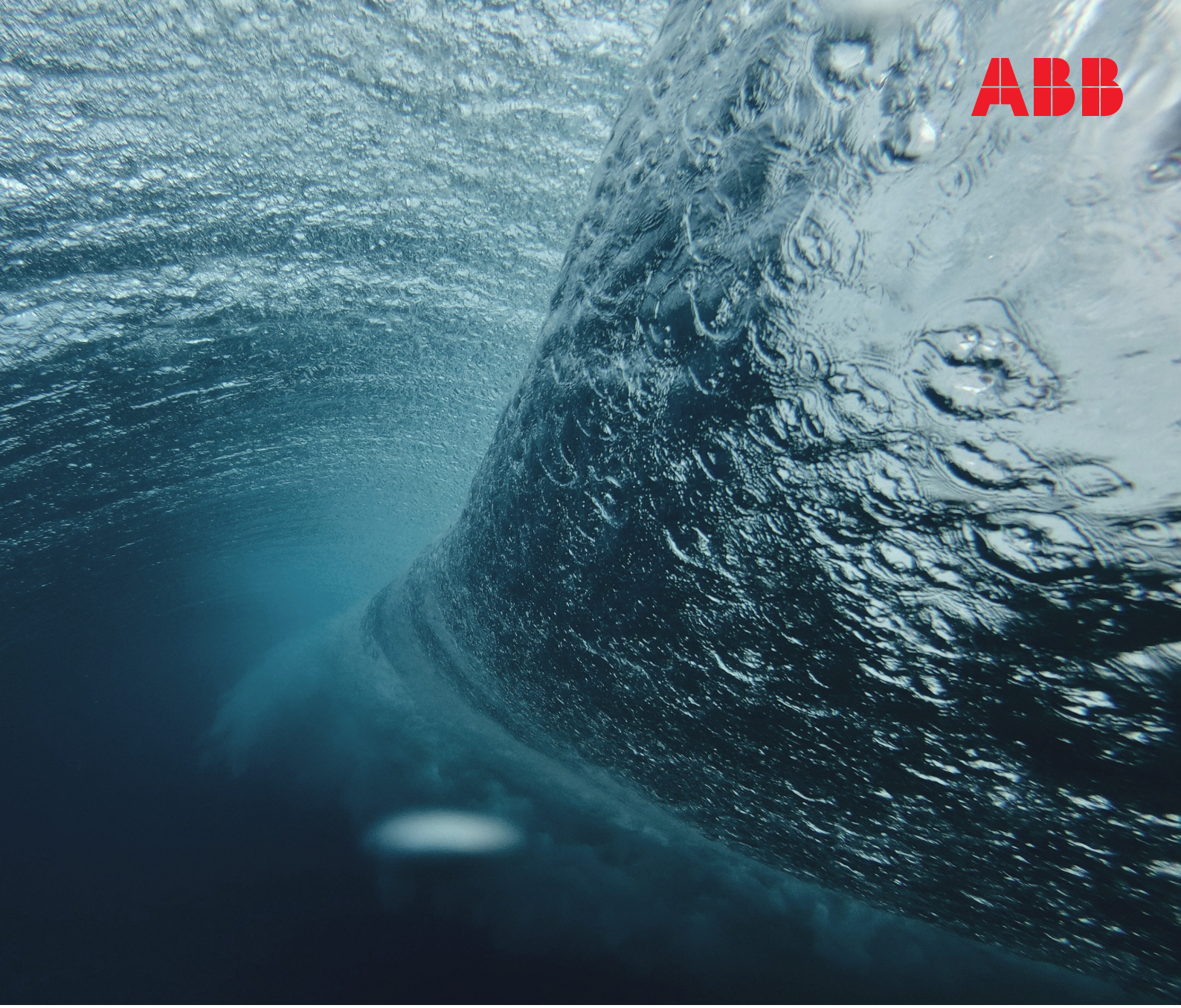

GENERATIONS

Transforming tomorrow

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Ambitions without borders

Captains Without Borders (CWB) is committed to creating equal opportunities for emerging maritime talent – opening up new pathways for women from underrepresented communities to take to the bridge. Captain Alexandra Hagerty, CWB Founder, explains the need for the campaigning non-profit, stressing that it's high time diversity finally set sail within shipping.

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Opportunity is not evenly distributed, but potential is.

Captain Alexandra Hagerty has set a course she does not intend to deviate from.

The determined United States Naval Ship (USNS) captain, currently in charge of the research vessel USNS Invincible, speaks with utter conviction about the lack of women within the maritime industry, and especially the difficulties faced by those from developing nations that dream of a life at sea.

"There are so many talented women that just don't get a chance to establish themselves," she notes.

"The reasons behind that are complex and diverse. To start with seafaring is still not a typical career path for women and, in some countries, cultural taboos may act as hurdles to participation. Nationality can be an added issue, as shipping and crewing companies tend to recruit from favored regional talent pools. For example, in their study from 2021 the United Nations Conference on Trade and Development identified that four of five of the leading nations to provide seafarers and officers are in Asia, with the Philippines ranking first. So, if you're say, African, how do you get on board? There's an unspoken prejudice at work."

Hagerty adds that "sea time" is essential to obtaining a deck or engine officer license, meaning young women need to find ways of gaining experience if they're to stand a chance of building meaningful international careers.

Putting diversity centre stage – Captain Alexandra Hagerty is one of a tiny number of high profile female officers within the maritime industry.

“It’s tough to get those opportunities, especially if you’re from an underrepresented demographic,” she states. “That’s why they need a helping hand. And that’s why Captains Without Borders was born.”

The two percent problem

Captain Hagerty is one of a pitifully small number of high profile female officers within the industry. According to the International Maritime Organization, women still constitute only around two percent of the global maritime workforce – a figure that has failed to show significant development over the course of the last decade.

Hagerty is well aware of the obstacles, both cultural and historical, that limit participation, adding that the profession is demanding, can be intimidating (in terms of being ‘isolated’ at sea with mostly male crews) and has obvious implications for family life. However, she is also adamant that “it is a fantastic career path”, noting:

“I cannot think of another job that delivers this level of freedom and opportunity, with the ability to travel all over the world, on different vessels, having life-changing experiences. Yes, it is tough, requiring grit and integrity, but it’s also hugely rewarding.

And the camaraderie that quickly builds between crewmates is something special. I can't imagine getting close to that in an office environment."

According to Hagerty, one issue is that there isn't enough focus on such positives, discussing challenges by default.

"In that way we don't highlight the opportunities to young women out there – we don't show them that this is an excellent career path to consider. So, we need a 'marketing' change as well as a structural change within the industry."

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We have to build maritime as a viable option, for everyone.

Opening doors to diversity

But, adopting a role of devil's advocate, is diversity really so important when it comes to life at sea?

Hagerty, who started her own career sailing tall ships for France's Etoile Marine Cruises when she was just 18, looks justifiably amused by the question.

"Are you asking why does an international industry that keeps the global economy functioning, serves the whole world and impacts upon the environment need the broadest possible range of perspectives, talent and ambition to succeed?" She replies, pausing for the answer to be contemplated, before continuing: "The International Labor Organization has been quite clear that there is a shortage of seafarers and a real need to improve diversity within maritime – recruiting women is an obvious answer. We need to engage people from diverse backgrounds and socioeconomic classes to make this industry truly sustainable.

"But, as I mentioned, to do that we need to provide opportunity and guidance, showcasing role models to demonstrate the potential, as well as mentoring young talent. However, we need to open the doors first."

Hagerty's organization aims to do just that.

Proactive platform for change

Captains Without Borders was formed by Hagerty in 2021 as a direct response to the issues already detailed. The charity is focused on providing assistance for "disadvantaged female cadets" that need a helping hand to access the opportunity many of their male counterparts take for granted. (See Lulu Chilumo Mwangulu's story at the end of the article.)

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Caring for the future – Hagerty, seen here onboard the Africa Mercy (with a new addition to the crew), is focused on highlighting maritime as an exciting, viable and rewarding career choice.

CWB primarily comes to their aid by providing financial scholarships. These help fund deck and engine studies at accredited maritime universities, as cadets work towards unlimited tonnage licenses and their first officer positions. In addition, CWB, through its developing global network, works to secure vital experience for its scholars on working vessels.

Initially this is being done in conjunction with medical charity Mercy Ships, with CWB covering the costs involved in volunteering onboard one of the organization's advanced hospital ships.

"This is something I have done myself," Hagerty says, explaining that she recently captained the 152-meter long, 4,150-deadweight tonnage (DWT) Africa Mercy vessel, sailing to the aid of communities in sub-Saharan Africa, which otherwise don't have access to modern medical amenities. "It's a fantastic experience and a win-win for cadets, allowing them to gain invaluable experience while contributing to an incredible cause. We're proud to partner with Mercy Ships."

But, she stresses, this is just the start.

Partnering for progress

Hagerty, who also works as an 'expert maritime witness' for a number of law firms, is looking to build CWB's, and her own, networks so the charity can work in closer partnership with shipping firms and other industry stakeholders.

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Real change only works when people do it together.

"Shipping has an obvious challenge here and we'd like to play our part in finding a solution, but we can't do it alone," Hagerty comments.

"We need partners from shipping companies to help train and mentor cadets onboard their vessels. This would be a gamechanger in terms of giving them their first step up the career ladder. We also need donations from forward thinking companies and stakeholders who want to actively support a progressive cause and increase diversity within maritime."

Get onboard

Hagerty stresses CWB is about more than seeing a few new faces come onboard, it's about fairness, equality, talent-acquisition and a sustainable future for our industry. "Who wouldn't want to play a part in that? So, please, get in touch if you think you can help."

Many already have, she adds, with a “first rate” team and board in place at CWB, a good group of volunteers and a new partnership recently signed with international maritime and ocean industries exhibition Nor-Shipping.

“This is both a sign that we’re being taken seriously, and a unique opportunity to take a global industry platform and connect with decision makers,” she says, concluding:

“Great social enterprises only ever work when there’s a groundswell of support behind them… and I think we’re building that. At the end of the day you can give opportunities to those with potential by partnering with us, volunteering or donating. We’d love you to get onboard and be the change this industry needs.” •

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ABB technology enables world’s largest civilian hospital ship to access even the most challenging harbors

Full steam ahead for Mwangulu

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Lulu Chilumo Mwangulu

Lulu Chilumo Mwangulu of Kenya is the personification of shipping’s potential/opportunity challenge. An academic high-achiever within her local schooling system, Mwangulu set her sights early on a career within the maritime industry.

Her talent saw her achieve scholarships to, amongst others, Ecole Centrales University in France, where she was accepted to study Marine Engineering. However, her family was unable to come up the required funds to meet their portion of the scholarships. Refusing to be blown off course, Mwangulu raised the funds to study the same discipline in Kenya, successfully achieving her Masters degree. She is now serving on local marine traffic, with the ultimate dream of crewing icebreakers in the Arctic and, one day, designing zero-emission icebreaking ships.

Captains Without Borders is hoping to help this future maritime star, working to establish a network of mentors, while awarding her a scholarship to continue her education and training.

ABB's Onboard DC Grid™ continues to set the standard in vessel electrification – 10 years after first installation

Ten years on from its first installation, Onboard DC Grid™ has established itself as a staple in multiple vessel segments, justifying ABB's decision to invest in DC as the backbone for the ships of the future.

With the groundbreaking first installation of Onboard DC Grid™ in 2013, ABB became the first company to deliver a direct current (DC)-based onboard power system to an oceangoing vessel. The decision to invest in DC had been motivated by a desire not only to unlock new efficiencies for contemporary ship operations but also to future-proof vessels for the advanced, environmentally-friendly energy sources of tomorrow.

From the beginning, we have listened to our customers about their needs.

"Direct current is the common denominator between many of the systems on board vessels, so the fundamental concept was to simplify the power setup by reducing the need for components like transformers and switchboards," explains John Olav Lindtjørn, Head of Product & Portfolio Management, Electric Solutions, ABB Marine & Ports. "But we were also aware of DC's role in the electrification of transport and saw that by investing in it as the backbone for emerging technologies like batteries, fuel cells and variable speed generators, we would be serving the ships of the future, too."

DC allows a leaner power system design than AC, unlocking considerable benefits. With fewer components, integration and maintenance are relatively simple and cost-effective, while fewer conversions mean the power train is more efficient, in turn reducing fuel consumption and emissions. Meanwhile, the

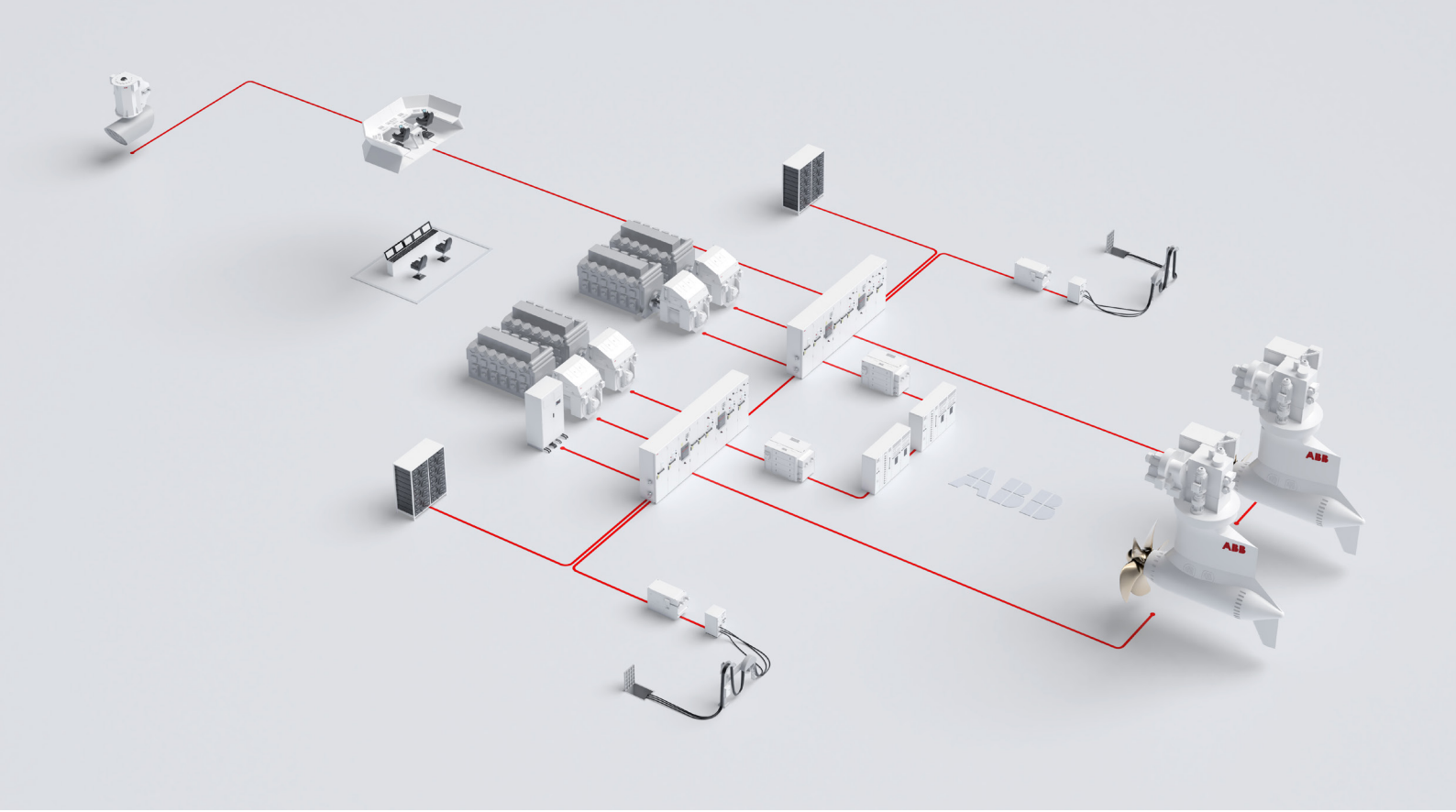

Illustration of battery-hybrid power train based on Onboard DC Grid™

smaller footprint minimizes weight and leaves more space for cargo, passengers and additional equipment and systems.

Onboard DC Grid™ initially targeted the offshore market, where its high fault tolerance and enabling of variable speed diesel engines were particularly valuable. However, also operators from other segments soon came to recognize the advantages of installing a DC-based power system onboard, this time driven by the simplicity of integrating batteries. The passenger segment became the largest market for the solution, which has played a pivotal role in enabling hybrid- and all-electric ferry operations. Yet Onboard DC Grid™ has since found a ready audience among most of ABB's served segments – from towage and fishing to research and naval.

The keys to this success, according to Lindtjørn, have been persistence, belief in the product and humility. "From the beginning, we have listened to our customers about their needs, constantly asking them and ourselves whether we are solving their problems in the most effective way," he says. "It's about staying relevant – not just focusing on the here and now but looking to and beyond the horizon to ensure that we're ready to meet new demands as soon as they emerge. Take fuel cells, for example. Already at a very early stage, we were discussing how fuel cells could be integrated into the power system, so when the market started asking the same question, we were ready to respond."

Lindtjørn also points to a modular development approach that allows ABB to expand its portfolio as requirements evolve and offer customers the flexibility to adopt new energy sources when the time is right.

“There have been a lot of discussions around hydrogen, fuel cells and fuels of the future, and it’s not always clear-cut to make the right decisions today,” he explains. “With Onboard DC Grid™, our customers have a modular system platform that allows them to pivot later on – whether that’s because it turns out the needs have changed since the first installation or simply because new opportunities have emerged. Onboard DC Grid™ is really a vehicle for meeting environmental goals in the long run – for us, for our customers and for the wider maritime industry.”

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It’s about staying relevant – not just focusing on the here and now.

Moving forward, Onboard DC Grid™ will serve increasingly advanced applications at higher powers, offering greater protection through closed-bus operation in the most demanding situations. It will also cater to lower powers, with user interfaces, footprints and delivery mechanisms geared towards smaller vessels and loads. Moreover, with DC providing the ideal platform for digital solutions, ABB is integrating Onboard DC Grid™ more closely with cutting-edge technologies such as advisory functions.

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NKT Victoria

For all its development in recent years, Onboard DC Grid™ remains fundamentally the same product that was first installed on board multipurpose offshore vessel Dina Star in 2013. “Part of the beauty of Onboard DC Grid™ is how little the original idea has changed over the years,” reflects Lindtjørn. “Although it has certainly evolved, and its market reach has grown significantly, the core product is still very much recognizable from its original form. This shows the strength of the concept and justifies our decision to invest in DC as the backbone for the ships of the future.” •

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John Olav Lindtjorn, Head of Product & Portfolio Management, Electric Solutions, ABB Marine & Ports

Turning the tide of marine pollution

Tackling maritime emissions encompasses more than just attempting to keep the air clean and the sky blue – we also need to address what hits the water. Water management specialist RWO discusses the pressing issue of toxic wastewater and sewage, looking at what can be done to safeguard fragile marine ecosystems and enhance the industry's environmental standing.

Emissions to air have, quite rightly, garnered attention from a broad range of stakeholders within industry and society, leading to stringent regulations and ambitious environmental targets. However, Lars Nupnau, Business Development Manager of leading marine water treatment company RWO, argues that waste emissions to water have largely floated by under the business, media and regulatory radars, failing to raise the concern they urgently deserve.

Effective policing of the oceans has so far been lacking.

No time to waste

"Smart and efficient water treatment onboard vessels is vital in curbing shipborne discharges of hazardous waste – waste that damages the marine environment in the same way emissions harm the atmosphere," says Nupnau.

He notes that individual shipping companies are waking up to this reality, particularly in the cruise segment, adopting new technology to safeguard the seas. However, Nupnau adds, more needs to be done on an industry-wide scale – and quickly:

"Global, regional and national regulation is necessary to drive wider investments in water treatment technology. Although the world is slowly moving towards tighter sustainability regulations and standards for water management, effective policing of the oceans has so far been lacking."

Special consideration
That's not to say that a regulatory regime is not in place, rather that more needs to be done.

