines each have 16 cylinders. For engines used in this kind of vessel power is usually somewhere in the range of 450-500 kW per cylinder. In this reference case we have assumed 500 kW per cylinder and that the DP operation would determine dimensions. The drilling equipment would be rated for power consumption around 8-10 MW. The reference case is shown with mechanical thrusters, as explained in the sections that follow.

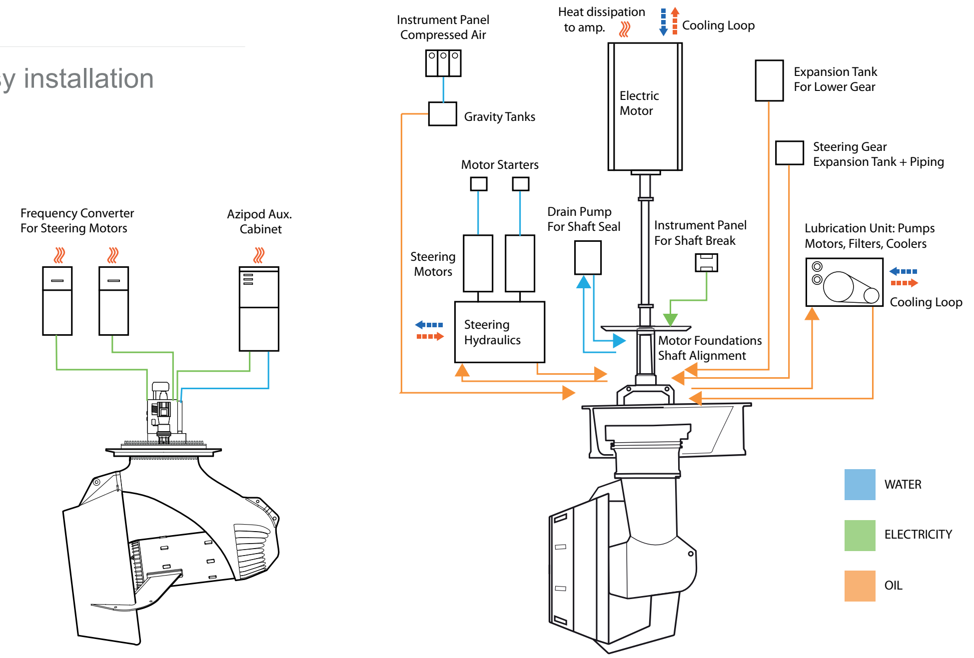
With a more efficient thruster system, not only the thrusters, but the whole power plant could be adjusted. By using Azipod CZ, an efficiency gain is possible by achieving the same thrust force in bollard pull but consuming only 4.5 MW from the frequency converters. The result would be considerable savings in installed power. It should be noted that the numbers given here are assumptions and also depend on other factors, such as ship design etc., which is not considered further here.

Figure 2 shows the single line example using 4.5MW power consuming Azipods. In this case, two fewer cylinders per engine, or a 12.5 percent reduction in installed generating power, could achieve the same output. Using 14-cylinder engines would thus cut fuel consumption, but should also reduce maintenance, given that this is typically based on the number of cylinders. It is, of course, also possible to consider other variations, such as installing different engine sizes to optimize diesel engine efficiency further.

Saving space and money: reduced complexity with fewer components

The current Azipod CZ design provides a simple mechanical and electrical interface for the customer for design and construction, and the steering and propulsion drives are the main components to be integrated with the ship power system. Figure 3

Easy installation



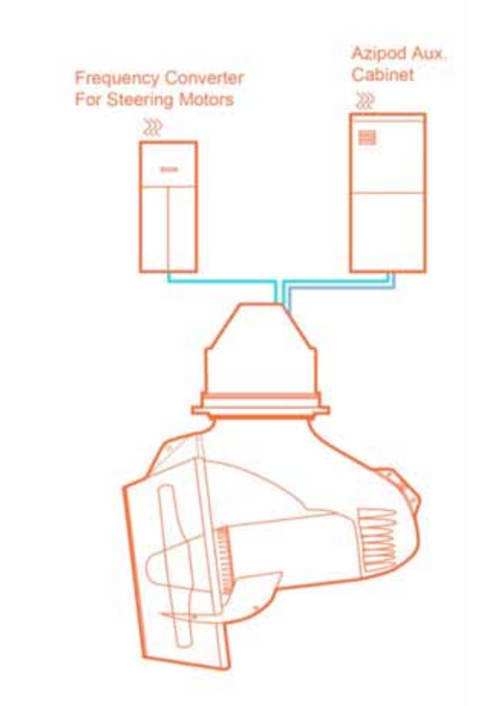
compares the number of components in Azipod CZ and the mechanical L-drive. Clearly, the simplicity of the Azipod is obvious when comparing it to the L-drive solution, which includes a vast number of auxiliary components. Additionally, cumbersome hydraulic piping works are not required for the Azipod, which involves easier and cheaper installation. If the Azipod is used and classified as a thruster only, one could even omit the second steering drive and leave one steering motor to carry the required steering load (Figure 4). The redundancy needed for steering is then covered by the redundant system design ie, by the split electrical system and the multiple thrusters installed.