Existing rules are built on the foundations of MARPOL, the International Convention for the Prevention of Pollution from Ships, adopted by the IMO in 1973, covering discharges of substances such as sewage, wastewater and oily water. This was updated with Annex IV, implemented in 2003, prohibiting discharges of sewage into the sea unless the ship has an approved sewage treatment plant in operation, or is discharging sewage that has been broken down and disinfected with an approved system at a set distance from the coast (more than three nautical miles).

In addition, in 2011 IMO's Marine Environment Protection Committee (MEPC) moved to protect the Baltic Sea. At this point it was designated a "Special Area" in which all sewage discharges from passenger ships are prohibited unless the vessel has a type-approved treatment plant that removes the nutrients nitrogen and phosphorous.

Disappointingly, for those such as Nupnau with a passion for clean seas, the Baltic Sea is currently the only Special Area named under Annex IV. On a brighter note, he adds, that doesn't mean the first is set to be the last, particularly given the growing environmental awareness of society at large.

"It is fair to assume that more areas will come under the regulations as public pressure to protect the world's oceans from pollutants continues to grow."

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Cruise companies are focusing more on their ESG image.

From pressure to profit
Customer-facing cruise companies, Nupnau says, are the first to react to that pressure, with increasingly environmentally conscious passengers creating momentum for change.

"Cruise companies are focusing more on their ESG image and are keen to advertise their low environmental footprint as sustainability becomes an increasingly important commercial factor," Nupnau explains. "Therefore, these companies are looking to invest in advanced water treatment technology, as it gives them a market advantage that can translate into increased profitability, while also putting them ahead of possible regulatory change."

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Lars Nupnau,
Business
Development
Manager, RWO

This applies not only to sewage treatment, but also areas such as water recycling, bilge water treatment with oily water separation, and ballast water management.

Nupnau, whose company works with everything from solutions for producing drinking or technical water to technology handling wastewater streams, notes that innovation is now accelerating within the segment. This is leading to advances such as game-changing membrane technology capable of removing over 99.9 percent of solids, including microplastics and viruses, to enhance water purity and prevent diseases.

Transforming technology

Last year RWO launched a new-generation wastewater treatment system – its CleanSewage Membrane Bioreactor (CS-MBR), a sustainable biological treatment technology designed to minimize a vessel's environmental impact.

The CS-MBR uses a three-stage treatment process that entails solids being removed from wastewater during mechanical pre-treatment, followed by a high-performance activated sludge process for biological degradation of pollutants, and separation of treated water from the sludge using a submerged membrane. This results in water that is completely free of solids and pure enough to be used for functions such as laundry.

The type-approved system has already been installed on the two cruise ships – the Celebrity Silhouette and Celebrity Reflection – with a further three Celebrity vessels due to be upgraded this year.

— CleanSewage Membrane Bioreactor dosing station installed on one of the Celebrity cruise ships

Nupnau says all water treatment technology needs to be “future-proofed” so that control software can be easily tweaked to comply with any upcoming, stricter standards.

For example, the area of oily water separation is subject to tighter regulation now, due to strict Port State Control (PSC) regimes, ie, the inspection of foreign ships in national ports. Incidents of oil pollution are often met by heavy penalties, such as multi-million-dollar fines or even imprisonment.

Technology has advanced together with regulatory pressure, new solutions now enabling remote monitoring of oily water separators, as well as sewage treatment plants. This facilitates earlier intervention to mitigate the pollution risk, says Nupnau.

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IMO legislation is moving slowly due to the multiple parties involved.

In it to twin it

RWO, in partnership with TUI Cruises and Leibniz University Hannover, is currently participating in the cross-industry Online Modelling, Simulation and Remote Control System for Environmental Technologies on-board (Cruise) Ships research project, known as OSCAR. Funded by the German government, the project focuses on designing a tool that enables ship management companies to simulate the advanced water treatment systems of a cruise ship onshore, utilising data from the vessel to support crew and provide guidance where required.

Nupnau points out that such technology initiatives are driven largely by commercial factors, as there needs to be a financial incentive to invest in measures for higher standards that also incur higher operating costs.

He concludes: “Some countries, for example Norway, are pushing for stronger regulatory enforcement in areas such as sewage management. However, IMO legislation is moving slowly due to the multiple parties involved. Only when there is joint, global regulatory action across the shipping industry will we see the wider application of water management technology to protect our oceans.” •

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Prevention of Pollution by Sewage from Ships

Q2/2023

Easier container flow for Rio Grande

Located in Brazil's southernmost seaport, Rio Grande Container Terminal has repeatedly demonstrated a forward-looking approach to technology since opening its gates in 1997. Known as Tecon Rio Grande, the operation has earned a reputation as a high-productivity facility connected by water, road and rail, with a capacity of 1.42 million TEU.

The first terminal in Brazil to invest in both a state-of-the-art operations management system (from Navis, in 1999) and a B2B portal for the port community stakeholders (in 2000), Tecon Rio Grande was also an early mover in deploying gate automation using advanced Optical Character Recognition for gatehouse operations (from ABB, in 2013).

Tecon Rio Grande Operations Director, Giovanni Phonlor, described the facility as "the most automated terminal in the country", adding that its willingness to innovate is wholly consistent with the ethos of parent company Wilson Sons – Brazil's largest integrated port and maritime logistics operator. Wilson Sons sponsors the Cubo Itaú innovation hub and is an investor in notable start-ups, including DockTech (a developer of seabed scanner for ports) Argonáutica (a dynamic draft tool for ship berthing/loading) and AIDrivers (adapting conventional vehicles to autonomous operations).

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We are a long-established user of ABB gate automation technology, and the system has proved highly accurate and very intuitive.

In early 2024, Tecon Rio Grande will sustain its 'first to market' reputation, after choosing ABB ahead of five competitors to become an early adopter of Optical Character Recognition (OCR) for quay crane operations and to become the first in the country to integrate QuayPro digitalised container stowage confirmation into its operations.

The Rio Grande Container Terminal is located in Brazil's southernmost seaport and has a capacity of 1.42 million TEU.

Phonlor stressed that return on investment has been the key driver for innovation throughout Tecon Rio Grande's 26-year history. "We operate in a tough market here and we don't have the luxury of the container numbers that the biggest container terminals work with to secure straightforward scale economies: we need to capture every available efficiency gain that new technology can bring us," he said.

Data capture

Accuracy in data capture and exchange has proved an especially fertile area for ROI. For example, the initial impetus to introduce OCR at the gatehouse in 2013 came from mandatory customs requirements, Phonlor explained, but Tecon Rio Grande took the opportunity to invest in ABB's state-of-the-art OCR to secure efficiency gains as well as compliance. By 2014, it had put in place a gate automation solution that featured biometric recognition for drivers, automatic weighing, and automated slot allocation via ticket printing.

"Our starting point was that each truck entering the port took roughly three minutes to deal with on a manual basis," said Phonlor. "Using OCR and the other gate automation technologies, the entire process can be accomplished in 15-20 seconds, on average."

Further upgrades to operations have included implementation of NAVIS N4 terminal software (2017) and an update to gatehouse hardware and software from ABB (2022). The latter consolidated a relationship which has led on to the upcoming adoption of Crane OCR and QuayPro, which both ABB and Tecon Rio Grande expect will bring a step change for productivity.

“We are a long-established user of ABB gate automation technology, and the system has proved highly accurate and very intuitive, with ABB also providing best-in-class support services in my opinion,” said Phonlor. “In considering Crane OCR, we surveyed what was available in the market and concluded that ABB had the solution that best meets our needs.”

KPIs and QuayPro

Installed across five ship-to-shore cranes, ABB Crane OCR automates data capture as containers are exchanged at the quay crane. Using ABB’s advanced AI imaging technology, the system captures container numbers, ISO codes, door orientation, bolt seal presence and hazardous material labels, as well as

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With Crane OCR the Rio Grande Container Terminal envision effects on crane operations at the quayside that will echo achievements with Gate OCR, used since 2014.

recording images for damage inspection purposes. The solution includes ABB MatchMaker™ which identifies the terminal trucks and enables automated handoff between cranes and terminal vehicles.

Crane OCR minimises the risk for human error in the handling operation. “Multiply the potential for keying errors, misunderstandings, inattention or even fatigue by thousands of containers a day, and the time and accuracy saved can add up to a significant efficiency gain,” said Phonlor. Web-based exception management software (XClerk) also means terminal staff can correct or adjust transactions in real time from a safe remote location.

However, ‘game-changing’ efficiency wins will come about as a result of ABB’s QuayPro module, Phonlor added, which extends the reach of the gains available to accurate data over the quayside and into the hold of the vessel itself. Where Crane OCR captures container data automatically, the QuayPro module automatically confirms that the load is being stowed in the right bay on the ship, with ‘CabView’ modules providing visual and audio job instructions to crane drivers.

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In considering Crane OCR, we surveyed what was available in the market and concluded that ABB had the solution that best meets our needs.

Real-time stowage planning

In addition, QuayPro can also adapt on-the-fly to events which change the loading sequence. Instead of requiring human intervention – and a chain of inquiries and instructions – QuayPro uses business logic to assess the impact of the change on the stowage plan and automatically generates the new loading instruction for safe stowage. In the same way, for discharge, the combination of QuayPro and Crane OCR confirms the accuracy of the inbound stow positions as reported to the terminal via BAPLIE EDI and highlights any deviations from the bay plan in near real-time so that yard equipment logistics can adjust.

The first solution of its kind to go live in the industry, ABB’s QuayPro application made its market debut in 2022 at the Exolgan Container Terminal, at the Port of Buenos Aires.

“Together, ABB Crane OCR and QuayPro will allow us to streamline the stowage process automatically, and we expect this to be a productivity differentiator,” said Phonlor. The ability to adapt to changing loading and discharge needs on-the-fly, will also have the effect of reducing terminal vehicle dwell time and related emissions, he observed.

Over the coming months, ABB will project manage installation, software implementation and commissioning of a new handling solution which both the supplier and Tecon Rio Grande view as more than an extension of Crane OCR. Phonlor expects that, drawing on Tecon Rio Grande's own breadth of expertise in IT, the combination of QuayPro and Crane OCR will seamlessly change the way container terminals operate.

"We can see that Crane OCR is going to have an immediate effect on crane operations at the quayside that will echo what we achieved with Gate OCR, but QuayPro's ability to adjust on-the-fly is a next level development," he said. "We also look forward to using this dynamic software to analyze our operations in new ways and to applying logic swaps with our TOS (terminal operations software) that will help us improve vessel planning." •

Kiosks featuring biometric recognition for drivers increase security and improve efficiency at gate entry.

Richard Micheli, Product Line Manager, OCR, ABB Ports

About the author

Richard Micheli is Product Line Manager, OCR, ABB Ports. He has extensive experience on OCR and container terminal automation through prior positions in ABB and APS Technology Group as director of Service and Operations, and in project management. Micheli holds a Bachelor's degree in Electronics Engineering from ITT Technical Institute, San Diego.

About Wilson Sons

Wilson Sons is the largest integrated port-shipping logistics operator in Brazil, with over 185 years of experience. The company operates across Brazil and offers complete solutions to more than 5,000 clients, including shipowners, importers and exporters, offshore energy industry, renewable energy projects, agribusiness corporations, and other players in different businesses.
Learn more at: www.wilsonsons.com.br/en

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Solutions for ports and cargo terminals

Crane OCR

QuayPro

Gate automation

ForSea sets the pace as decarbonization pioneer

Sweden's ForSea is the largest high-frequency RoPax ferry line in the world utilizing electric power to gain major emissions reductions and other environmental and operational benefits. Henrik Fald Hansen, Senior Chief Engineer on the Tycho Brahe and Christian Andersson, Senior Chief Engineer on the Aurora, describe the core business considerations behind the switch to battery propulsion, excellent collaboration with technical solution provider ABB Marine & Ports, and how the ships have been making a big splash in the market.

The Tycho Brahe and Aurora, originally built in 1991 and 1992, respectively, are a familiar sight on the four-kilometer-wide Øresund Channel separating Denmark and Sweden, serving as a 'floating bridge' between Helsingør and Helsinborg. Each perform close to 46 trips daily carrying more than seven million passengers and 1.9 million vehicles every year. "The ships sail mainly manually and no trip is the same in the heavily trafficked waterway, in fair weather and foul," says Fald Hansen.

Relying on the technology expertise of ABB Marine & Ports, the two sister ships underwent a comprehensive rebuild and conversion from marine diesel to electric power four years ago. The scope of the work included the installation of 4,160 kWh battery packs, ABB's award-winning Onboard DC Grid™ power distribution system, as well as energy storage control systems and a state-of-the-art shore-side charging solution. The vessels were officially inaugurated in November 2018.

Main motivators driving electrification

Fald Hansen explains that back in 2015 when ForSea first considered electrifying the ferries, the main economic driver behind their investment decision was to find savings at a time of soaring fuel prices. At same time, the company wanted to promote green values, reducing emissions above and beyond national climate goals.

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Aurora at Helsingborg

“We have worked for years on sustainability improvements, switching to low-sulphur marine diesel oil (MDO) and installing catalytic cleaning on all our vessels in 2006, which was always a red line for us as we sail in and out of city centres. The municipalities certainly encouraged us to become more climate-friendly, but it hasn’t been regulations driving us; we have led the way. We installed the catalytic converters voluntarily at very little cost as we were able to negotiate lower harbor taxes. As we are a very visible transport link in the Øresund region, with many people commuting every day to Denmark, the improvements boosted our positive perception among the public.”

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We have worked for years on sustainability improvements.

Another important consideration was ensuring the local grid power provider would be able to supply energy and collaborate on the necessary infrastructure on shore. Only green renewable energy (with the highest classification) is used for charging the ships’ batteries.

Benefits for shipowner, passengers, local citizens, and sea life

Since the vessels began battery-powered operations, ForSea has achieved a CO2 reduction of over 37,000 tons, equal to total emissions by all four ferries on the route during one year of diesel operation. Following the Tycho Brahe upgrade (see below), in full electric mode both that vessel and the Aurora are expected to reduce CO2 by 65 percent compared to the base year of 2016, and very close to the 70 percent target set by the Danish Government, to be completed by 2030.

Electrical power substantially reduces noise and vibrations, benefiting passengers, local citizens and sea life. Recent studies indicate that fish stocks in the local area are rising, notably cod and tuna. “Tuna had disappeared from this area for the last 40 years, but they seem to be back since last year. Now there are even local operators doing tuna safaris. Historically the area around Gileleje was big in fishing so we hope we can contribute to a better future for local communities. Air pollution has also been reduced in Helsingborg after we started with electric operations,” says Andersson.

On the operational level, electric sailing has massively improved the onboard working environment. “While previously we were used to a lot of decibels, now the engine rooms are quiet and more pleasant versus the mechanical past. Where we had separators, which required a lot of protective gear to clean because of the dirt and cancer risk, now we only have filter units. Being a first mover and having all this data-driven high-tech equipment and the DC system is also really nice. It’s a different mindset and makes it much easier to recruit young men and women to work on our ships,” says Fald Hansen.

An additional unexpected benefit, according to one of the ship’s captains, was that replacing what would have been tonnes of marine diesel oil (MDO) in the bottom tanks with the addition of 200 tonnes of topside equipment has led to improved stability.

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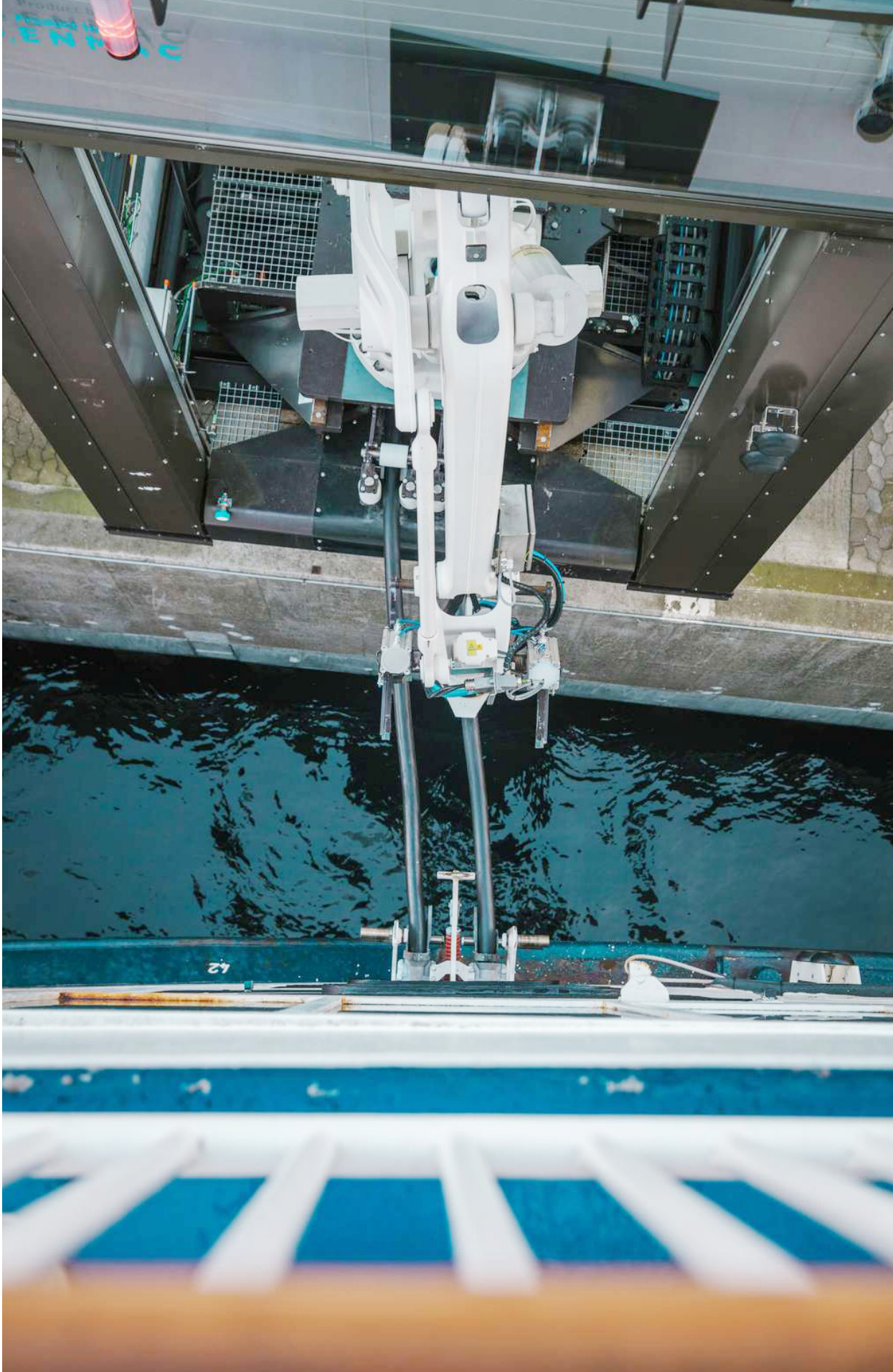
The improvements boosted our positive perception among the public.

Shoreside innovation

The batteries onboard Tycho Brahe and Aurora are charged typically for a period of six to nine minutes on both sides of the channel, using four advanced charging robots mounted on mobile ‘sledges’. The robots pull into and connect to the vessels automatically using machine vision technology. Each approximately 20-minute one-way trip uses 20-25 percent of battery capacity, sailing at a speed of 10.5 knots to maintain schedule. Just Aurora has executed upwards of



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Robot charging solution in Helsingborg

50,000 connections, which no electric ferry in the world comes even close to. The success rate is more than 95 percent including weather-related issues and human-related faults/disconnections.

“It is ideal to charge the batteries to 83 percent of capacity. If something goes wrong with charging on one side, there is still enough energy to get back to the other side. For safety, the diesel motors will start automatically as soon as battery capacity falls below 30 percent,” adds Fald Hansen.

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We hope we can contribute to a better future for local communities.

Tycho Brahe undergoes major upgrade

Due to various technical problems, it was decided in early 2021 to upgrade the Tycho Brahe with a new battery pack, increasing capacity by 50 percent from 4,160 kWh (4.16 MWh) to 6,400 kWh and doubling its lifetime from five to an expected 10 years. “Tycho Brahe was converted first so we learned many lessons from what was essentially a pilot project. Those learnings we brought forward to Aurora. The new system gained classed approval from Lloyd’s Register (LR) in what was a truly collaborative endeavor. Class also learned a lot during the process,” says Sami Lehikoinen, Head of Marine Services at ABB Marine & Ports.