By combining the propulsion and steering drives within the same physical space, additional savings in costs, interfacing, and installation can be achieved (Figure 5). In an Azipod multidrive concept the steering and propulsion are combined in one cabinet. The total footprint of the drives will be unaffected or reduced, while the need for a low voltage supply switchboard would be smaller, providing savings in cabling and installation costs. If auxiliary voltage for the Azipod could be supplied through one cabinet, it would offer one simple interface to the yard. The same cabinet would then serve as the I/O interface eg, for ship automation and remote control when integrating with the automation system.

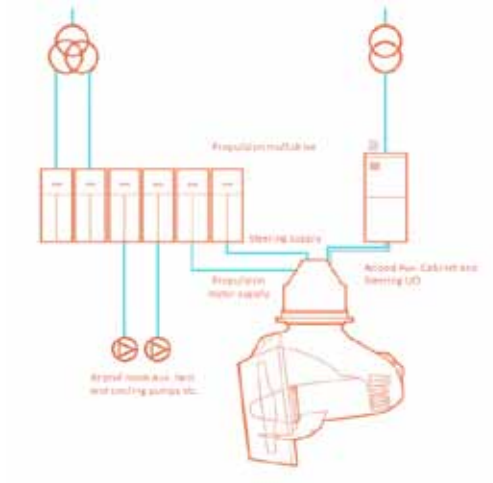
The Azipod room itself also requires ventilation, while the drives and transformers need water cooling; these are normally provided by separate power supplies. By also integrating these into one multidrive, more savings can be achieved in terms of cabling installation work. Cabling represents a significant installation cost, and the solution offers great potential for savings, particularly where low voltage switchboards are located on the main deck while the Azipod room (with drives) is below (Figure 4).

By optimizing the power system's design and using multi-drives, several hundred meters less cabling can be used. Again, fans and pumps could be controlled if needed, according to the cooling needs required at any time, instead of running them with full power continuously, thus reducing energy consumption and the wear and tear of mechanical components.

4 **Azipod CZ as a thruster unit, with a single steering drive**



5 **Multidrive concept**



By combining the propulsion and steering drives within the same physical space, additional savings in costs, interfacing, and installation can be achieved.

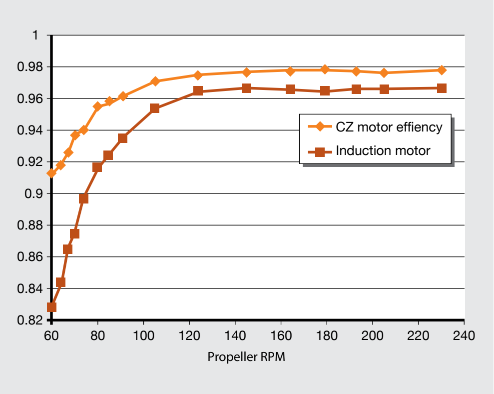
PM motor efficiency: high result with effective motors

Since the propulsion system's load profile has a huge impact on the vessel's operating cost, the selection of the motor type alone is a significant factor in the energy efficiency and fuel consumption. The Azipod has the capacity to provide immediate full torque, which is available without any mechanical limitations or losses occurring in the transfer between motor and propeller, giving fast thrust and steering response. All of the heat produced by the motor is also cooled directly by sea water, which means the cooling capacity installed in the vessel can be reduced. The following drillship concept calculation shows the savings in real terms.

An evaluation is made to compare the yearly energy consumption of two different concepts of propulsion: 6 x Azipod CZ 4,5 MW thrusters and 6 x Mechanical L-drive 4,5 MW thrusters. The operational profile is based on the assumption that 5 percent of the vessels operations per year are at full speed. The remaining 95 percent of the time is dedicated to DP operation according to statistics provided for a similar DP vessel.

6 **A typical power system installation of a drilling semisubmersible rig**

7 **Electric motor efficiency curves induction motor versus permanent magnet motor**



Efficiency points were modeled with a VSD-motor simulation tool for 4.5 MW induction motor for thruster drive and Azipod C with permanent magnet motor.

Note: The efficiency curves are represented from 60 rpm propeller speed to full speed. 230 rpm point represents the transit mode

Meanwhile, 90 percent of DP operating, the thrusters function at lower than 100 rpm propeller speeds (ie, less than 15 percent of rated power). Mechanical, hydrodynamical, hull interaction, thermal and electrical losses are calculated based on load share.

The comparison shows that that Azipod CZ is about 7 percent more energy efficient on a drillship operation than the L-drive. This is due to the use of permanent magnet technology, which has a remarkably higher rate of efficiency when running at low RPM (Figure 5). If energy costs are given as $330 per MWh, this would reduce annual energy costs by about $480,000.

From small creeks to great rivers: PM auxiliary losses

The following model presents losses in auxiliary systems, including those additional loads which are typically not taken into account when comparing different drive systems.

A mechanical thruster system will have a significant base load that is largely unchanged by the load on the propeller, and this in particular contributes to a relatively high contribution to energy losses when operating at partial loads (low powers), such as DP operation (Figure 8). Therefore, such components as cooling fans, lube oil pumps etc.. have been taken into account in this analysis. The aim was to compare ”apples to apples,” hence all losses that are equal to the systems, such as transformer losses, electric power transmit losses etc., have been disregarded.

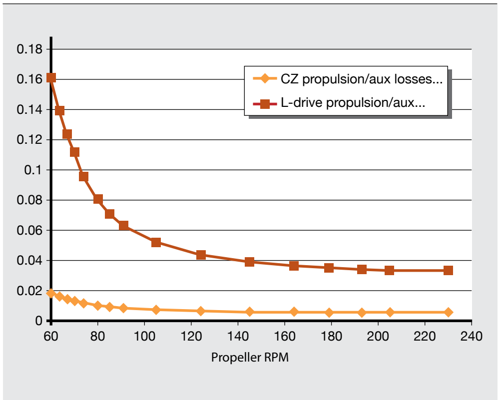
In conclusion, the analysis shows that there is the potential for annual energy savings of 3-7 percent using Azipod CZ propulsion.

Certain variables are unknown and have been omitted from the evaluation, such as losses in hydraulic steering gears, additional ventilation and the cooling needed for higher ambient losses from the mechanical thruster. Thus, the real difference should be even higher than calculated here.

Hydrodynamic benefits

In addition to the direct differences in electrical efficiency already discussed, the Azipod CZ propeller shaft is installed with a 7-degree tilt angle in order to improve hydrodynamic efficiency and reduce thrust losses from hull interaction (Figure 9). The tilt angle also reduces interaction with other pontoons and thrusters, limiting further interaction with the hull (the Coandă effect) without the need for the tilted nozzles that are used in several mechanical thrusters which, while avoiding such effects, bring the disadvantage of increasing thrust losses. Hydrodynamically, this means a 4-8 percent advantage in thrust, compared with the tilted nozzle used with mechanical thrusters. A design that did not incorporate any tilt angle would lead to 10-30 percent loss of unit thrust.

8 Thruster auxiliary losses



Auxiliary losses in relation to actual power at specific load point. (LV electric drive additional losses 0.5 percent are included in Azipod CZ curve)

9 Azipod CZ comes with a built-in tilt angle of the propeller shaft

Concluding remarks

There are a number of factors contributing to the greater efficiency of an Azipod CZ thruster over its mechanical counterpart, and the type of electric motor, mechanical connection, tilting and hydrodynamic considerations all need to be considered in order to optimize energy efficiency and minimize thruster losses.

The potential of utilizing higher energy efficiency and power and energy savings depends on the design requirements and operational profile of the vessel, and should thus be checked case by case. The benefits of the Azipod CZ thruster can affect the design and dimensioning of the power plant for drilling vessels either by reducing the installed power capacity for same station keeping performance or by retaining power capacity while increasing the boundaries and margins of operations.