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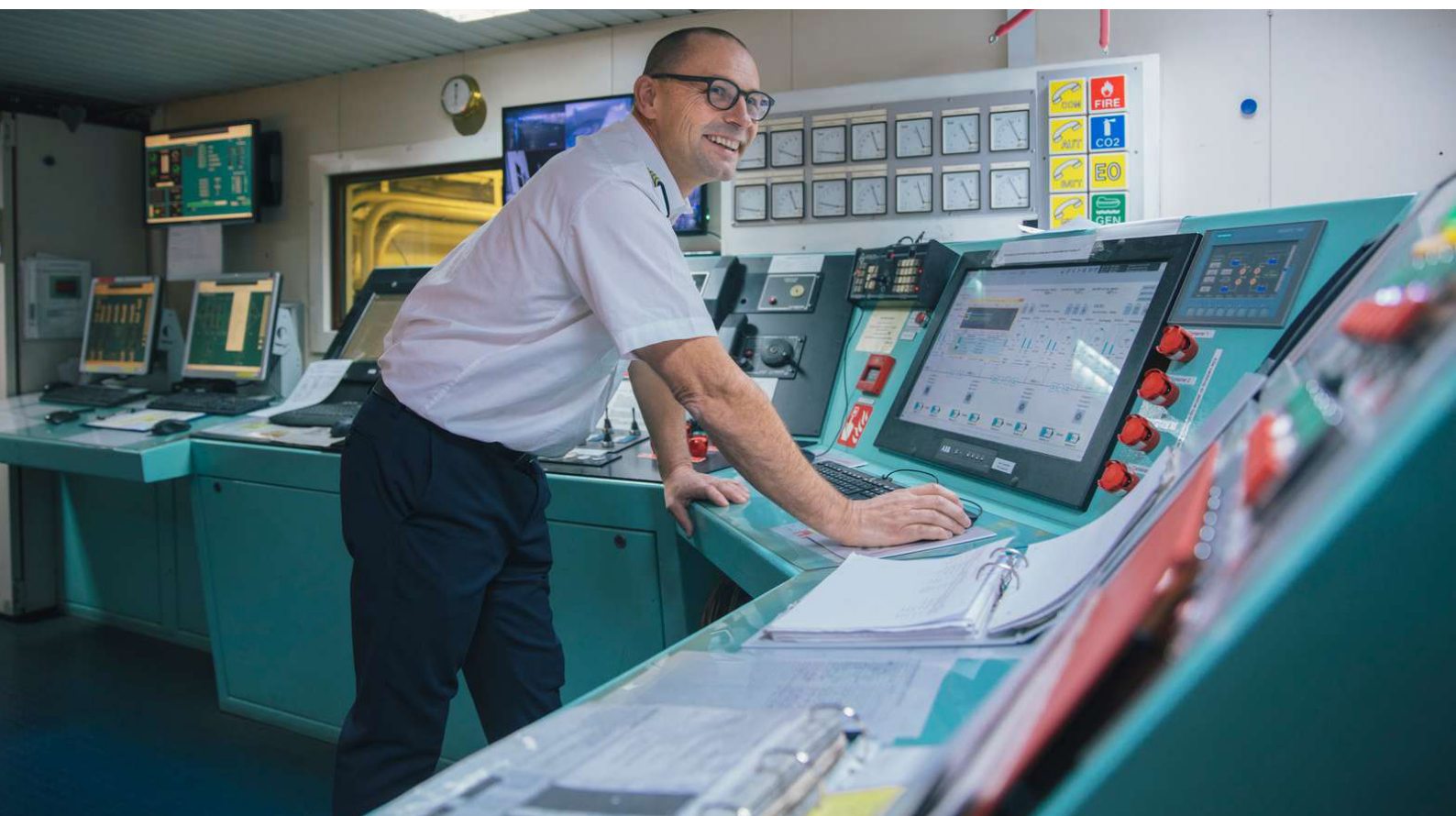
Henrik Fald Hansen, Senior Chief Engineer, Tycho Brahe



Housed on deck without wasting space inside the vessel, the battery pack is the largest with the highest capacity installed on any ferry worldwide. The complete energy storage solution comprises four ABB e-House containers, two housing the Corvus batteries and two housing electrical equipment, drives and cooling equipment. Although most heavy metal work was executed at Oresund DryDocks in Landskrona, a lot of follow-up work, including fastenings, was performed while the ferry was in operation to minimize disruption to ForSea's high-frequency schedule.

The upgrade was a turnkey agreement with ABB. "That made their offering unique and was a big benefit. Having only one company to work with and one point of contact made it very easy for us," says Fald Hansen. Tycho Brahe returned to full electrical sailing in October 2022.

Collaboration is everything

Cooperating with ABB during the conversions and the upgrade was a "fantastic journey as a first-mover project", says Fald Hansen. "ABB supplied at a high level and we've met many skilled and inspiring people. The installation was very professional in terms of equipment, table works, drawings, cable markings, and all the other high-quality details. When we put the new system into operation it was really easy to use the electrical drawings to fix issues. We learned a lot with ABB from the start on how to operate with batteries, and also about collaborating with class societies. The risk assessment was excellent."

Regarding the charging solution, Andersson says it is no secret there were some hiccups at the outset. "The main issue was with the charging tower connections. We started with a wireless link but that proved unstable and was replaced with a radio link. The scanner used to calculate movements of the vessels was first just 3D and it took a year to correct this using 3D laser machine vision instead.

—
Aurora

A particular challenge was coping with the angle of sun at certain times of day, which required extensive testing. Again, as a first mover we had to gradually learn the system's DNA and how to maintain and improve it. It meant a lot of work for ABB and the crews understanding the issues and taking plenty of notes."

"We learned from ForSea that they really appreciated our can-do attitude and that we were always there for them bringing our expertise to overcome challenges – large and small. Together we proved that, yes, this can be done. Many companies boast that they are planning these kinds of complex projects, but we actually did it," says Lehikoinen.

Positive feedback

Both Fald Hansen and Andersson stress the market reaction to electrification has been fantastic. "It's been a great journey to be part of. We have had many US visitors from shipowners, ports and transport departments in New York, Washington and the West Coast, as well as delegations from Brussels, European countries, Singapore, Japan and even South America. Christian and I have shown around 4,000 people around the ships – there is so much curiosity," says Andersson. "We certainly hope more shipowners will take the same course, especially in shortsea shipping. Our message is: Go for it. The world needs it."

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Battery racks

Christian Andersson, Senior Chief Engineer, Aurora

Andersson says port operators are especially interested in how ForSea handled the charging solution, given that many are facing logistics challenges as alternative new fuels including batteries, hydrogen, ammonia and methanol become available. “There’s also interest in how the charging system could be adapted for cruise ships,” Andersson adds.

Our message is: Go for it. The world needs it.

Passengers on side

Many customers want to go down to the engine room, youngsters especially, to see for themselves how it all works. They are also keen on the possibility of charging electric vehicles onboard. ForSea is currently working on a pilot project that should be finalized by June. “We are already plugging in refrigerated trucks and now working on installing eight car charging points on each ship for a trial period. The biggest challenge is cable management,” Andersson says.

The plan is also to upgrade the battery pack on the Aurora in 2024 and to convert the sister vessel Hamlet to battery-electric operations by 2025. “Our realistic ambition is to be one of the most sustainable ferry companies in the world and by the end of this decade we should be running all our ships with zero CO2 emissions.

In September 2023 ForSea Ferries was rebranded as Øresundslinjen.

Both chief engineers say being a first mover is no easy ride, but a very rewarding one. “It took a lot of hands-on effort. Henrik and I have put four years of our lives into this, and we’re very proud to have achieved it. We have tremendously enjoyed the outcome!” •

Centralized fleet support

Where digitalization and sustainability meet

Shipowners and operators are looking to leverage the power of data to enhance operational performance across multiple vessels. Leading industry experts from ABB, Wallenius Marine, Carnival Corporation and the fleet support center OVERSEA share their insights into what will be a key enabler of efficient shipping in the future.

Osku Kälkäjä, Head of Digital Business at ABB Marine & Ports

At a time of increasingly strict regulations and climate challenges, many shipping companies are currently dealing with digitalization processes to better understand how individual ships are performing, the differences between them, and applying the learnings across fleets. The end game is securing long-term sustainability in terms of improved energy efficiency and emissions reductions, operational savings, and business success.

Companies don't need to load up on tools; what they need instead is support in how to leverage them to improve performance.

Digitalization and the knowledge gap

The industry is now flooded with enterprise management tools targeting different shore roles within shipping companies as well as digital applications at the disposal of masters and crew. Early adopters were big companies wanting to gain competitive benefits while also addressing the climate crisis. "It is important that everyone, no matter their size or competence, has digital initiatives going forward. If you miss the train, you will get nowhere," says Osku Kälkäjä, Head of Digital Business at ABB Marine & Ports.

Johan Mattsson, CEO of Wallenius Marine

Johan Mattsson, CEO of Wallenius Marine, adds that given the conservative nature of shipping, implementing digital systems requires a new mindset. "A certain amount of caution is good as costs are high. Technology development is rapid but there is an urgent need for harmonized standards and better

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Andrew Paul, Senior Director Maritime Innovation at Carnival Corporation

understanding of what digital tools and data can achieve. Proper training on new systems is also crucial to realize return on investment."

The pace of change in the global maritime segment can be a barrier to introducing sustainable practices worldwide, notes Andrew Paul, Senior Director Maritime Innovation at Carnival Corporation. "The industry must continue to progress its sustainability efforts as rapidly as possible. We are making huge strides towards 2050 goals, but there still needs to be masses of more investment in technology and operational compliance."

His top tips for companies in the early stages of digitalization is to get key personnel engaged as soon as possible. "Top down doesn't work well and can create conflict between shore and vessel teams. Secondly, define clear incremental steps. In Carnival Corporation's experience we needed to break out comparable ship classes and normalize for different theaters of operation. Step back from the big picture, separate out best practices and go from there."

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Niklas Sundén, Commercial Manager at fleet support center OVERSEA

In many cases digital tools are not being used to their full potential simply because users don't have the necessary competence. "Knowledge barriers might be the biggest challenge shipping companies face today – more competence is needed to translate the data generated by these tools into action. Companies don't need to load up on tools; what they need instead is support in how to leverage them to improve performance," says Kälkäjä.

What centralization offers in a fast-changing world

The solution is to adopt a centralized way of working. “Centralization has all sorts of negative connotations but for shipping it is only positive. The benefits for marine operations are concentrating expertise and experience under one roof,” Kälkäjä points out.

Some large companies with large fleets have the resources to do this in-house but for smaller owners and operators it is beyond the scope. The big benefit of using ABB’s network of Collaborative Operations Centers is that everyone receives the same level of expertise and competent advice.

“The staff members of our Collaborative Operations Centers are former captains, chief mates and marine engineers with on-board commissioning and service experience, so customer crews can trust they know what they’re talking about,” says Kälkäjä. “The other major benefit is having a common support system across all vessels. There is no need to invent anything new for each vessel because ship operators can use data that’s already been analyzed. They can unlock the value of the fleetwide data to compare vessel performance, identify specific areas of improvement and advise crews accordingly.”

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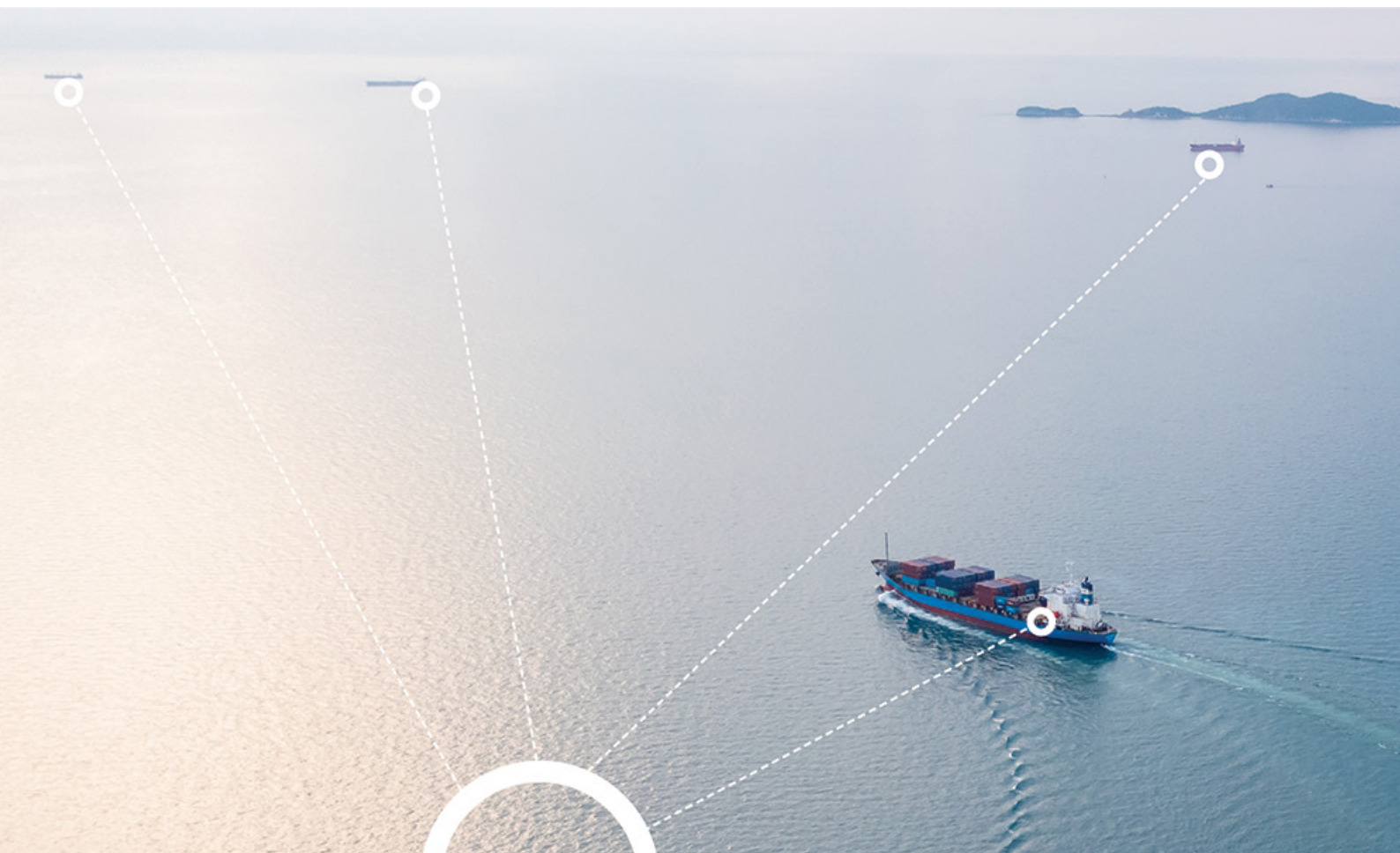
ABB and Wallenius Marine introduce pioneering digital offering OVERSEA



Getting the best out of the data

However, Kälkäjä points out it is not just a matter of installing sensors onboard ships and starting to collect the data, and then, hey presto, every ship starts performing better and saving money. “The first challenge is deciding how and what data to harvest and then how to utilize it both on board and on shore. When it comes to comparing different types of data and performance parameters, there are multiple variants and data needs to be combined to generate the best possible outcome. This requires knowledge of both vessel and fleet operations and management alongside specialized IT competence.”

For Wallenius’ part, Mattsson says the company has been working on fleet management for the past 15 years. “Collecting, analyzing and putting data into action is by no means straightforward. Data handling needs to be synched and compared to get an accurate picture of what is happening onboard each vessel. This requires good teamwork, especially as captains have many other duties aside from optimizing performance for the next days. Out at sea the conditions can be challenging. Computers can still do this also in severe weather, which is a big benefit of centralized support.”

Mattsson adds that a typical mid-size fleet benefits from the OVERSEA support both to collect the data and unlock critical information, as well as for training. “We need to be jack-of-all-trades, and gaining that level of insight and action is harder for smaller operators. The shore team is working in the background tracking the performance of each ship and recommending actions. That’s the essence of centralization.”

Speaking for Carnival Corporation, Andrew Paul says the company is now 10 years into its digitalization journey and was a pioneer in streaming data from its ships to its Fleet Operations Centers (FOC) in Hamburg and Miami. “But what to do with it all? Through trial and error, we learned how important it is to carefully identify your scope. We are now using data insights to work towards everything from more efficient voyage passage planning to compliance monitoring and embedding an excellence culture across the fleet. The Fleet Operations Centers, alongside fuel and energy data analysis teams, drive a very positive feedback loop.”

He adds that there is also an exciting evolution taking place as more technology vendors are beginning to work collaboratively on data sharing. “It can be challenging but in Carnival Corporation’s case it is hugely positive as it helps us to centralize data in one place and put it to work.”

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OVERSEA fleet support center as a service

What differentiates OVERSEA?
OVERSEA combines fleet management expertise with advanced analytics. It was specifically developed by ABB and Wallenius Marine to help shipping companies reduce emissions, choose better routes and perform more efficient maintenance.

“Most fleet management solutions claim similar values such as saving fuel, passage planning, condition monitoring of engines and environmental reporting. What differentiates us is our strong centralized philosophy and process-driven approach. Sure, you can buy niche applications for specific tasks but OVERSEA is a one-stop solution covering all key parameters. We also take data insight a step further, supporting customers with recommendations to ships until each performance issue is solved,” says Niklas Sundén, Commercial Manager at fleet support center OVERSEA.

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We have the knowledge. The challenge is to connect and transfer it seamlessly from office to vessel, no matter where you are.

The connectivity challenge
Meanwhile, Sundén points to connectivity issues that still need to be taken into consideration, not only in terms of speed but in remote locations where the capacity of satellite coverage may sometimes be lower. “We have the knowledge. The challenge is to connect and transfer it seamlessly from office to vessel, no matter where you are.”

Mattsson concurs that data speeds are still too slow and expensive. “But things are getting better as new satellite systems go live to keep ships continually connected and enabling more user-friendly live video communications.”

Better connectivity has provided shipping companies in segments like shortsea and coastal trades with a lower barrier to digitalization, Kälkäjä notes. However, in international trading with fragmented connectivity there is still great potential for centralized operations to generate significant savings.

In Carnival Corporation’s case, Paul says the company is already receiving 10 million data points from its fleet per day and “the sky is the limit going forward”.

Teamwork is everything
Paul says tackling the human factor issue of legitimate crew concerns against centralized support is quite straightforward. “If you implement a digitalization regime as an office-led silver bullet to improve fleet performance you’ll probably

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OVERSEA

run into problems. Providing comparative data with other ships in the fleet and evolving that into procedural upgrades will turn sea colleagues into internal advocates. Remember they are motivated by the same goals as shore personnel, to be profitable and successful, and are central to our ability to meet the industry's 2050 goals. If you do it right, you'll get tremendous uptake, especially with the upcoming digital-minded generation."

Kälkäjä agrees that collaboration is key. "Every instruction from shore should be backed by indicative data but there should always be a ''conversational' approach, as those on board might understand a particular issue better despite the data. Then those insights can be duplicated across the fleet."

Based on his experience of crew reactions to OVERSEA implementations, Sundén also ranks teamwork as a top priority. "Sea personnel are likely not to trust shore support given by experts without seagoing experience. That's why our digital fleet support is manned by former masters and chief engineers with the right knowledge base, similar to ABB's Collaborative Operations Centers. It's much easier to build a common understanding. Even the most experienced captains will accept recommendations from professionals who are their equal."

Choosing the right partner for centralized support
Paul advises shipping companies to look for willing partners who have already made investment in this space. Engaging multiple critical vendors that are not able to cooperate effectively can increase the risks for the end customer. “However, we are seeing a positive culture shift, such as common standards for data protocols and key touch points. From there, look at the vendors’ culture around data strategy and data virtualization. It is also that they can demonstrate a strong track record of operating to the highest standards of cyber security.”