The energy and fuel saving potential of choosing the Azipod CZ solution established in the evaluation indicates that around 15 percent less energy can be used annually over a mechanical thruster. This is the result of electrical and hydrodynamical efficiency and will depend on propulsion load profile.

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Achieving improved fuel efficiency with waste heat recovery

MARKUS VIRTASALO, KLAUS VÄNSKÄ - Using a waste heat recovery system is becoming an increasingly viable means of reducing fuel costs by increasing the energy output from combustion engines. This article describes the technology and its application in a marine environment and sets out some of the savings that can be achieved.

Waste heat recovery has significant potential for use in marine propulsion systems. Even with current conventional two-stroke propulsion power plant, approximately 50 percent of the energy content of the fuel is lost, mainly to heat, without being used for mechanical work. By supplementing the ship's main propulsion plant with a waste heat recovery system (WHRS), the fuel can be utilised more efficiently, because less energy is lost in the exhaust gas flow. As a further environmentally-beneficial consequence, the amount of CO_2 emissions in relation to the engine's mechanical power output can be decreased.

Through the WHRS, the recovered energy, which typically amounts to about 10 percent of main propulsion's shaft power, is converted back for mechanical work. When the WHRS is provided with a propeller shaft generator/motor, a further saving is gained by improving the main engine's loading condition at various points within the ship's operating profile. In addition, energy recovered from the main engine exhaust can be converted to mechanical work and added back to the propeller shaft as well.

What is a WHRS?

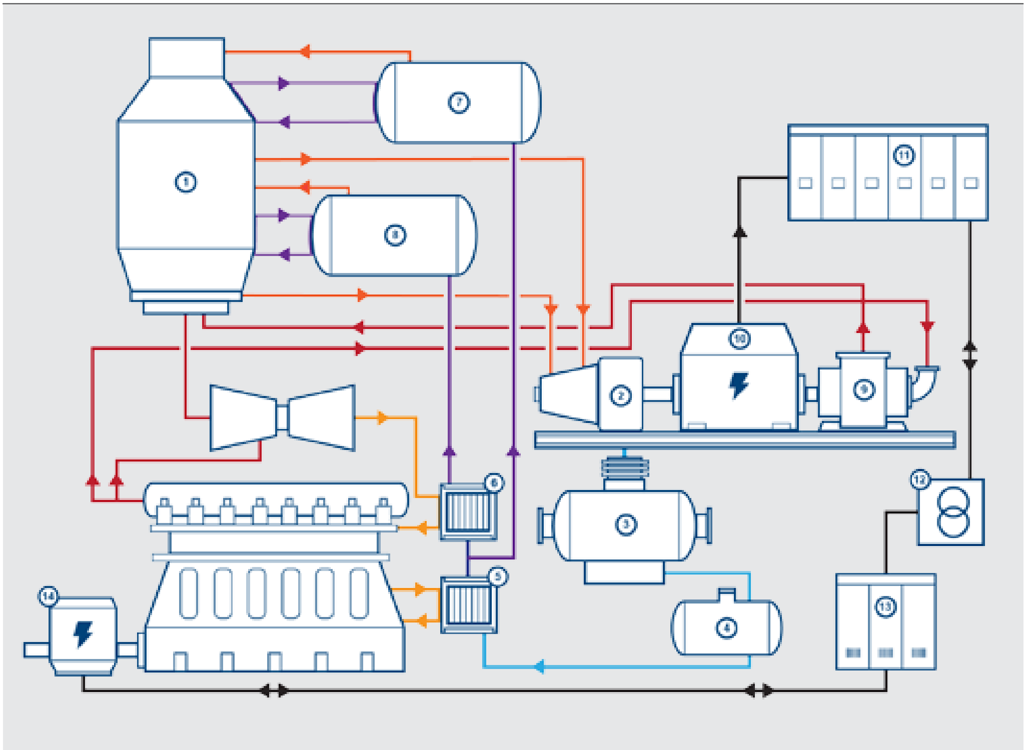
A WHRS is a combination of equipment installed on board to assist the ship's main propulsion machinery recover a part of the energy contained in the fuel that cannot be efficiently utilised by the main engine. Without the WHRS, that energy would be lost as heat into the atmosphere and sea water. The technical details of the WHRS can be tailored to suit each application, but typically the following main components are provided (details shown in Figure 1):

- Dual pressure exhaust gas boiler
- Steam turbine generator unit with vacuum condenser
- Exhaust gas power turbine
- Boiler feed water heater(s) from main engine scavenging air and/or jacket water
- Propeller shaft generator/motor with frequency converter
- An electric system and power management system for distribution and control of the power generation and flow

How does the WHRS work?

The mechanical efficiency of the main engine is close to 50 percent. The rest of the energy contained in the

1 Waste heat recovery system process flow and main component diagram



The following units are shown: 1. Exhaust gas boiler, 2. Steam turbine, 3. Vacuum condense, 4. De-aerating feed water tank, 5. Feed water heater (ME jacket water), 6. Feed water heater (ME scavenging air), 7. Boiler steam drum, low pressure, 8. Boiler steam drum, high pressure, 9. Exhaust gas power turbine, 10. Turbine unit generator, 11. Switchboard, 12. Transformer, 13. Shaft generator/motor frequency converter, 14. Shaft generator/motor

fuel consumed by the engine is not converted into shaft power, but is lost, mainly to heat and friction. The WHRS is designed to recover as much energy from these losses as is economically viable.

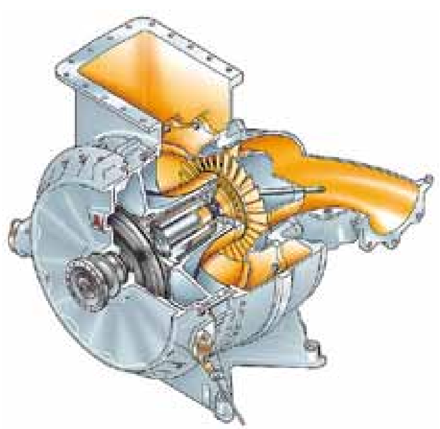
Recovery of the waste heat begins in the exhaust gas boiler (Figure 2). Compared with conventional exhaust gas boilers, the WHRS' dual pressure exhaust gas boiler is designed to efficiently generate steam with characteristics that make it suitable for electricity generation.

For optimum efficiency, steam is generated at two pressure levels - high and low. Both high and low pressure steam flows are then led through the ship's steam piping system to a condensing steam turbine, which is connected to a generator. The turbine will then convert the thermal energy of the steam into mechanical energy to run the generator. When the thermal energy has been used, steam will exit from

Through the WHRS, the recovered energy, which typically amounts to about 10 percent of main propulsion's shaft power, is converted back for mechanical work.

2 Exhaust gas boiler

2 Exhaust gas boiler



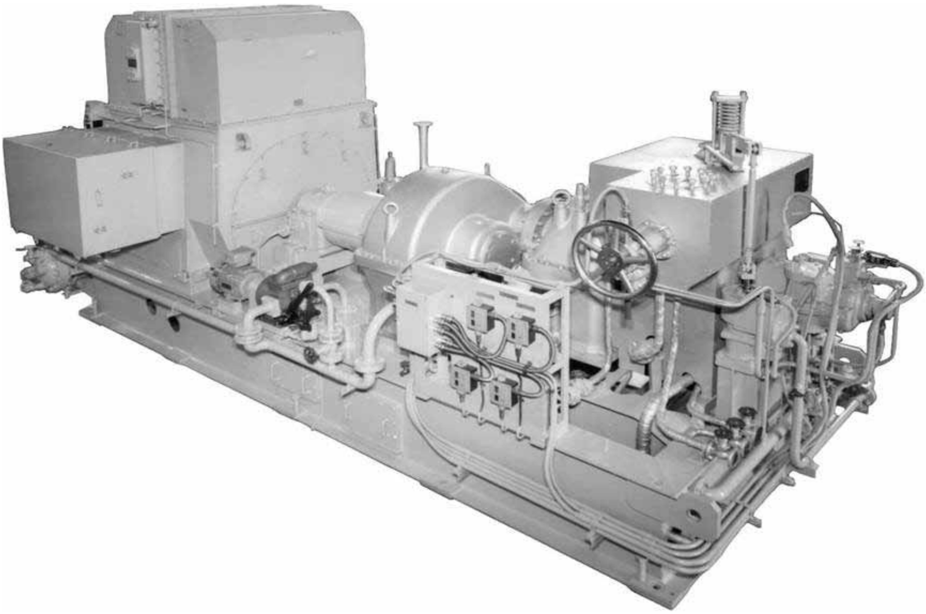
the turbine and condense in the sea water-cooled vacuum condenser attached below the steam turbine. This condensate water is collected into a deaerating feed water tank and pumped back into the exhaust gas boiler. On its way there, the condensate will recover heat from the main engine jacket, cooling water and/or the main engine scavenging air by flowing through the respective heat exchangers. This part of the process is called feed water heating. The entire circulation process of the steam and condensate water is closed, and the quality of steam/condensate is monitored.