Mattsson echoes this. “Examine performance track record. Do they have the required deep knowledge and a solution that is trusted in the market? Can they connect reliably to your systems and ships? If they can prove that, OK. Price is obviously an issue, of course, but as important is – like ABB and OVERSEA – do they have genuine interest and enthusiasm for what they’re doing? If they can prove that, go ahead and ask for a quote!”

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Going forward, the sky is the limit.

Successful digital transformation
Digital transformation does not happen overnight and is not a straightforward journey from A to B. It requires time, planning, experience and expertise. There is no one solution that fits all, but the requirements vary depending on the operations, current form and level of digital maturity, the aspiration of the customer, and the scale and scope of digitalizing operations. The key to success is understanding what is required in terms of resources.

Osku Kälkäjä sums up: “Collecting insights and turning these insights into actions plays a key role in accelerating digital transformation, improving operational efficiency, and driving growth in today’s rapidly evolving digital landscape.” •

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OVERSEA

Wallenius Marine

Digital services and solutions

Azipod® propulsion ticks all the boxes in the growing retrofit market

ABB's market leading Azipod® electric propulsion system has become a commercially attractive retrofit option for existing vessels as shipowners seek ways to comply with new emissions regulations.

Toni Roiha, Global Sales Manager, Marine Propulsion Services, ABB Marine & Ports

The International Maritime Organisation (IMO) introduced its new EEXI and CII regulations at the start of this year with the target of reducing greenhouse gas emissions from international shipping by 40 percent by 2030.

The new rules apply to all cargo, Ro-Pax and cruise vessels over 5,000 GT and include an annual emissions ratings system that will get increasingly stricter year-on-year. Many vessels across different classes will struggle to meet the increasingly tighter regulations.

In addition, poor CII emissions ratings for ships will likely have adverse effects for vessel operators as charterers and financiers will favour more sustainable vessels. Hence the regulation will serve to strengthen the green economy across all aspects of the industry.

There is a lot of potential.

Regeneration game

These changes have sparked a surge of inquiries from shipowners looking at ABB Azipod® electric propulsion as a potential cost-effective retrofitting solution to keep aging ships on the right side of compliance and to extend their lifespan.

"We have seen a rapid increase since the turn of the year in the number of inquiries for retrofits using our Azipod® propulsion system," says Toni Roiha, Global Sales Manager, Marine Propulsion Services, ABB Marine & Ports. "There have been more inquiries in the first couple of months of this year than in the whole of last year."

“There are plenty of vessels out there that could benefit from some kind of retrofit,” he adds. “Utilizing a hull that is still workable could add a further 10 to 20 years to a ship’s lifetime. There is a lot of potential.”

Jumping the queue

Shipyards have a long backlog of newbuilding projects, so retrofitting older vessels with a new propulsion system is a much quicker modernising solution than having to wait for a production slot for a new ship.

“There is a long wait for new ships, so more and more operators are looking to find other ways for their fleet to meet the new regulations,” says Roiha.

This jump in interest towards ABB’s services is also based on the long track record Azipod® propulsion has in the newbuild segment, where the system has delivered unparalleled efficiency, reliability and sustainability over 30 years. In total, ABB has sold more than 700 Azipod® units. Azipod® propulsion improves operating efficiency, boosting a ship’s hydrodynamic performance and cutting fuel consumption by up to 20 percent when compared with a traditional shaftline setup. In addition to improved maneuverability, vessels featuring Azipod® propulsion benefit from reduced noise and vibrations for greater passenger and crew comfort.

The simple and flexible structure of the Azipod® units allows optimized positioning of the propeller according to a ship's hull shape. Adjustable strut height of the underwater propulsion module allows using the best possible propeller diameter without a head box on the ship's hull and large tilting angles of the Azipod® units in both longitudinal and transversal direction. This enables locating the Azipod® units to undisturbed wake field, ie, water flow. The flexibility of the electric propulsion system gives ship designers more freedom as the hull shape, especially the skeg, can be designed based on hydrodynamical evaluation without the dimensional restrictions of a long, traditional shaft line. The propeller positioning and the hull form are always designed together with the shipyard or design offices. Additionally, the 360-degree directable thrust of the Azipod® propulsion units eliminates the need of stern tunnel thrusters, leading to more optimized hull shape and less hydrodynamic drag. Space saved by locating the motor outside the ship allows for more flexible design and frees up space for cabins, cargo or other features.

It is no wonder ship owners are now reviewing the potential for Azipod® propulsion as a retrofit solution when they are drawing up investment plans on how to modernize.

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We have seen a rapid increase since the turn of the year in the number of inquiries for retrofits using our Azipod® propulsion system.

Single point of contact

ABB's focus is to provide a one-stop shop for Azipod® propulsion retrofitting projects, handling everything from start to finish to make the process as smooth as possible for customers. The service covers all stages of a retrofit, from assessing whether a vessel is suitable, to the full design and installation phase, and then monitoring the units once in operation for maximum efficiency. Having a single point of contact saves time and money.

Each Azipod® system retrofit unit is made in the same ABB factories as the newbuild systems and has the same components. However, each retrofit takes on its own unique profile and design, depending on the dynamics of the ship's hull.

ABB is ideally placed to assess each project by working together with customer and shipyard teams. Not every ship has a suitable hull to accommodate a retrofit, but ABB's team seeks to identify any potential.

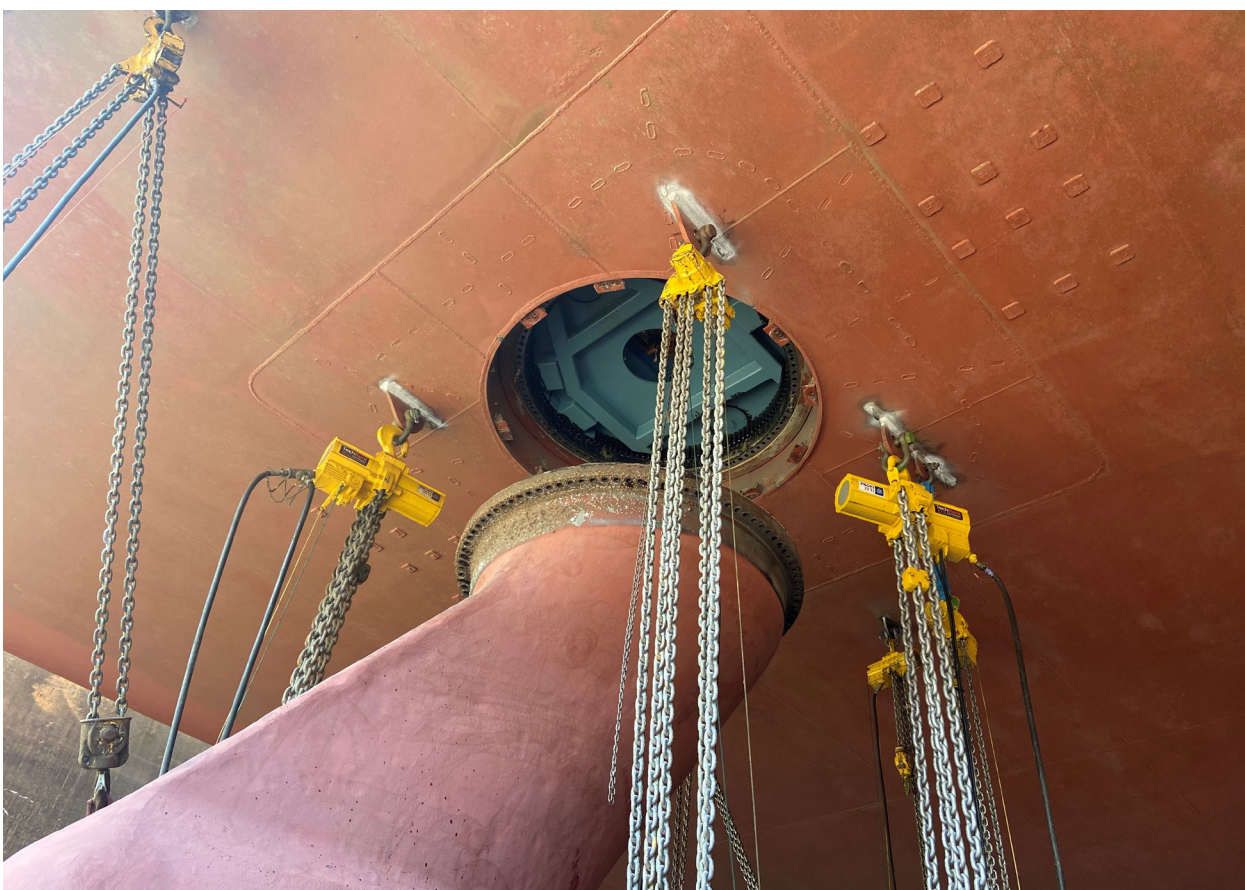
“We work with the customer’s teams so that we are able to find a solution that is easy to fit in and can improve value for the customer,” says Roiha. “We always do a design review with them. Our hydrodynamicists and naval architects work to find the most suitable Azipod® propulsion model, so customers can see an increase in avoided emissions and capital savings from using less fuel.”

At your service

The Azipod® propulsion system's high level of reliability and ease of access for maintenance are common themes across a wide range of vessel types. A further key benefit from getting an Azipod® system retrofit is each new customer will gain access to ABB Marine & Ports global service network. ABB Ability™ Collaborative Operations Centers around the world provide 24/7 support ensuring dedicated expertise and fast response times.

“We also provide comprehensive condition monitoring, so we can see what is happening in the units in real time when the vessel is in operation,” says Roiha. “We can plan for any maintenance with the operators, so that it matches their business needs.”

“It doesn’t matter if a customer is operating in the Pacific or Arctic or even going all the way to the North Pole or the other direction, we are at your service.” •



Rationale and technical development of the ABB Dynafin™ concept

Growing concern over climate change has sharply increased the demand for greener solutions in the global shipping industry to limit greenhouse gas (GHG) emissions. The International Maritime Organization (IMO) has issued resolutions to cut GHG emissions by 50 percent by 2050, compared to 2008 levels, however it will be challenging to achieve this target without major technological advances in fuel technology, adopting alternative energy sources such as batteries and fuel cells, and in propulsion technology.

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Jani Hakala, Product Manager, ABB Dynafin™, ABB Marine & Ports

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Veli-Pekka Peljo, Senior Project Manager, R&D, Marine Propulsion, ABB Marine & Ports

Because of these and other increasingly strict regulations, there will be a high demand for viable solutions that can significantly reduce emissions from vessels in the future. ABB Marine & Ports is committed to conceiving and delivering low-emission and energy-saving solutions to help solve this challenge. Our latest innovation is ABB Dynafin™ – a new, highly efficient cycloidal-type propulsor concept designed to meet the urgent demand for even higher efficiency and emission reduction requirements.

Today, almost all vessels still rely on screw propellers for propulsion, and even though there is still space for efficiency improvements in such systems, these are considered to be more or less incremental. In contrast, the new, fully electric ABB Dynafin™ concept has been developed to achieve very high propulsive efficiency, which will directly translate to lower fuel consumption and lower emissions.

In addition to high efficiency, the concept will enable superior vessel maneuverability. These two benefits can significantly lower operating expenses for vessel operators, as well as increase safety at sea. The concept also means that fuel consumption can be reduced regardless of the fuel type used.

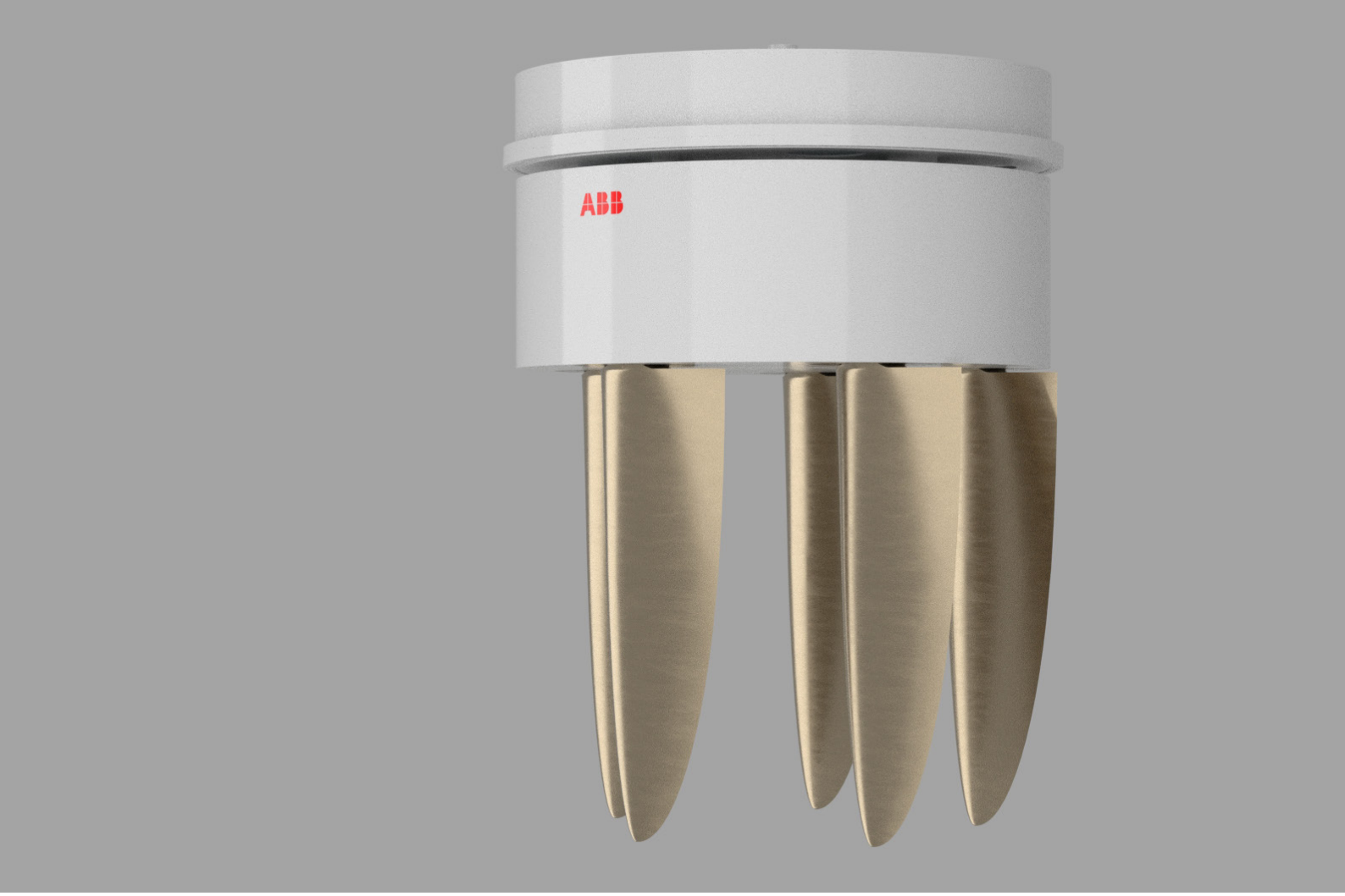

Figure 1:
Illustration of the
ABB Dynafin™ unit

Background

Development of the ABB Dynafin™ propulsion concept has built upon the strong legacy of ABB's breakthrough innovation of the Azipod® propulsion system. The first idea for the Azipod® system was generated in the late 1980s. Since then, we have collected over 30 years of experience in this unique maritime technology.

Over recent decades, Azipod® has proven its worth on a multitude of vessels, taking a prime position in the global market as one of the most energy-efficient and advanced propulsion systems available. ABB has also continued to develop the system to further enhance its performance and reliability.

Meanwhile, propulsion systems featuring screw propellers have reached their limits in terms of radical efficiency improvements. With this in mind, and amid increasingly strict environmental regulations and strong focus on higher efficiency in the shipbuilding market, ABB set out to investigate possibilities for novel, high-efficiency propulsion concepts already at the end of 2013 (internal 'Rankki' and 'Tankar' projects, co-funded by Business Finland). Among the 69 concepts considered over the following two to three years was a cycloidal

propeller, but the key differentiator from any existing solution(s) is that all the blades are independently controlled enabling unmatched operational efficiency as a trochoidal propeller (see section below explaining how the concept works).

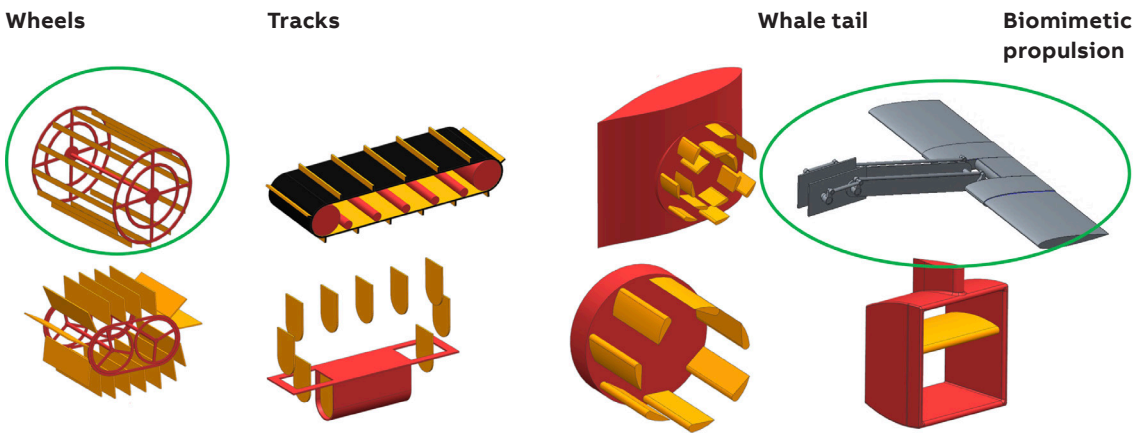

Figure 2: Some examples of the 69 different propulsion concepts ideated during early concept development phase

Following thorough screening and analysis, we recognized that what is now known as ABB Dynafin™ was a potentially winning concept, and it was further developed during 2016–2019. Mechanical, electrical, and control elements were matured to assess full-scale feasibility, as well as evaluation of hydrodynamic performance using advanced computational fluid dynamics (CFD) simulations.

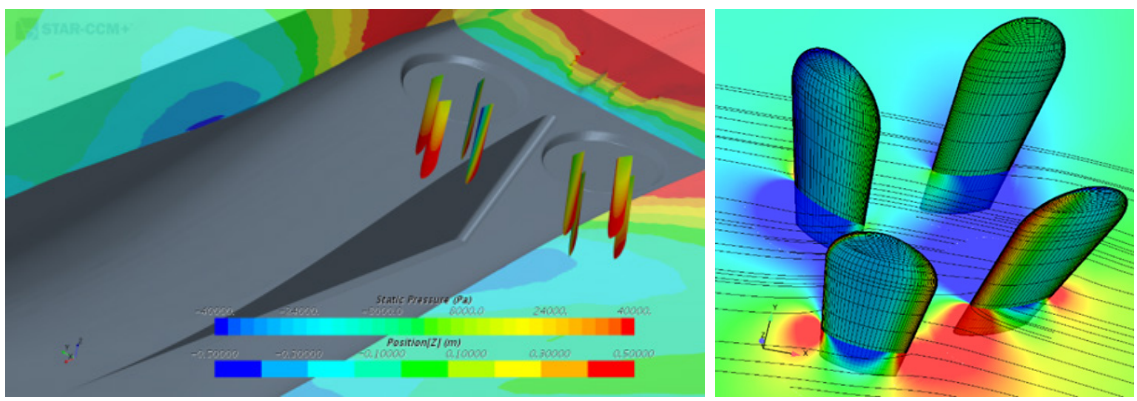

Figure 3: ABB's expertise in advanced, full-scale CFD simulations played a significant role during the concept development phase. With almost limitless possibilities, CFD simulations provided the fastest and most cost-efficient way to investigate hydrodynamic phenomena and to improve the concept.

Following successful open-water tests in model scale carried out at the VTT Technical Research Centre model basin located in Espoo, Finland, the concept development team moved on to self-propulsion testing in order to analyze propulsor and vessel hull interaction and propulsive efficiency. Propulsors were retrofitted to a platform support vessel (PSV) hull to get a direct comparison against existing Azipod® units in the same power range. The final phase in

concept-proving was to confirm maneuvering capabilities in lake trials using a test matrix based on IMO maneuvering parameters. This was the first time such tests have been carried out with a trochoidal propeller.

These in-depth studies, conducted in collaboration with the ABB Corporate Research Center at Västerås in Sweden, clearly demonstrated that achieving extremely high open-water efficiencies of up to 80–85 percent was both realistic and achievable, providing up to a 25 percent efficiency improvement compared to existing propulsion systems in the same power range.

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Figure 4: Self-propulsion test with two ABB Dynafin™ units retrofitted to a PSV hull model

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Figure 5: Lake trials demonstrating maneuverability capabilities of a vessel equipped with ABB Dynafin™ propulsors

Following the successful simulations and model-scale tests, ABB engaged in productive discussions with several ship design offices, shipyards, and ship owners and operators to validate the feasibility of the concept. Receiving direct feedback from customers, understanding their needs and trends in the market is essential in this kind of high-stakes product development.

Encouraged by the feedback from customers and highly promising results from the CFD analysis and model tests, a full-scale development project, co-funded by Business Finland, was initiated at the beginning of 2022. The aim of the project is to further develop, enhance, and productize the concept during the coming years.

The ABB Dynafin™ concept was unveiled to the market on 31 May 2023.

Customer benefits
The ABB Dynafin™ propulsor concept has been designed to achieve very high propulsive efficiency resulting in reduced fuel consumption. Significant benefits for owners and operators of various type of vessels include:

HIGH EFFICIENCY
- Open-water efficiency up to 85 percent
- Significant fuel savings resulting in emissions avoidance
- Less installed power, supporting the electrification of vessels and utilization of greener fuels

EXCELLENT MANEUVERABILITY
- Instant control of thrust and its direction, supporting operational safety and flexibility
- Suitability for demanding operations and sea conditions
- High dynamic positioning (DP) capability

HIGH RELIABILITY AND EASY MAINTENANCE
- Low number of components = minimized need for maintenance
- Easy access to main components
- Modular, standardized structure = better availability and easier management of spare parts

HIGH ONBOARD COMFORT LEVEL AND SUSTAINABLE OPERATIONS
- Low rotational speed minimizes cavitation, pressure pulses, noise, and vibration
- Low underwater noise, enabling operation in sensitive sea areas

When evaluating propulsion options, ship owners and operators seek the lowest possible total cost of ownership, in other words not only the highest possible efficiency and maximized payload, but also minimized maintenance costs. As environmental regulations become stricter, compliance using traditional technology is becoming increasingly challenging and expensive.

Cost benefits

Higher total efficiency compared to existing propulsion systems leads to direct savings in fuel costs. This is increasingly important as the shipping industry starts to adopt greener fuel alternatives such as e-LNG, methanol, hydrogen, and ammonia. Higher efficiency also makes it possible to reduce the size of the power plant. Main engines and main components of an electric power train can be made more compact, with a direct effect on capital costs and indirectly on maintenance costs. This is of particular benefit to hybrid or fully battery-powered vessels, as the size of costly battery banks can be minimized. Lower fuel consumption, enabling smaller fuel tanks, as well as a smaller footprint of the power train, provides more flexibility in general arrangements and more space for passengers and cargo. These indirect savings can have a major positive impact on profitable vessel operations.

Superior responsiveness

The design of the ABB Dynafin™ allows instant generation and direction of thrust. This ability gives a vessel extremely fast responsiveness, resulting in, for example:

- Faster port operations (approaches and departures)
- Better resilience to weather (wider availability window)
- Lower total energy and fuel consumption
- Improved passenger comfort
- Improved operational safety
- Improved DP capability

Components that don’t exist, can’t fail

The number of components in ABB Azipod(R) units has been reduced to the bare minimum compared to competing azimuthing thruster systems. The ABB Dynafin™ minimizes the total amount of components even further by combining both the functionality of the propulsor and steering units in one single package, and by having a direct electrical power train for both the main wheel and the blade modules.

In addition, the absence of wear-sensitive gears and using moderate 30–80 rpm of the main wheel minimizes wear of components. Construction of the unit also allows access inside the main wheel, enabling inspection and replacement of many components inside the vessel, improving the ability to monitor components and increase the availability of the vessel. This minimizes time and

expenses during dry-docking. The unit's modular structure and higher degree of standardization also serve to improve the availability of the spare parts, simplifying spare part management across an entire fleet.

Reducing underwater noise pollution

In addition to GHG emissions, underwater radiated noise (URN) is increasingly recognized as a major issue due to its harmful impact on the marine environment, especially in regions where ships and marine life coexist. Underwater noise pollution is a significant threat to aquatic ecosystems, and anthropogenic sound is noted as one of the most detrimental types of pollution.

Limiting acoustic emissions from shipping is expected in the near future either via technological advancements or policy commitments. National as well as international regulations are inclining towards stricter limitations on allowable underwater noise levels. In ABB Dynafin concept, underwater radiated noise can be considered having two main sources: electromagnetic and hydrodynamic noise. In ABB Dynafin, electromagnetic noise is minized by having the electric motors inside the vessel's hull structure.

Low pressure pulses and blade tip speeds, resulting in less cavitation and turbulence, are indicating low level of hydrodynamic noise. In addition, individual blade control enables usage of optimized trajectories to minimize hydrodynamic noise in different operational situations.

Wide-ranging application

Initially, ABB is concentrating on the development of ABB Dynafin™ units in the power range of 1–4 MW per propulsor. With two or even four units installed, the product is a feasible solution for many different vessel types requiring propulsion power between 2 and 16 MW.

In addition to having a direct electrical power train for both the main wheel and the blade modules, construction of the concept also allows powering the main wheel mechanically via a bevel gear. This feature enables the ABB Dynafin™ to be connected directly on the main engine, extending the benefits to vessel segments where electrical power trains are typically not used.

Given the flexibility of the power range, configuration, and suitability to various operating profiles, this new electrical propulsion concept would bring significant benefits to (but not limited to) the following segments:

- Small and medium-size passenger vessels (single and double-ended ferries, small cruise ships, and yachts)

- Offshore energy vessels, service operation vessels (SOVs), cable laying vessels (CLVs), foundation installation vessels (FIV), offshore construction (OCVs) and support vessels (OSVs), PSVs, and anchor-handling tug supply vessels (AHTS)
- Research and survey vessels
- Merchant ships (container feeder ships, dry cargo vessels, small tankers)
- Special purpose vessels such as tugs, dredgers, and rescue and salvage vessels

How the ABB Dynafin™ works

The concept is essentially a cycloidal propeller with individually controlled blades. The operating principle allows the unit to utilize a trochoidal blade path, which is analogous to the movement of a whale tail. Similar kinds of trochoidal propellers have been studied theoretically to some extent in the past, but until now technology constraints have prevented them from being commercialized and introduced to the market.

The ABB Dynafin™ generates thrust by means of profiled blades that project outward from the bottom of the ship. Each blade can rotate both around the global axis of the main wheel and around its own local axis, which acts as a pivot point for enforcing a prescribed pitch motion. The thrusting blades can move following trajectories like the tails of whales and dolphins. Thus, the unit works as a biomimetic device. This sort of pitch motion leads to a very high propulsive efficiency. The propulsor can also change thrust direction almost instantaneously, increasing vessel maneuverability. In contrast, an azimuth thruster, where a conventional propeller is rotated around the vertical axis to direct its thrust, is slower and thus less efficient in maneuvering the vessel.

Key factors driving high efficiency:

LARGER PROPULSIVE AREA

The larger propulsive area A_0 (ship's transverse surface area for propulsion) covered by ABB Dynafin™ lowers the loading of the propeller, giving the lowest

Thrust loading coefficient **Efficiency**

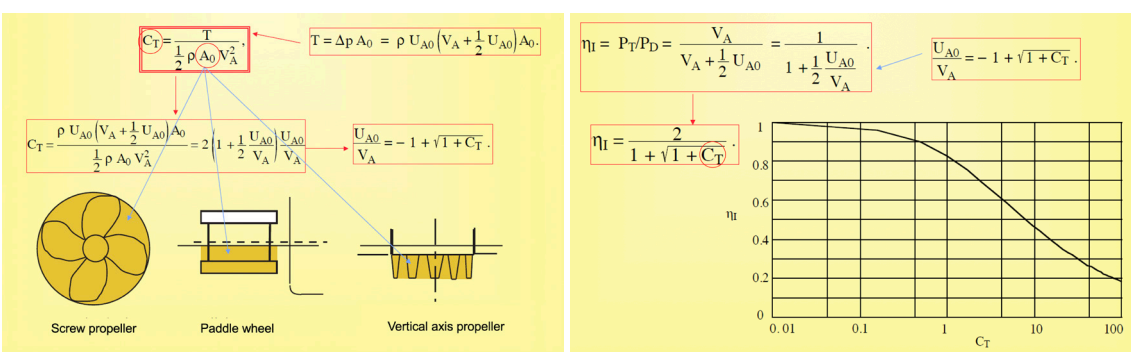

Figure 6: Effect of thrust loading coefficient CT and cross-sectional propulsive area A0 on efficiency, according to theory regarding the ideal propulsor. The smaller the thrust loading co-efficient CT (ie, the bigger the area A0), the higher the efficiency.

thrust loading coefficient, C_T. The lower the C_T, the higher the ideal open-water efficiency of a propulsor. The propulsor's rectangular shape is obviously larger than the circle of a same-sized screw propeller, and additionally, the wheel diameter is not limited by the ship's draught as in the case of conventional propellers. In this respect, ABB Dynafin™ propulsors are perfectly suited also to shallow-water vessels with limited draft.

HIGH ASPECT RATIO

The high aspect ratio of each blade (blade span divided by chord ie, the longitudinal dimension of the cross-section of blade) significantly increases the lift/drag ratio of each blade to be much higher compared to a conventional screw propeller.

INDIVIDUAL BLADE CONTROL

Each blade is individually controlled by an electric motor, frequency converter, and control logic, without mechanical restrictions. This enables the imitation of a high-efficiency fishtail movement and adjustment of the blade movement (eccentricity, advance ratio, and angle of attack) depending on different vessel operational situations, maximizing efficiency and thrust in both transit and DP modes (see Figure 7 below).

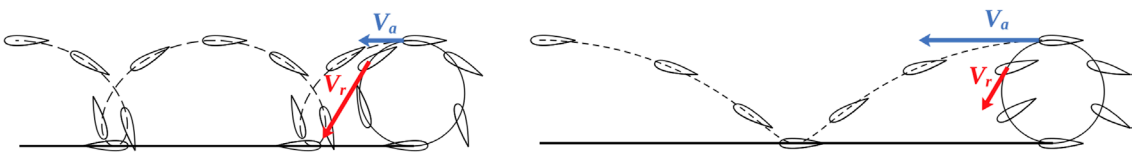

Figure 7: Left: Epicycloidal path of a blade with eccentricity and advance ratio λ<1 (cycloidal propeller) Right: Trochoidal path of a blade with eccentricity and advance ratio λ>1 (trochoidal propeller)

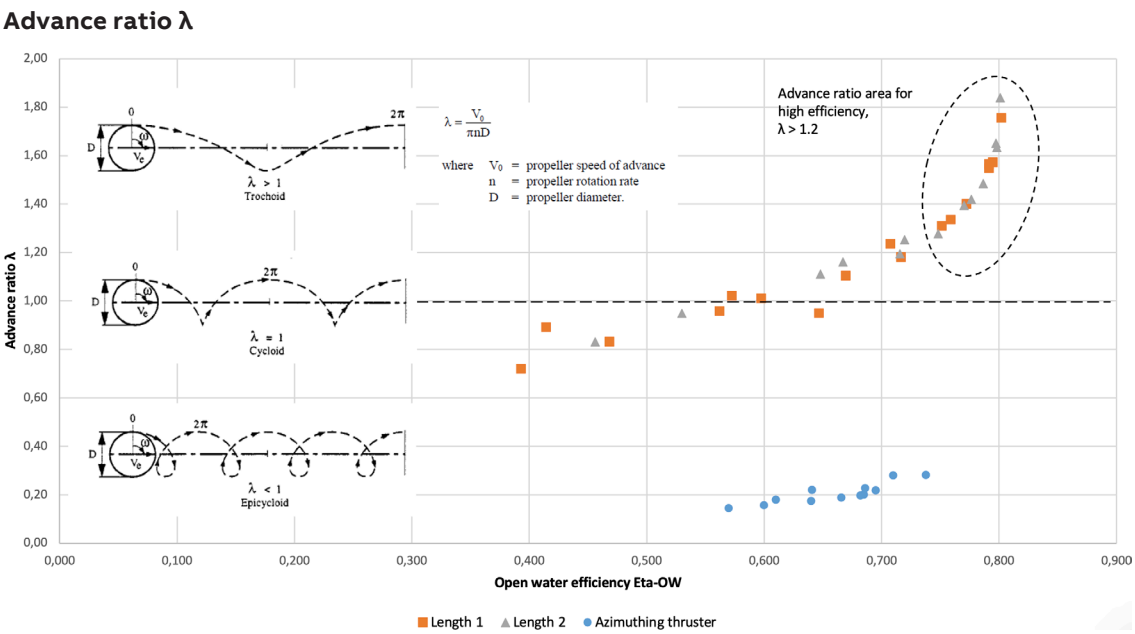

Figure 8: The effect of advance ratio to open-water efficiency with two different spans of the blades

MINIMAL ROTATIONAL LOSSES

Screw propellers with rotation axes parallel to the inflow induce rotational losses in their wake; this is avoided in the cycloidal propulsor as there are no major rotational components in the wake flow.

MINIMAL APPENDAGES EXTERNAL TO THE VESSEL HULL

Propellers with a traditional shaft line require a rudder and struts for the shaft, which induce additional drag. For a cycloidal propulsor there is no need for a rudder and the only parts protruding from the hull are the blades. Thus, there is minimal added drag, improving the vessel's hydrodynamic performance.

As stated previously, gains in propulsive efficiency reduce not only emissions but also operating costs. High efficiency means smaller power plants, leading to a more flexible general arrangement, more room for cargo and passengers, and lower maintenance costs. Additionally, the ABB Dynafin™ will improve maneuverability by innovatively combining the propulsion system with a new intelligent control system, which in turn will result in more efficient and safer ship operations.

Rotational movement of the main wheel is produced by an electric direct-drive motor. The main wheel is rotating at relatively low rpm, for example in the range of 40-80 rpm depending on the operational situation. Direction of rotation is kept the same under all operational situations and amount and direction of thrust is managed by a combination of adjusting the movement of the blades and rpm of the main wheel. The main wheel is equipped with four to six identical blade modules, consisting of a blade, a direct-drive motor, and a frequency converter to control the torque and rpm.

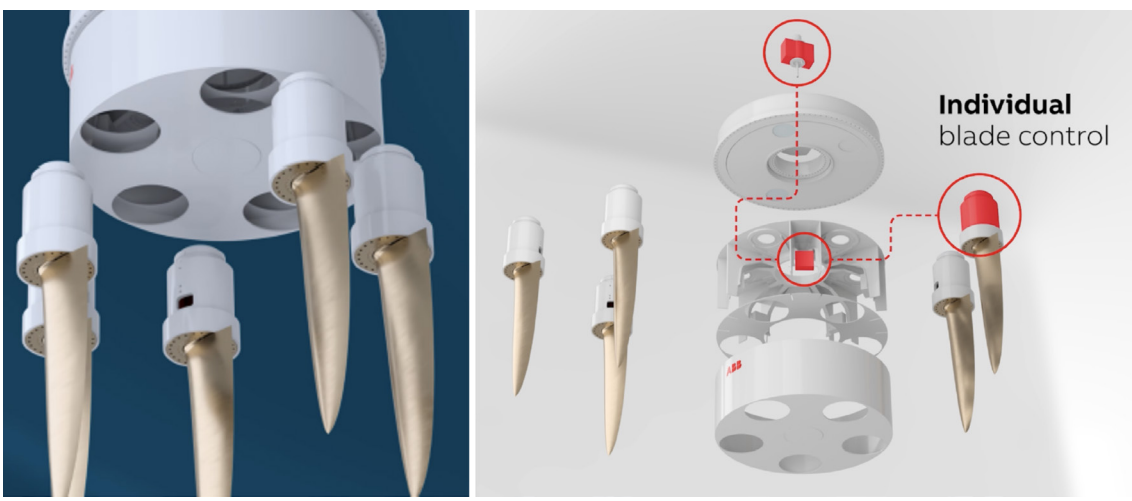

Figure 9: ABB Dynafin™ unit showing the main wheel and individually controllable blade modules

Independent control of the blades makes it possible to optimize the blade movement according to the ship's operational point requirements. A major difference to a typical fixed pitch propeller, which is optimized to a single operational point, is that the ABB Dynafin™ now enables utilization of multiple design points. Control system of the unit can adjust the movement of the blades continuously to meet optimal performance at a wide speed range and different wake fields. The unit's control and software technology opens possibilities to continuously improve and optimize the performance of the vessel throughout its lifetime, creating the concept of a 'digital propeller'.

The ABB Dynafin™ can also be operated in 'rudder mode', meaning that all the blades are controlled as conventional rudders. This feature can not only bring benefits for double-enders and sail-assisted vessels, but also increases redundancy in failure situations, providing partial steering capability.

As already stated, construction of the unit allows access inside the main wheel, enabling inspection and replacement of many components inside the vessel, thus reducing the need for and time spent in dry-docking.

Future development

ABB's combination of expertise in hydrodynamics, mechanical systems, ship electrification, and automation and control put us in a unique position to create and further improve this ingenious integrated solution. The ABB Dynafin™ will add a new level of adaptability and intelligence at the heart of propulsion performance.

At ABB we believe that ABB Dynafin™ will change the way the shipping industry thinks about propulsion systems. Our driving force and objective is to enable safe and zero-emission maritime operations sooner, and for a wider range of vessel types, than currently envisioned. We look forward to continuing this development together with our customers and research and technology partners. •

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Up, up and away with Artemis Technologies

Artemis Technologies is looking to take maritime transport to new heights with its ingenious “flying” passenger vessels. Romain Ingouf, the company’s Technical Director, explains how an innovation from the sailing world can transform commercial operations, with greater comfort, speed, efficiency, and a fast-track pathway to decarbonization.

If you happened to stroll past Belfast harbor in the past year, the chances are you may have stopped to rub your eyes in disbelief. Or spat out your coffee. Or just stood there, momentarily, in a state of stunned silence.

It has grabbed quite a lot of attention.

After a brief second to allow for some extra brain processing, you’d be left with no choice but to accept the reality of the situation playing out before you.

“That boat out there…it’s…it’s flying.”

But this wouldn’t have been a case of magic, or a maritime miracle, rather just the team at Northern Ireland’s Artemis Technologies putting the prototype of the world’s first commercially viable, high-speed, 100 percent electric foiling vessel through its paces.

“It has grabbed quite a lot of attention,” admits a smiling Romain Ingouf, “and I think it’s going to get a lot more when we start delivering them to customers this summer.”

With the first international orders now placed for the 12M Artemis eFoiler® powered multi-purpose workboat, a flying vessel could be coming to a harbor near you. Prepare to set eyeballs to stunned.


TO BE KEPT CLOSED AT SEA
PIONEER
PIONEER

—
Workboat foiling in Belfast Harbour

Less is more

At this point, as Ingouf notes, it's helpful to clarify the "flying" reference. The reality of Artemis Technologies' innovation is not levitation, but rather foiling; with an "underwater wing" (a hydrofoil) sitting beneath the hull. This is fitted with a high power density electric drivetrain.

Ingouf explains: "It works just like an aircraft wing, although it's much smaller, of course, as water is 1,000 times denser than air. Basically the craft starts accelerating and as speed increases lift is created. The hull then lifts out the water and stays there, with a computer system autonomously controlling the hydrofoil; constantly adjusting it with actuators in much the same way as flaps work on aircraft wings. Stability is ensured without human input, leaving the pilot to focus on getting his or her passengers to their destination."