Energy is also mechanically recovered from the main engine exhaust gas flow. Part of the main exhaust gas flow is diverted into a power turbine (Figure 3), which is connected to a generator. This part of the process runs the power turbine, which is similar to the turbine side of a main engine turbocharger, and thereby complements the steam turbine's generating capacity.

The steam turbine and the power turbine can be installed in two different configurations. They can either be on the same bed frame with one common generator or on separate bed frames with dedicated generators (Figure 4). The choice between the two options can be made on the basis of the ship's engine room layout, as well as what is technically the optimum and most feasible approach. In all configurations the turbines are connected to the generator through a reduction gear. With the common generator configuration, the power turbine and generator connection are also provided with a special freewheeling clutch, enabling automatic engagement/disengagement depending on operating conditions.

On ships with two main engines, a configuration with two power turbines, one for each main engine, can be considered. In special cases, a WHRS with only a steam turbine and generator or only a power turbine and generator, can be provided, but with consequentially a lower heat recovery capability.

The propeller shaft generator/motor will maximise the utilization of the recovered energy. When provided with a highly flexible variable frequency drive, the shaft generator/motor can convert electricity into additional propulsion shaft power, as well as propulsion shaft power into electricity, a change in functionality that is achieved seamlessly without any interruption to the operation. This flexibility is due primarily to utilizing a frequency converter between the shaft



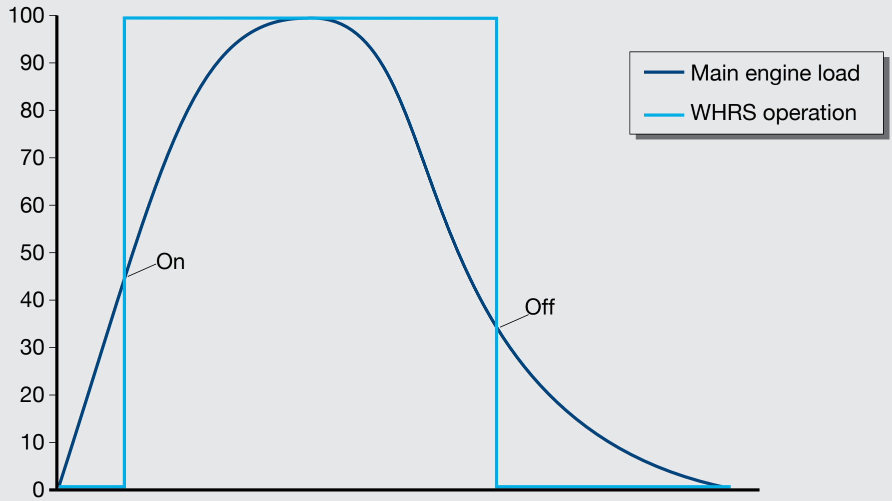
generator/motor and the ship's electric network. As a result, the energy recovered in the steam turbine and power turbine can be directly utilized as mechanical power on the propeller shaft. On the other hand, in slow speed situations where the ship's consumption of electricity exceeds the amount recoverable from waste heat, the shaft generator/motor will feed the ship's main network, thereby utilizing the main engine's increased efficiency.

Where and when can the WHRS be used?

The WHRS can be applied to any propulsion plant with sufficient power output to make the investment economically viable. There is a clear economy of scale here, and the bigger the main engine output, the more waste heat can be recovered. The power level above which the WHRS becomes economical depends on the price of fuel, as well as required payback time, and should be validated by making detailed calculations as to system efficiency. As an indication, however, given various parameters prevailing at the beginning of 2012, ABB estimates it would be economically feasible to use WHRS on board container ships with main propulsion machinery with a mechanical output of 20 MW or more.

ABB estimates it would be economically feasible to use WHRS on board containerships with main propulsion machinery with a mechanical output of 20 MW or more.