The fact that the hull is lifted out of the water dramatically reduces hydrodynamic drag, thus increasing efficiency. Ingouf says that drag is reduced by approximately 90 percent compared to a comparative non-foiling vessel, translating to huge gains in terms of energy consumption.

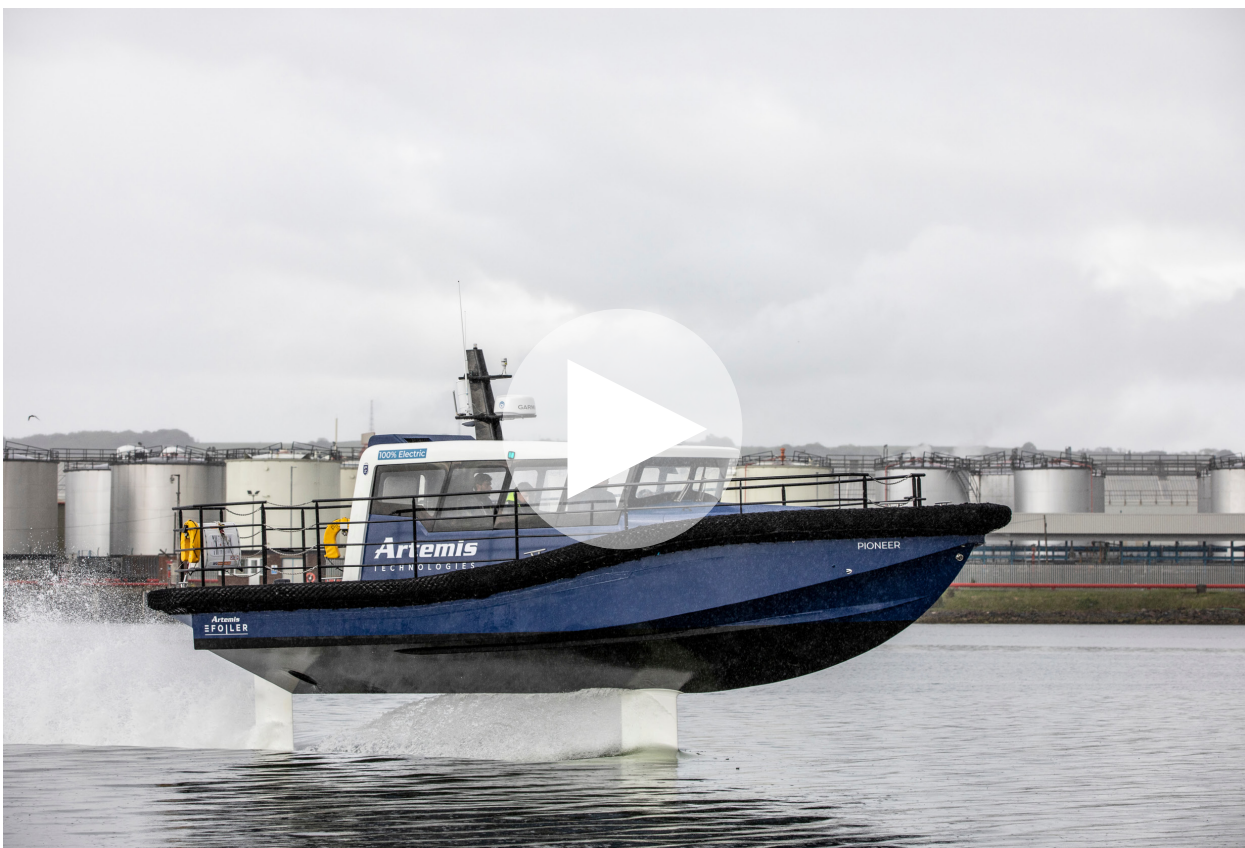
“This opens up new possibilities for batteries,” he adds, “as they don’t need to work so hard – they don’t require the same stored energy capacity – for operations. In other words, less drag, less energy, longer operational ranges. We believe this can really transform the potential for rolling out zero-emission electric drivetrains in maritime.”

The cure for seasickness?

And it doesn’t stop there. Artemis Technologies’ first vessel, the Artemis EF-12 Workboat, is designed for the fast transportation of personnel out to facilities such as windfarms. Normally, this would be a stomach-churning experience for all concerned, but the elevated nature of the hull transforms this too.

“Windfarms, aquaculture and other offshore facilities are often located in areas where the seas can be rough,” Ingouf comments. “But with the foiling system vessels are lifted above the waves and that delivers a stable, comfortable ride. You can basically wave goodbye to seasickness.”

The waves and wind also create power demands for traditional craft that have to “fight” their way out to sea, but the reduced drag – as the foil slices through the water – negates that too. In addition, this slicing means there’s almost no wake, protecting the environment and ensuring the workboats (which, thanks to their electric propulsion, are also silent) meet the strictest local regulations.



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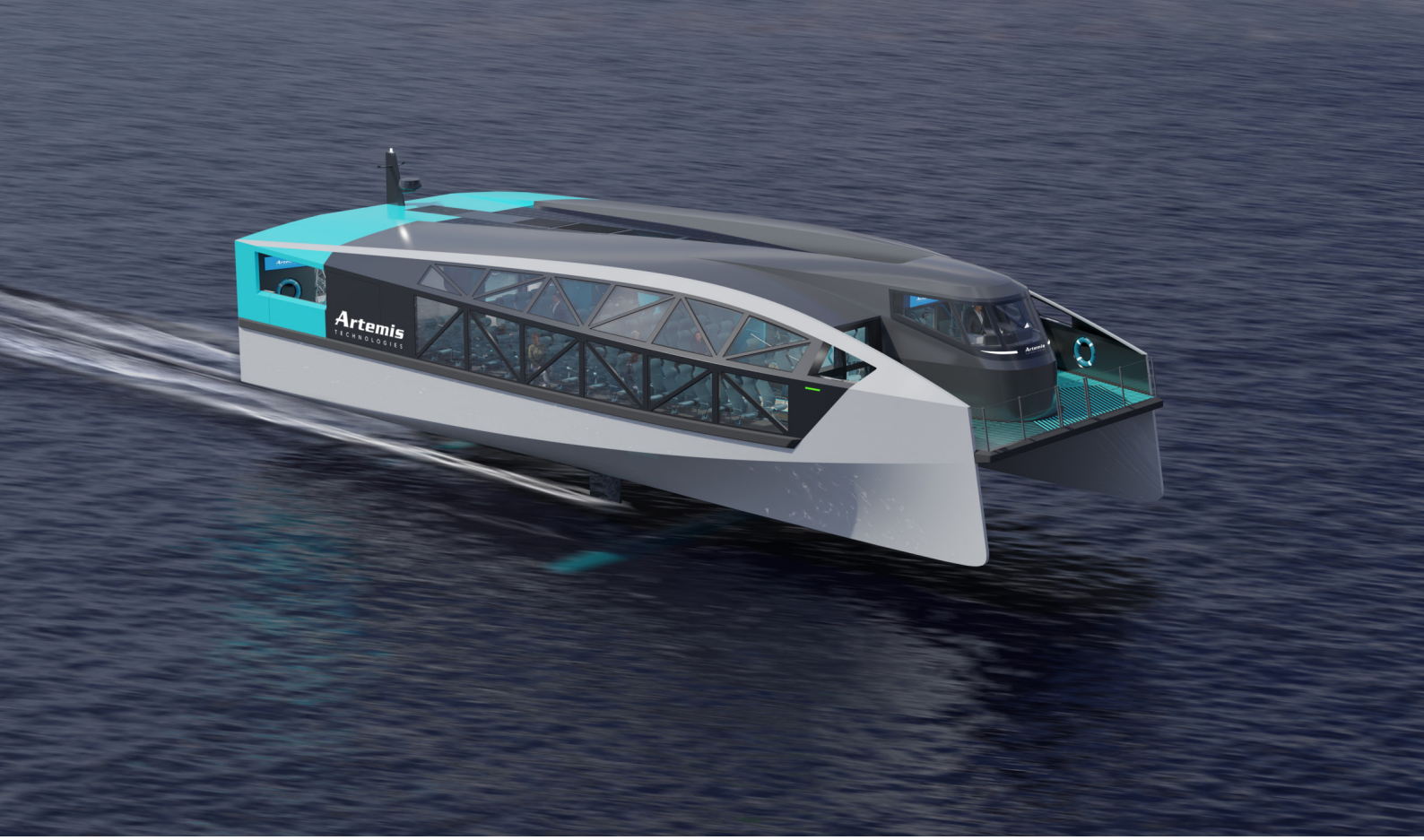
Pioneer foiling montage in Belfast Harbour



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Artemis Technologies unveils worlds most advanced electric passenger ferry EF-24 Passenger

Seen as a complete proposition, Artemis Technologies' innovation seems almost too good to be true; zero emissions, significant OPEX savings, quiet and comfortable, minimal wake, and outstanding energy efficiency.

So, why hasn't anyone else done this before? Why is a comparatively small company from Northern Ireland leading the way on commercial foiling technology globally?

The answer lies in sailing and, more specifically, the America's Cup.

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Less drag, less energy, longer operational ranges.

Racing ahead

Artemis Technologies was born out of Artemis Racing in 2017. The racing team launched in 2006, with Ingouf joining to help design the cutting-edge yachts in 2014. Together they focused on creating robust, lightweight glass and carbon fiber boats that used foiling to harness the power of the wind in the most efficient way possible. Ingouf says the designs could deliver a four-fold return on windspeed, meaning yachts skipping above the waves at 40 knots on a 10-knot breeze.
"It was a lot of fun," he smiles, reliving the team's long experience with the America's Cup, where they reached the Challenger Series Final in Bermuda in 2017.

“We have a background in naval architecture, advanced simulation, aeronautical engineering, computerized fluid dynamics and design optimization from the racing,” Ingouf continues. “We were used to getting the optimal efficiency from designs for the best possible performance. So, we thought, with the growing need for a sustainable maritime future, why not transfer that expertise into the commercial arena? Why not go from racing to an area where we could positively impact on the world? At the end of the day, the design parameters and the users may be different, but the principles, the foundations of the technology, are exactly the same. We saw huge potential here.”

Radical growth

They weren’t alone. In 2020, the Belfast Maritime Consortium, led by Artemis Technologies, was awarded a 33-million pound grant from the UK Research & Innovation Strength in Places Fund with a view to developing a zero-emission high-speed ferry based on foiling technology. This ‘vote of confidence’ encouraged potential private investors to get onboard, leading to a rapid expansion of the company from around 10 staff to over 120 three years later. Ingouf says this is “just the beginning” and that, as awareness of the electric foiling concept grows, interest will, like the vessels, really take off.

— Introducing the Artemis EF-24 Passenger – Artemis Technologies

But bold concepts aren't always immediately welcomed by traditionally conservative industries – isn't this a concern for a company adopting such a radical approach?

"The benefits, both commercial and environmental, are so great here," he says, "that we're convinced people will be won over. We've been working on validation and verification testing with the workboat for over a year and the prototype is now successfully commercially coded. As this vessel is a world first, we've had to work very closely with Class societies and take them on a bit of a journey. It's been demanding, but it has to be. These vessels will work for perhaps 10 hours a day, every day, in all kinds of conditions, and we're committed to very safe, reliable and efficient operations. Once people see them proving their ability day-in, day-out we expect a strong uptake."

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We saw huge potential here.

Foiling plans

Going back to his "just the beginning" comment, it appears to be entirely justified. The workboat is now set to be joined by a 12-meter crew transfer vessel (CTV) with a capacity for 12 passengers. After this Artemis Technologies will debut the largest iteration of its workboat design, in 2024, with a CTV capable of carrying 24 passengers quickly, quietly and comfortably above the waves. However, it's another segment that seems to make Ingouf's eyes really light up with potential, as he refers back to the Belfast Maritime Consortium and that grant.

"The foiling system isn't applicable to all sectors as you need a certain speed, while vessels are limited in terms of size and operations by battery capacity, if we're looking to zero emissions," he says, adding; "You're not going to see a container ship racing over the surface."

"However, when we consider the decarbonization of transport, enabling clean infrastructure for communities, then medium-sized ferries are absolutely ideal for this concept. We aim to demonstrate that with the Artemis EF-24 Passenger ferry."

Bottom line benefits

The Artemis EF-24 Passenger is described by the firm as "the future of maritime transport". With the backing of the grant, this eye-catching 24-meter long, 150 PAX vessel will slide into action in 2024 with a city-to-city pilot scheme between Belfast and Bangor in Northern Ireland, taking commuters and day trippers from point to point at a cruising speed of up to 38 knots, with a 'take off velocity' of 18 knots, and a range of 80 nautical miles (nm) at 32 knots.

The foiling system should, according to forecasts from the firm, transform the fuel costs and emissions profile for the route, potentially reducing OPEX by 85 percent compared to a typical diesel fueled craft. In total (if the ship operates an average of 200 nautical miles per day, 350 days a year) fuel worth of approximately 2.6 million pounds could be saved annually, preventing the release of up to 8,000 tons of CO2 into the atmosphere.

“This is so exciting,” Ingouf states. “It’s a vessel concept that can be adopted right around the world to deliver clean, efficient, comfortable, fast and truly sustainable operations. This can replace existing, conventional ferries, encourage cities to utilize under-used waterways, and be a key part of enabling multi-modal urban transport, helping address local congestion and pollution issues. We see this as a major step forward.”

Interest from around the world is already building, he says, with the first deliveries beyond Northern Ireland scheduled for 2025.

“Just thinking that we’ve gone from racing to this in a few years is crazy,” he concludes. “Imagine if we could use this sailing technology to help lead the decarbonization of maritime globally. And I don’t see why not! Wouldn’t that be just amazing?”

Some might even say this would be magic, or a true maritime miracle. Watch out for an Artemis Technologies vessel taking off near you soon… •

Artemis EF-12 Workboat – the lowdown on the high performer

Length	12.5 meters
Crew	two
Passengers	six
Top speed	32 knots
Cruise speed	25 knots
Cruise speed efficiency	5.6 KWh per nautical mile (nm)
Range	60 nm
Material	glass and carbon fiber composite
Fast charge	52 seconds per nm, full charge in one hour

Energy uplift

Tomas Tengner, Global Product Manager, Energy Storage, ABB Marine & Ports, discusses how foiling vessels can combine with the latest developments in battery technology to power passenger transportation towards a greener tomorrow.

Tomas Tengner, Global Product Manager, Energy Storage, ABB Marine & Ports

Foiling concepts can be the key to unlocking electrification of ferries and other vessel types where, up until now, battery sizes have been a major barrier. The energy consumption demanded by ships of a certain size, with conventional displacement hulls, has meant that, in many cases, electrification simply hasn't been an option due to the unfeasibly large size and weight of required battery packs. However, the innovation and efficiency of designs like the Artemis workboats, or the new P12 full-electric shuttle ferry from Candela, rewrites the rulebook in this regard.

Building benefits

When you combine these designs with the rapid advances made in battery technology - both on base technology, integration and packaging, as well as on the supply chain and scale-up level – the benefits build exponentially. What we are seeing now is an ongoing increase in the energy densities of conventional lithium-ion batteries, with potential for stepping up to a new level with (yet to be commercialized at scale) lithium-ion batteries with lithium-metal anodes, solid-state technology, and lithium-sulfur batteries.

These high density technologies hold the promise to electrify not only ground and water transport, but also enable electric aircraft, such as those being developed by Airbus, Rolls Royce and Heart Aerospace. Interestingly, leading battery manufacturer CATL has now announced the development of a "condensed battery" with a claimed 500Wh/kg energy density. This could be a key step forward.

Trusted for tomorrow

Back on the water, ABB's successful track record in electrical integration and propulsion technology, as well as proprietary automation and control technologies, can help ship builders to realize their dreams of zero-emission battery electric vessels. Beside the integrated systems onboard, ABB can also provide fleet management, advisory solutions and charging infrastructure, working as a trusted partner on the industry's journey towards more sustainable horizons.

Q3/2023

Revolutionizing the shaft generator with powerful permanent magnets

Yaskawa Environmental Energy / The Switch knows all about the efficient production of electricity on ships. The company leads the field in megawatt machines using innovative permanent magnet technology, pre-assembled at its impressive Large Drive Test Centre near the university city of Lappeenranta, Finland. ABB Generations met Vice President of Technology, Panu Kurronen, to discuss how exhaustive testing ensures reliability prior to delivery.

Panu Kurronen, Vice President of Technology, Yaskawa Environmental Energy / The Switch

Generating the required electricity to power operations and amenities on ships is an issue that has haunted the industry for more than 150 years, since the dawn of the electrical era.

The challenge is even more pertinent today as shipowners hunt for new ways to increase energy efficiency and cut emissions amid ever-tightening climate regulations.

“People are focusing on propulsion as the obvious area to look at for efficiency improvements, especially as new sustainable fuels become available. However, shaft generators also require scrutiny as they play a key role in modern propulsion systems,” says Kurronen.

How shaft generators can help reduce fuel consumption

“Let’s rewind a bit first. Electricity has traditionally been produced on ships using standalone synchronous excitation-based generator sets – or gensets. These require an external fuel source to produce the electricity, typically provided by an auxiliary diesel engine completely separate from the ship’s main engine,” he explains.

“The first shaft generators were developed in the 1960s and were a big step forward in reducing the historical reliance on gensets and thirsty auxiliary engines. By connecting directly to the propeller shaft, they make electricity using

This and following photos show permanent magnet shaft generator setups at the LDTC in Lappeenranta.

the energy already supplied by the main engine. The gensets can then be turned off, so reducing fuel burn. Shaft generators are also more effective when used in conjunction with the huge drive power of two-stroke main engines, versus less powerful four-stroke engines."

But there was still one major drawback – although shaft generators connect directly to both the ship's propulsion shaft and the ship's onboard grid, there was no frequency converter in between them.

Our machines use modern neodymium magnets that create the magnetic field much more efficiently.

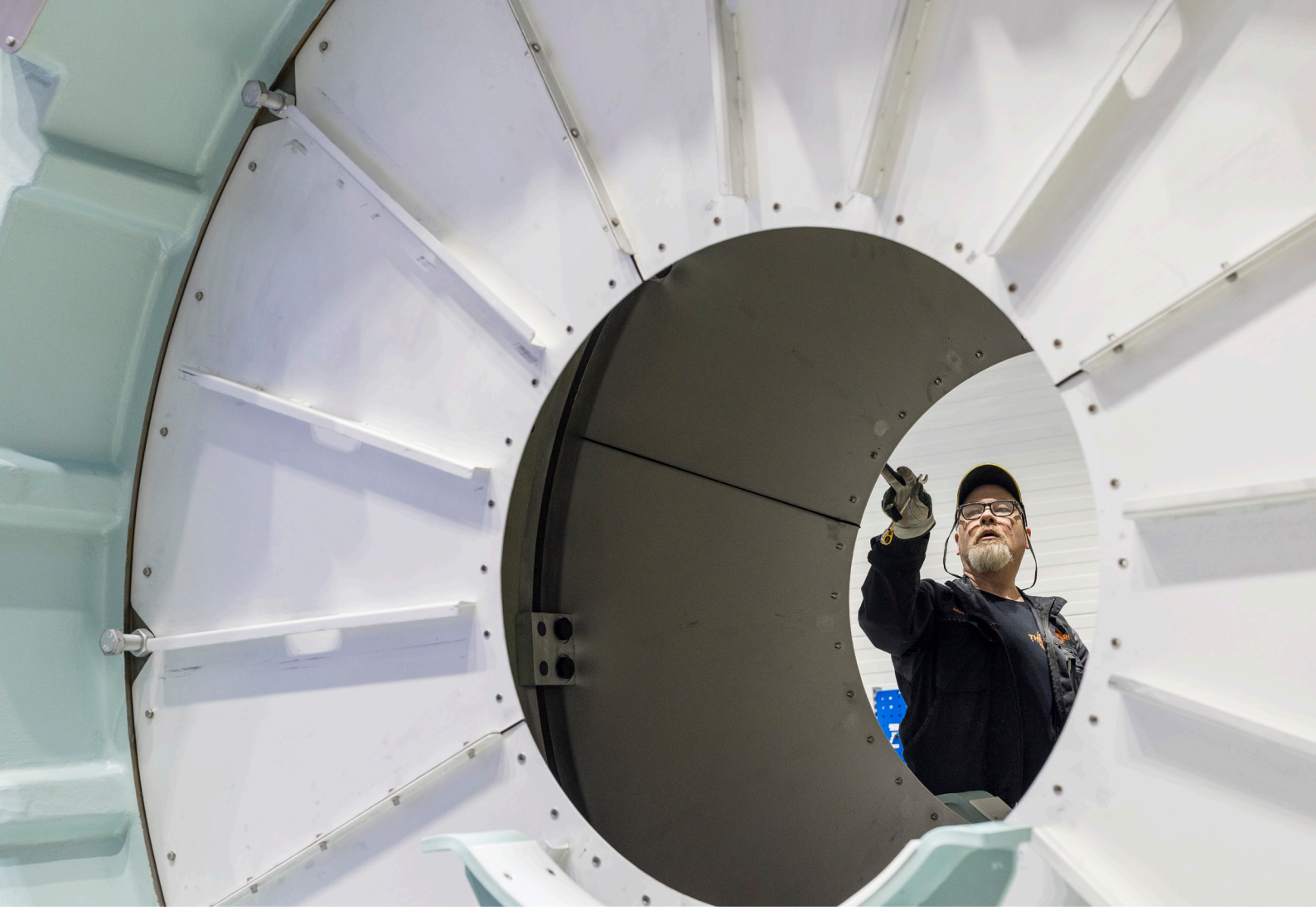
The frequency bottleneck

"This limited their efficacy as they could only cope with a constant speed from the ship's propulsion drive. When the ship's speed changed, the frequency of the electric current produced fluctuated, rendering the shaft generator unusable. It would then have to be disconnected, and the genset(s) would take over," Kurronen explains.

This issue was resolved in the 1980s when frequency converters were introduced. “The shaft generator then came into its own as it could cope with any speed from zero up to the ship’s design-rated speed and feed a constant frequency to the ship’s electrical grid.”

Conventional shaft generators combined with frequency converters can be used as the sole generating source of electricity onboard a vessel or as a supplement to the gensets, reducing the need to burn fuel. “They can also be used as a source of power to drive the propeller at very low speeds, which is useful for saving emissions when moving around in port. The system can also be used for occasional propulsion power boosts of up to 15 percent if needed to break through ice, for example, or when sailing in strong headwinds.”

However, despite these benefits, there are some key areas where conventional shaft generators fall short. “Conventional systems still require a current to flow in a rotor winding to create the magnetic field, so there is always energy loss through heat. Heat loss means lower power conversion efficiency, resulting in higher fuel consumption in the main engine. They, of course, generate savings versus gensets, but more advanced units go further,” says Kurronen.



The PMs are so strong that the whole unit can be reduced in size, typically weighting 30–50 percent less than conventional machines.

Magnetic innovation

This is where permanent magnet (PM) shaft generators are a game-changer. “Our machines use modern neodymium magnets that create the magnetic field much more efficiently, without the need for external power supplying a current to the rotor. This immediately decreases the amount of fuel required. The PMs are also so strong that the whole unit can be reduced in size, typically weighing up to 30–50 percent less than conventional machines,” says Kurronen.

The system can cut fuel consumption by a further 2–4 percent compared to conventional units, generating savings that are becoming ever more potent as emissions regulations get stricter. “This reduction applies to emissions as well. Over a typical 20–25-year lifespan of a large vessel, these savings can bring an estimated $2 million reduction in fuel costs and help avoid 5,000 tons of CO_2 emissions.”

Easy installation, lower maintenance

This added efficiency can also help a vessel gain a better Carbon Intensity Indicator (CII) rating. Plus, the solution eliminates genset wear and tear or failures that could require disruptive and expensive repairs. “The simple mechanism also means there are almost no wearing parts, dramatically increasing reliability and simplifying installation. With more than 100 of our units in operation today, not a single failure has occurred,” Kurronen says.

The company supplies shaft generators to OEMs and systems integrators, including ABB Marine & Ports, looking for market-ready solutions that enhance performance and reliability for their customers. “We are currently involved in a major ABB Marine & Ports delivery of permanent magnet shaft generator systems to a series of very large containerships under construction in China and South Korea. They are expected to yield up to 17 percent greater efficiency during voyages versus diesel gensets,” he adds.

Michael Christensen, Vice President, Segment Manager, Dry Cargo Global Sales at ABB, comments: “We have a great relationship with Yaskawa Environmental Energy / The Switch and applaud the innovations they have made in the

demanding field of shaft generators for marine use. Like ABB, they are equally committed to helping customers convert, store and consume energy more efficiently and reducing CO_2 emissions per capacity mile."

Yaskawa Environmental Energy / The Switch has been at the forefront of exploring and expanding PM machine technology for two decades, first for wind power applications and since 2013 for marine.

"The technology has the potential to reduce emissions beyond simply improving operational efficiency. As an investment, it has a very short payback time, especially in view of the expected high cost of new sustainable fuels. Vessels equipped with a shaft generator system may also require lower installed genset power; and with running hours reduced, the gensets require less maintenance. This means a reduction in both Capex and Opex," Christensen adds.

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The technology has the potential to reduce emissions beyond simply improving operational efficiency.

Enter the Large Drive Test Centre

Kurronen explains that, prior to delivery, all PM shaft generators are exhaustively tested at the Yaskawa Environmental Energy / The Switch's purpose-built Large Drive Test Centre (LDTC) next door to its factory in Lappeenranta. "The LDTC is one of the world's largest facilities to test large electric machines and converters for marine and renewable energy configurations, and we can now push the boundaries for the biggest machines in the business. We performed our first factory acceptance test (FAT) for three PMM1000 shaft generators in August 2021, and today we regularly test 12-MW back-to-back electrical drive systems."

This year, capacity has been extended to test systems up to 18 MW. "That beats almost anything else available globally – and it's all happening out here in the middle of the Finnish countryside," says Kurronen.

Construction of the LDTC started in the summer of 2019 and was completed in 2020. "We went ahead with the investment simply because equipment is getting bigger all the time, and drives are getting more powerful. It was essential to have a place where we can verify the reliability of the units alongside customers as they move towards a greener future."

Prototypes are given a back-to-back full-load FAT to test them to full capacity. "In practice, each marine project has different speed, power and torque requirements. So typically, a new machine type is developed for each new project, and the first machine always undergoes back-to-back FAT. In addition, each individual machine we produce is given a no-load FAT before being shipped," says Kurronen.

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Engineers in the LDTC control room during a PM shaft generator FAT

Tailored testing
The LDTC can also combine testing with individual customers' own components, such as their own shaft, bearings, beds or converters. "And we can design and manufacture any other tooling customers might require, providing as close to real-life validation as possible," Kurronen adds.

The centre can undertake around 50 test sets per year, depending on test complexity and the size of the machines, which are typically of at least several megawatts capacity and weigh in at 20 to 80 tons. "We have space to run two parallel test sets simultaneously, or one running and another in preparation, which shortens throughput time. We can also perform certification tests for classification societies."

Kurronen adds that there are clear benefits for customers in that they can have complete confidence in the thermal, electro-magnetic and mechanical behaviour of each machine. "Finished units that have been tested to full capacity, with certification carried out on site, also save time and money during the commissioning phase. Customers can also request special tests, including using a third-party converter and/or the actual components to be installed in the vessel. These include no-load string tests and back-to-back string tests at full power."

In conclusion, he quotes the company's mission to electrify the world with game-changing green technologies. "But we are very careful to ensure everything works reliably before we sell it to others. Customers can rest easy knowing that the shaft generator they have bought has already been through an ultra-marathon at the LDTC." •

Large Drive Test Centre

The 1,155-square-metre factory expansion features:

- Advanced liquid cooling system
- Electrical distribution centre
- Two overhead cranes with a total maximum capacity of 100 tons
- Concrete floor more than two meters thick and weighing around one million kilograms
- Heavy-duty steel construction that can withstand back-to-back tests up to 80 tons, as well as all associated forces and machine vibrations

Marine technology thrives on open dialogue with class

ABB and the American Bureau of Shipping (ABS) collaborate towards the common goal of accomodating maritime regulations and the recent developments in marine technologies.

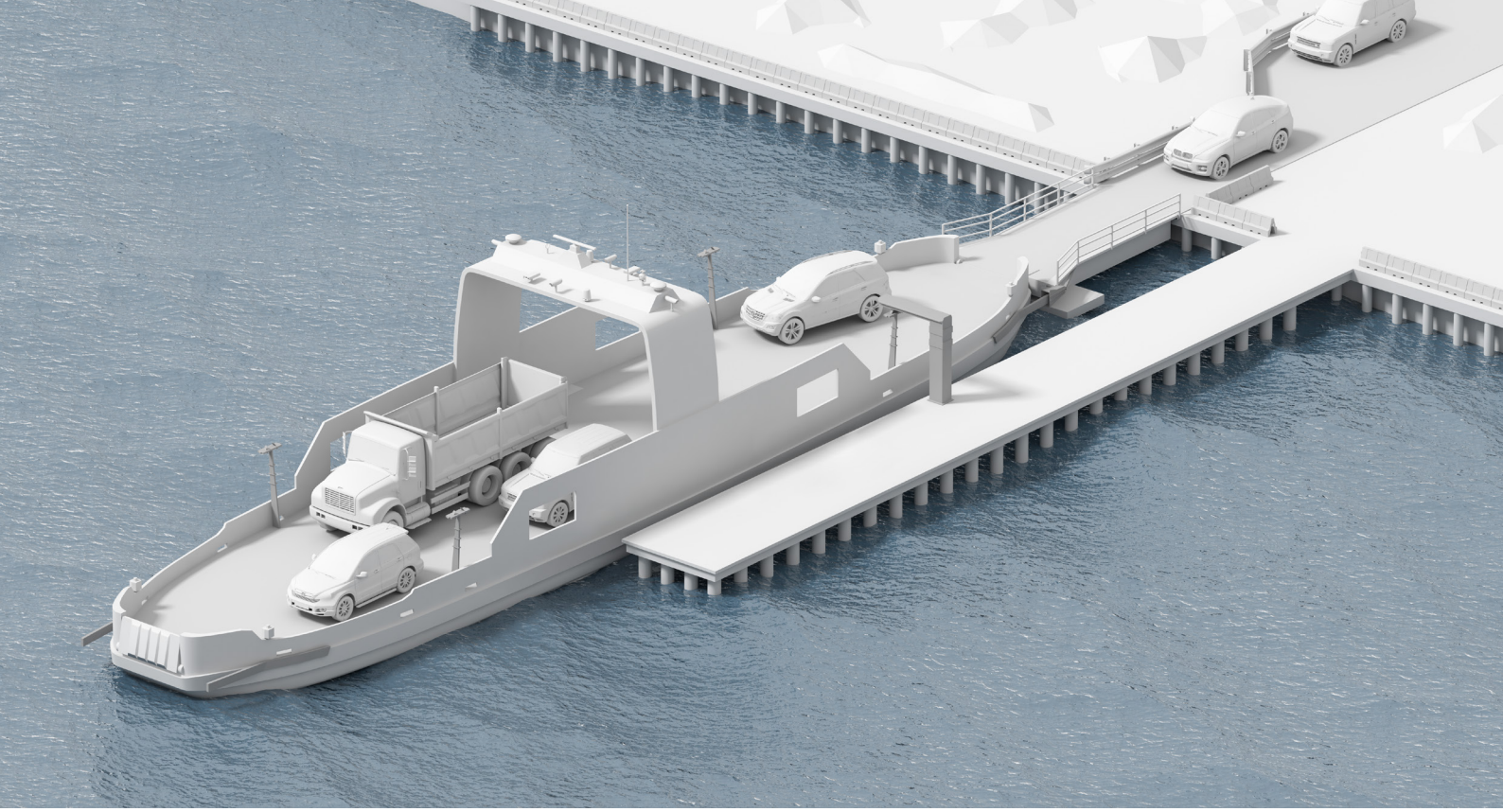
Frequency, intensity and constructive feedback are changing the shape of the conversations between technology providers and classification societies as two key maritime stakeholders look to find the most effective routes to decarbonization, digitalization and autonomous technologies.

In recent years, advances in technology have significantly outpaced the development of regulations shipping relies on to protect safety, security, and the environment. While regulators work continuously to close the gap, suppliers and class have increasingly needed to approve technology developments on an 'in principle' basis because global maritime rules are lacking or incomplete.

Collaboration has been both essential and the most effective way to lay the groundwork for progress.

Kalevi Tervo, Global Program Manager, ABB Marine & Ports, has led the division's strategic development covering digitalization, ship control and autonomous vessels for more than a decade. With technology moving relentlessly forward, he describes the relationship between the technology provider and class has changed significantly over the last years.

"We have been working with class on many items where the technology is groundbreaking – for example, with regard to decarbonization, digitalization and autonomous ships – and where maritime regulations don't currently exist. Collaboration has been both essential and the most effective way to lay the groundwork for progress."



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Concept illustration of an autonomous ferry

Touchpoints connecting ABB Marine & Ports with ABS extend from bridge to propeller, taking in ship power, control and distribution, Azipod® propulsion and an array of advisory software, and beyond, to shore power.

Autonomous action

Plenty of opportunities exist for advancing technologies to drive a new type of relationship, but accelerating automation is exerting the most intense pressure for greater collaboration on both sides, says Tervo.

Chih Wei Lui, Technology Manager, ABS, leads autonomous ship developments at the class society and was part of the International Maritime Organization regulatory scoping exercise on MASS (Maritime Autonomous Surface Ship).

Lui comments: “When owners go to yards today, they want an idea of what they can expect for the ship they are ordering down the road. One example is future fuel oil consumption and expected CII performance. However, the rules on autonomous ships cut to the very core of not only equipment functionality, but how it is used. That has profound consequences for the relationship between makers and class.”

Recent projects involving ABB and ABS have included the harbor tug Maju 510, which last year became the first vessel to receive Autonomous and Remote-Control Navigation Notations from ABS, and the first Singapore-flagged vessel

to receive Smart (Autonomous) Notation from MPA. The Keppel Offshore & Marine (Keppel O&M) project saw a successful demonstration of automated situational awareness, collision avoidance, and maneuvering using ABB Ability™ Marine Pilot Vision and Marine Pilot Control.

ABB and ABS agree that a higher level of automation could help most – if not all – vessels to improve safety, efficiency and sustainability in operations, with optimized maneuvering helping to prevent accidents, enhance productivity and reduce fuel consumption.

Critical MASS

For regulators, though, levels of autonomy in ship operation change the relationship between the seafarer and the ship in ways that still need to be fully defined at IMO. The development of Maritime Autonomous Surface Ships (MASS) rules on a goal-based rather than a prescriptive basis is therefore pivotal to their ability to respond to a changing world later on, rather than being framed in terms that freeze technology at a moment in regulatory time.

“Maritime safety is the goal for developing rules for MASS that is common to all stakeholders,” Lui says. “However, these new technologies involve wholesale change, not just for design but for the way ships can be operated.”

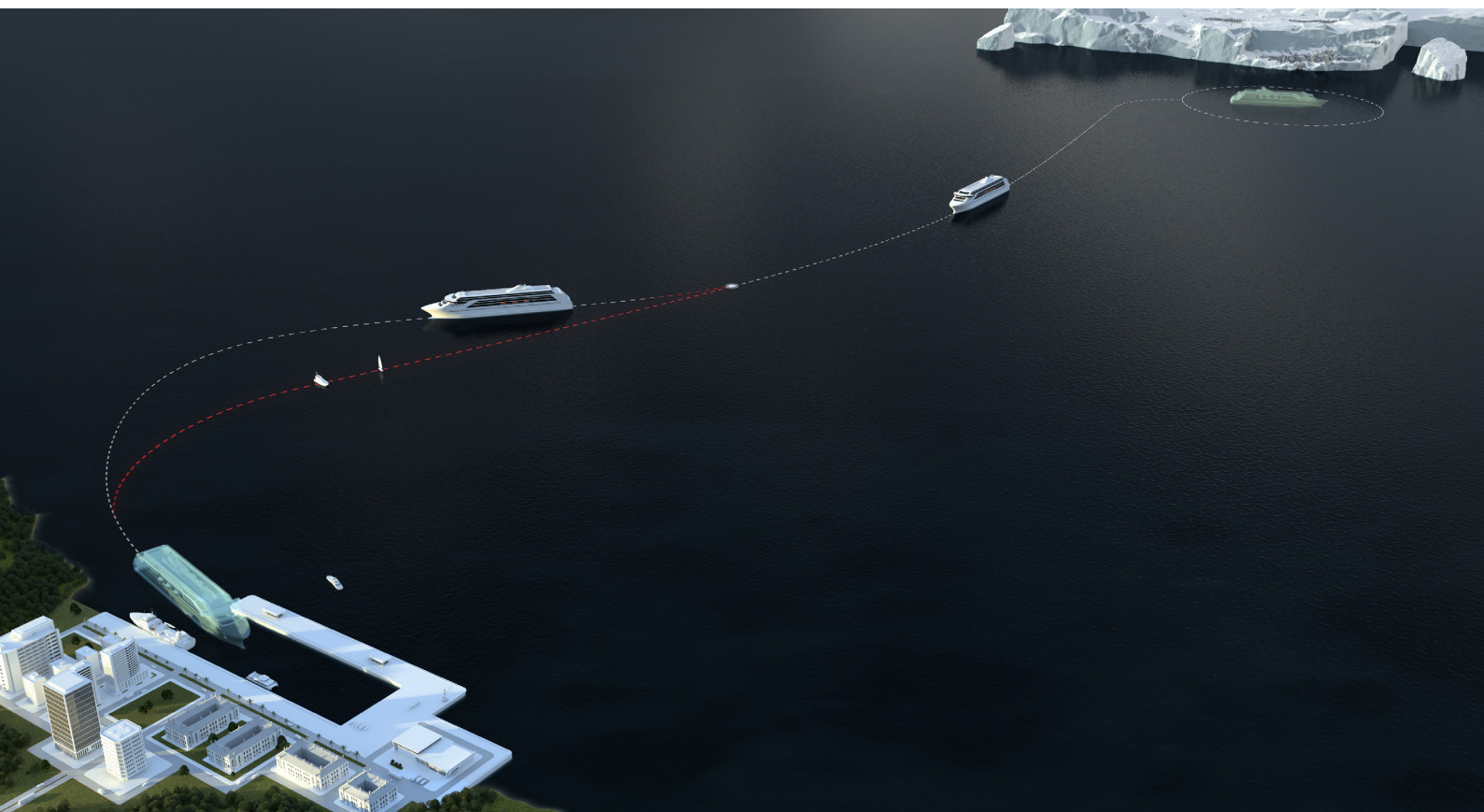

ABB Ability™ Marine Pilot Control – Exploration cruise

Where internationally agreed maritime rules do not yet exist, working towards formal certification of technologies like ABB Ability™ Marine Pilot calls for new levels of transparency between class and technology developers, and a dialogue that goes far beyond the novel concept approvals class has offered up to now.

Last year ABB and ABS organized two workshops – one in Houston and one in Helsinki – focusing on autonomous ships, associated technologies and provisions for remote control. “These were focal points for what has become a continuous discussion, where ABS gains better understanding of the technology and provides feedback in a collaborative way,” says Lui.

“It's a different level of dialogue now, since both ABB and ABS have gained experience from multiple ship automation and autonomous ship projects. Ultimately, these learnings can benefit the entire industry,” comments Tervo.

Continuous discussion between ABB and ABS is also getting to the heart of prevailing industry concerns on the substance of regulations for the MASS future.

Ship operating principles

“In conventional operations, everything – including the rules – revolves around the human as the agent responsible for different subsystems,” observes Lui. “It all works based on humans looking out the window or referring to screens and taking decisions based on what they observe. However, while training standards are exact, the individual will always be a variable.”

Introducing autonomous technology requires a different approach, he adds. Rulemaking is straightforward from the point of view of equipment functionality, but that is not the same as developing safe procedures on decision-making for real maritime operations.