5 Economical operating range of the WHRS



Ships with a relatively stable operating profile, especially with higher propulsion loads, have the biggest potential for savings.

Another consideration, which determines the economic viability of the WHRS, is the operating profile of the propulsion plant. Ships with a relatively stable operating profile, especially with higher propulsion loads, have the biggest potential for savings. The more the vessel has a high-load operation, the shorter the payback time for the WHRS will be. The WHRS is not run in port or manoeuvring situations, so the smaller these are as a portion of a ship's overall operating profile, the greater the economical potential of the WHRS.

To date, WHRS have typically been installed on deep sea container vessels and very large crude oil carriers (VLCCs), equipped with a two-stroke engine propulsion plant.

The WHRS will function only when the main engine load is above a certain limit. That limit depends on the system design for each project, but is typically about 40 percent of the main engine MCR for an ABB WHRS. The propeller shaft generator/motor is functional from any low load, the main engine can run up to 100 percent of the main engine MCR and the shaft generator/motor can be optimised to give 100 percent output power at a specified main engine load, for example 80 percent of the main engine MCR. Optimising specifications during the design phase allows for maximum flexibility in the recovery and utilisation of waste energy during the ship's operation.

Is the WHRS complicated and does it require special skills?

The basic technologies used in the WHRS have existed for decades and no new technologies, for instance, fuel cells, are incorporated in the systems being offered on the market today. The reason it has now become more feasible to make use of WHRS technology is primarily down to improvements in component design, as well as increases in fuel cost and a greater awareness of the importance of energy efficiency and the need to reduce emissions. What allows a conventional auxiliary steam system to become a modern WHRS is basically the increased capacity of the auxiliary steam production and the conversion of the steam's thermal energy into electricity instead of other purposes like heating.

Exhaust gas boilers and auxiliary steam systems are standard on practically every ship. The steam turbine is installed on an integrated standalone bed frame and requires little maintenance between scheduled overhauls. The power turbine is similar technology to the main engine turbochargers, and so maintenance procedures are also basically equivalent. The overhauling period of the propulsion machinery is not affected and the WHRS components need only similar intervals between overhauls.

Since ABB offers the WHRS as a single integrated package, the functionality of the complete system can be optimised at the design phase. The operation of the WHRS after startup is controlled by local and centralised automation systems and the loading of the units is controlled and adjusted automatically by the power management system. In addition, an advisory system is available to make a thorough evaluation of and if necessary adapt the WHRS when faced with any new operating conditions.

Why start using WHRS now?

The use of WHRS has become more economically viable due to the rise in fuel costs over the past decade. As a result, the payback time for the system has reduced and future restrictions and penalties for CO_2 emissions will enhance the attractiveness of having WHRS even further. The improved efficiency of propulsion machinery with WHRS gives the operators a competitive edge over those with conventional propulsion machinery and provides them with a reduced carbon footprint and other environmental benefits.

The WHRS package offered by ABB uses well-proven technology that customers have had experience with for many years. The steam system-related components have been selected from manufacturers that are equally well respected in their field of expertise. In delivering a complete package, ABB provides a single point of contact for all customer communication during a WHRS project. In addition to the WHRS package, ABB can also supply the power management system, integrated automation system, main electric network and propulsors required for the project.

How much does it cost?

There is no one simple answer to this to cover all applications. The initial cost of the WHRS will eventually be covered by the fuel savings made during the operation of the vessel. The WHRS system can be optimised to meet a required level of efficiency and tailored for the specified propulsion plant. Based on these main parameters, a payback time can be estimated in advance, relative to the prevailing cost of fuel and the operational profile of the ship.

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The next issue of *Generations*…

Improved safety and reliability are pivotal for the maritime industry's performance and success. New technology promises significant gains in operational efficiency and safety, but also poses challenges. A vulnerability factor is emerging, as crews that were once able to repair onboard equipment find themselves unable to tackle problems with today's programmable logic controllers and advanced sensor technology. Software quality and the availability of hardware components over a vessel's lifetime have become major risk factors.

As these technologies and solutions become increasingly advanced, the responsibility for end-to-end solutions becomes a critical risk factor. The key to creating safer and more reliable solutions appears to be long-lasting partnerships between yards, ship and rig owners and the project and services teams working on.

The next issue of *Generations* will look at how advanced technology and new insight is helping leading maritime players to improve their operations and to take on new hazards and challenges.

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