“As technology developers, we are increasingly working more closely with class to secure a mutual understanding of how the technology will be used and to work towards a way to certify it for commercial use,” says Tervo. “Class can offer insights on the regulatory landscape based on their experiences across the whole maritime industry globally, while we can offer guidance on how operations might be adjusted to optimize use of the technology. With the framework for MASS at an early stage, operational definitions and equipment functionality are in a kind of dialogue that is informing the iterative regulatory process.”

New applications of autonomous ship technology are already enhancing safety as part of conventional ship operations. Last year, for example, Wonder of the Seas set sail as the first ship in the world to feature ABB Ability™ Marine Braking Assistance. At the push of a button, the new digital solution initiates an automated braking sequence, optimizing the angles and power of all the Azipod® propulsion units based on vessel position, heading and speed to maximize braking efficiency. This gives the operators time to attend to other urgent matters while retaining control over steering.

Other ABB projects underway cover a proposal for a ‘Bridge 0’ conditionally and periodically unattended bridge, while separate trials focus on ABB Ability™ Marine Pilot functionality to perform as an ‘electronic lookout’ to support greater maritime safety.

“Today we are continuously in dialogue with our class partners on our research projects relating to the autonomous ship, to leverage their knowledge. We can always call on them for informal but invaluable peer review,” says Tervo.

“What’s important is that the industry moves away from the isolated product-driven approach and towards software and data-defined functionalities. We already know that there will be new software functions during the lifetime of the ship that existing regulations and procedures won’t be able to handle. We need rules which frame the ship as a system that can evolve during its lifetime. Collaboration with class now is imperative.”

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The relationship between ABS and ABB is evolving.

Remote concerns

Lui says “frank discussions” have taken place between ABB and ABS on concept of the Digital Control Center, where key ship functionality can be controlled from afar.

“That is an example of how a new holistic approach can benefit operating rules, and the effective use and development of technology,” comments Tervo. “In the digital and connected world, it is not relevant whether the technology user is located on the bridge or in a remote center. But it is relevant that documentation on risk assessments is in line with the expectations of customers and flag states.”

“The relationship between ABS and ABB is also evolving,” adds Lui. “It’s no longer about ABB submitting user manuals to us for class recognition. Even on the technology itself, there’s a more extensive engagement, where we work with ABB to ensure our class recognition documentation fits the real purpose of the product throughout, rather than only engineering characteristics.”

And while projects relating to autonomous ship technology may command the highest profile, the new type of relationship that is being established between ABS and ABB is being replicated in a growing number of areas, Lui adds, above and below the waterline.

“ABB has the whole full suite of systems for ships and this type of collaboration is fruitful at all levels. My colleagues across ABS are engaging with their ABB counterparts on the same basis, on everything from motors and thrusters to power networks, control systems and maintenance standards – not to mention underwater noise.”

“We see it as a holistic engagement that is not limited to one technology group or part of our organizations but works towards viewing the entire vessel as a system of systems. In some ways, it is a change that is necessary to support integrated maritime digitalization.” •

The value of generative AI for the marine market

ABB Marine & Ports experts and invited partners share a remote panel conversation over the emergence of ChatGPT and how Large Language Models (LLMs) can be optimally used in a marine engineering context.

ChapGPT, driven by developer OpenAI's GPT4 engine, has attracted massive attention since its launch in March. It has become so talked about that it is now shorthand for LLMs in general. Microsoft followed up with its GPT4-based Microsoft Bing search chatbot, Google with its competing Google Bard, and recently even information hub Bloomberg is in on the act with the release of its BloombergGPT purpose-built for finance.

Here ABB Generations was party to a free-wheeling conversation on LLMs featuring Peter Sarlin and Tarmo Pajunen, CEO, and Business Development Executive, Industrial Sector, respectively, at Silo AI, the largest private AI lab in the Nordics; Igor Balashov, Senior Data and AI Specialist, Manufacturing, at Microsoft; Roy Funck, Head of Technology, at ABB Marine & Ports and colleagues Tomas Tengner, Global Product Manager, Energy Storage Solutions, and Ola Hjukse, Portfolio Manager for Automation and Control Products.

The 'packaging' is the revolution

ROY FUNCK (ABB): "Generative AI is itself old news, but engineering it for public use is the new frontier. Other AI offerings are more powerful but not wrapped in the same user friendliness. ChatGPT is basically a smart super-search engine able to respond to prompts with human-sounding answers."

PETER SARLIN (SILO AI): "GPT models are just one aspect of large language models (LLMs) and LLMs one aspect of generative AI. We have been working with these models for years. They're self-supervised systems designed to solve what is called a 'token' or word prediction problem. They learn to predict the next

word in a sentence from a vast dataset. In simple terms, these models merely provide a probability distribution of the most likely next words, and we've now gradually learned to better control, instruct and finetune them to create value for specific tasks. This is still far from 'super-intelligence' or from how the human brain works and human-level performance."

TARMO PAJUNEN (SILO AI): "The whole world is now aware of ChatGPT because of its impressively successful product launch. But as Peter and Roy say, the real revolution is not scientific but on the product side, in the value-creating user experience and conversational interface. OpenAI has spent a lot of money on making it fun to use."

PETER SARLIN (SILO AI): "It's important to remember that generative AI applications like ChatGPT are not creative in themselves, but good at creating novel content by combining individual elements from the vast amount of data provided to them. The quality of their output is dependent on the quality of the data they've been trained on. They have the potential to help enormously in content creation, search tasks and human-machine interfaces. Quality control

should, however, still be a human responsibility as the output of these models isn't guaranteed to be factually correct. In most cases, the more controlled, instructed and fine-tuned a model is for a specific use case, the better the output."

IGOR BALASHOV (MICROSOFT): "I conquer with Peter's perspective. It is noteworthy that Language Model Platforms (LLMs) such as ChatGPT and Microsoft Bing Chat, both built upon the foundational models GPT-3.5-turbo and GPT-4, signify a significant advancement in the process of democratizing search capabilities. These platforms mark a substantial departure from conventional search engines, introducing a user-friendly approach that substantially augments access to information and facilitates the exploratory quest for knowledge."

PETER SARLIN (SILO AI): For me, the launch of ChatGPT was a 'Tesla moment' for generative AI. When Tesla triggered a hype wave around self-driving cars, it served as a trigger for a wave of investment in autonomy-related tech. We're seeing the same thing now; rather than being transformative on its own, ChatGPT will spark significant investments in generative AI as a value creator in software products. OpenAI has made a big contribution by paving the way."

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ChatGPT is basically a smart super-search engine able to respond to prompts with human-sounding answers.

Versatile coding assistance

OLA HJUKSE (ABB): "Given that it can feed on the entirety of GitHub (the world's largest code-sharing platform designed to simplify project collaboration and management), ChatGPT can help to write, test and improve code. It can clean up existing code by correcting mistakes, simplifying complex ideas, and flag up bugs. At ABB, we can use it to get part of the way in writing, for example, executable Python code for simple applications, or controller code for motor and converter controls. It's cool to be able to write code without having to be an expert in the Python mindset. It's efficient in all kinds of languages."

TOMAS TENGNER (ABB): "That's right. I actively use ChatGPT in my work to generate code for useful everyday functions. For example, I struggled to code a fast tool that can highlight any category of abbreviations in a Word document, but was able to do it in ChatGPT. It also clearly understands the purpose of the code. For example, I pasted in a snippet of code from GitHub and it described exactly what the code did (downloading TV shows from a Swedish streaming service). It also commented on the code in a pedagogical way by adding a warning about infringement of copyright laws."

TARMO PAJUNEN (SILO AI): “I’d caution that getting ChatGPT to, for example, create a poem for a colleague’s birthday is one thing, but it’s quite another to write software for real-world applications using code that it pieces together from someone else’s code from GitHub. That could potentially open up a hornet’s nest of intellectual property rights (IPR) issues. Because if your code isn’t all open-source, to whom does it, or bits of it, actually belong to?”

OLA HJUKSE (ABB): “In cases where we do use open-source data to develop a certain piece of software, often we will start out using a code base facilitating general functionality not specific to marine – for example, the layer that sorts data, handles interfaces, and generates alarms. This we can get, for example, from online R&D use forums. All this needs to be in place before we start on the ‘marinizing’ bit, developing code specific to the maritime use case, which is the value-adding layer. Generating the base layer has traditionally been a very manual approach where we can now save effort and money by using LMMs, before we focus on the marine-specific application.

One proviso is that the usefulness of the LLM is dictated by the quality of human input. The better the framing of the problem statement or prompt, the better the answer. For coding in the marine electronics context, it will force the experts to adopt a better-thought-out design approach earlier, versus the earlier tendency to shift responsibility to software developers with loose definitions. The experts will really have to analyze key system functionality questions ahead of time, which could result in faster prototyping with end-users.”

Simplifying documentation and design processes

IGOR BALASHOV (MICROSOFT): "From a contractual standpoint, AI chatbots or Language Models (LLMs) offer the intriguing capability to generate robust contract frameworks based on user instructions. Non-legal individuals with clear objectives can create comprehensive draft contracts through simple descriptions of requirements. However, professional review and translation remain essential before these drafts attain legal status.

This technology also enables revisions and corrections. Beyond legal use, it aids in generating marketing plans. The streamlined process of editing existing drafts eases the review process, showcasing the power of this feature."

TOMAS TENGNER (ABB): “In the context of having the LM trained on internal proprietary documents like design guidelines, ChatGPT could also be useful to support the drafting of routine policy documents, as well as content assistance for our sales team, who in our case often get inquiries or specific questions from potential clients regarding batteries and battery chemistry. Our sales colleagues could potentially use ChatGPT to generate relevant technical explanations without having to spend a lot of time researching the material themselves.”

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Accelerating the research phase with ChatGPT can support faster decision making.

IGOR BALASHOV (MICROSOFT): “Within the context of advanced technological developments, it is evident that the potential for leveraging models trained on existing design data and relevant physical principles holds immense promise, particularly within the realm of industrial design optimization. For instance, when confronted with the intricate task of refining ship or vessel system designs, these models emerge as valuable tools, capable of effectively addressing complexities such as the strategic layout of systems, encompassing components of an electrical nature.”

TOMAS TENGNER (ABB): “In addition, you can save time on basic research, for example when you’re trying to get to grips with a new field. If you have the luxury of consulting an expert you might expect to get an answer in hours depending on the complexity of your request. The next option would be using a conventional search engine but that still requires wading through a lot of information just to answer your one question. Accelerating the research phase with ChatGPT can support faster decision making.”

ROY FUNCK (ABB): “Google Bard has the advantage of being able to access up to date information where the public ChatGPT stops at 2021. The latest GPT4 and Microsoft Bing also provides references/sources for answers, which is very useful for more scientific research.”

IGOR BALASHOV (MICROSOFT): "It's important to note that Microsoft employs various generative AI technologies beyond GPT-4. Bing Chat serves as a public LLM for democratizing search, but Microsoft's cognitive services portfolio is multifaceted. We're integrating LLMs and generative AI into traditional MS Office products. The Copilot framework in Microsoft 365 and Microsoft Power Platform layers OpenAI tech, offering AI-driven assistance for content creation and tool development, democratizing creativity.

Our focus extends to enhancing user experiences by linking with Azure cloud. For coding, we're introducing a novel approach: customers can describe solutions in everyday language, and Copilot translates it into low-code apps or websites. This minimizes complexity, expediting development for both citizen and professional developers."

Overall benefits – and limitations

TOMAS TENGNER (ABB): “The most salient benefit of using LLMs is boosting efficiency and productivity. Models like GPT4 can assist us in doing a better job, while saving time frees us to focus on our most value-added tasks. In a sense they provide individuals with superpowers to move faster towards mastery – a master marketer, master speech writer, master coder – allowing us to reach further.”

ROY FUNCK (ABB): “I just want to emphasize again that the answers LLMs generate are not always right. You can’t 100 percent trust the answers ChatGPT comes up with. It’s just a mathematical model. It produces answers that may sound convincing, but, since it is only a model, it has no real clue as to what it is doing.

In addition, from a general perspective, answers could potentially discriminate against certain sections of the population as they might include hidden biases reproduced from the vast public domain dataset. You also have to be careful not to embed biases in prompts.”

OLA HJUKSE (ABB): “In the same way as the discriminatory perspective is a clear area of sketchiness, so is the fact that LLMs may deliver wrong answers. They are not a replacement for software engineers but rather an assistant. Code generated by ChatGPT should always be verified before implementing. Everything needs to be checked. Keeping humans in loop acting as a validation gateway of output is necessary. Again, you also need to be careful of legal issues in terms of it reproducing code that has IPRs connected to it.”

TOMAS TENGNER (ABB): “I agree. Right now, you definitely have to quality check the results but probably very soon you’ll only need to do regression testing on the source code to quality check the outcome.”

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Models like GPT4 can assist us in doing a better job, while saving time frees us to focus on our most value-added tasks.

Next steps in LLM commercialization?

TOMAS TENGNER (ABB): “It will be interesting to explore with our partner Microsoft training an LLM on our own proprietary data to maximize that knowledge base. The model would likely be adapted from Bing GPT4 but in a bespoke way because we don’t want to release information to competitors. Only Microsoft would have access. Competitors are in the same position, of course. But the key is do we have sufficient own corporate data for the model to become smart enough to useful?”

“Because GP-4 now includes multimodal capabilities, ie, it can understand images, it could open up the possibility to train models on our single-line diagram design instructions for Onboard DC Grid™. This would help to automate a lot of daily work especially in the bidding phase of projects. Owning a bespoke model trained on our own proprietary data has great potential.”

OLA HJUKSE (ABB): “It could be very useful also for our technical support service, as engineers would be able to use our own siloed data to come up with suggestions as to what caused a specific issue. That would save them a lot of time.”

IGOR BALASHOV (MICROSOFT): "I concur. A pertinent advancement for all companies lies in crafting GPT-4-based models capable of contextualizing conversations. ABB has the potential to establish a contextualized Chat, utilizing internal data alone.

We're actively collaborating with ABB on pilot initiatives to enhance customer service via generative AI for summarizing case resolutions, freeing humans from routine tasks. Additionally, our GitHub Copilot promises significant strides in software development's agility. The interplay between GPT-4 and OpenAI's DALL-E for image generation holds promise for product design aesthetics.

It's worth emphasizing the necessity of innovative players and heightened competition to drive technology adoption across diverse industries."

PETER SARLIN (SILO AI): “Quite right. Customers we talk to are concerned about using closed generative AI models. I definitely think the commercial future of LLMs is in secure, bespoke downstream applications built on top of open or otherwise accessible base models, fine-tuned on narrow proprietary data sets, and trained to solve specific use cases very well.”

TARMO PAJUNEN (SILO AI): “ABB has a huge pool of proprietary data where generative AI could be very powerful in bringing new ways of utilizing, reusing and accessing that data. But in general terms of monetizing LLMs going forward, I believe it will happen with various different types of interfaces and integrated to products and services. I believe that a minority of use cases are best solved by manually chatting to AI with text interface. It will be interesting to see what it looks like in two to three years’ time.”

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ABB has the potential to establish a contextualized Chat.

The genie is out of the bottle

TOMAS TENGNER (ABB): “Things are moving extremely fast. Big companies have to deploy this technology because they can’t risk being left behind. Where would you be if a main competitor used it to radically improve the efficiency of their processes from coding to marketing and sales, for example? The challenge is that nobody quite knows where it is going, or what is happening inside the ‘mind’ of the models. We can certainly use of GPT4, but what will GPT5 bring?”

ROY FUNCK (ABB): “What is certain is that the existing regulatory framework simply doesn’t apply any more. The speed of regulation is glacial compared to this exponential progress, so we need a new approach and fast. In a few years’ time, our main competitor may be an AI system with no humans involved. What would people do if we rationalize ourselves out of work? Do we really want that?”

TOMAS TENGNER (ABB): “It’s a bit scary but I also think these type of AI systems can be of immense value to humanity. They may come up with counterintuitive solution that can be used to develop new concepts. The internet contains so much information that could be combined in new ways, connecting different fields of expertise that no human could. I certainly think they can be very helpful in the development of my specialty, which is battery and electrochemical technology, but it will need to be carefully managed.”

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ABB has a huge pool of proprietary data where generative AI could be very powerful in bringing new ways of utilizing that data.

ROY FUNCK (ABB): “At the same time, we should never trust a super search engine that combines texts. It can certainly dig out data but there is no guarantee the assumptions will be correct. We will have to be careful about where we use the technology in terms of actual benefits rather than hype.”

IGOR BALASHOV (MICROSOFT): “Our current engagement with AI is productive. If the outcomes extend further than human understanding, it prompts a need for thoughtful contemplation. In the coding realm, GPT-4 LLM can identify correlations, unexpected solutions, and permutations that may not be apparent, owing to GitHub's extensive training dataset. Thus, the development of solid and responsible AI frameworks remains vital, reflecting Microsoft's commitment to responsible AI principles. Additionally, it's essential for society to collectively assess suitable contexts for deploying this technology. Along these lines, we firmly advocate for the inclusion of regulatory measures to help shape the industry.”

PETER SARLIN (SILO AI): “Primarily I would focus on the possibilities and opportunities that come with these new technologies, but I agree that we will have to also be concerned about potential risks. For instance, despite not being artificial general intelligence, implying human-level general intelligence, today we have AI that passes the Turing test. The implications of that will pose risks that we need to consider.”

Blink and you might miss the next exponential leap in generative AI. Watch this space. •

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The discussions took place in April/May 2023.

Aeolus collaboration offers a compelling path to future-proof yachting

Designed to stand the test of changing attitudes to the environment and lifestyle at sea, the unique superyacht concept Aeolus is a multidisciplinary collaboration with power and propulsion technology from ABB at its core.

In late summer 2022, custom yacht builder Oceanco hosted a roundtable to discuss a revolutionary vessel concept – Aeolus – that would set new standards in superyacht design. Bringing together some of the sharpest creative and technical minds from the yacht industry and beyond, the meeting aligned with the goals of Oceanco 'NXT', an initiative that seeks to respond to evolving attitudes by harnessing perspectives and skillsets from different sectors.

In attendance were Giles Taylor, a renowned British car designer responsible for Aeolus's exterior design; Njord, the yachting arm of award-winning interior design studio Bergman Design House; Lateral Naval Architects, a superyacht naval architecture and engineering specialist; MTU Solutions, the power systems business unit of Rolls-Royce, which will deliver the vessel's prime mover engines; and ABB, which will supply an integrated power and propulsion technology solution.

"All the partners involved in this project are exceptional in their field, and that shone through at the roundtable," comments Paris Baloumis, Group Marketing Director, Oceanco. "This was a new way of collaborating for Oceanco, but it set the scene for the whole concept, providing an opportunity for everyone to contribute their thoughts and knowledge and share constructive feedback. We concluded the meeting entirely convinced that this would be a fruitful collaboration."

Future-proof for energy transition

As the engineering partner, Lateral was tasked with "shaping the technical narrative" for a vessel that would address current and future requirements in a feasible and marketable way. Key to fulfilling this ambition is the Energy

Transition Platform (ETP). Developed by Oceanco and Lateral in collaboration with MTU and ABB, the Energy Transition Platform is an adaptable architecture concept that presents a practical roadmap to more environmentally friendly superyacht operations in three stages.

At stage 1, Aeolus is fitted with ‘current state-of-the-art’ technology for efficient diesel-electric operations, including three 16V 4000 M54 main diesel gensets and two 16V 2000 M782 auxiliary diesel gensets from MTU; a future-proof fuel storage system engineered by Lateral; and dual Azipod® electric propulsion units, battery energy storage system and Onboard DC Grid™ with a Power and Energy Management (PEMS™) system from ABB.

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All the partners involved in this project are exceptional in their field.

There are direct parallels between Onboard DC Grid™ as a physical system and the Energy Transition Platform as a concept, says Riccardo Repetto, Global Segment Manager, Superyachts, ABB Marine & Ports. “Onboard DC Grid™ power

distribution supports the principles of the platform," he says. "It is flexible and customizable by design, facilitating the integration of new energy sources and loads as requirements evolve and technology develops. For Aeolus, as for so many existing vessels across multiple segments, it represents the future-proof foundation for achieving long-term efficiency and sustainability goals."

At the Energy Transition Platform stage 2, the 'mid-life upgrade', the two auxiliary diesel engines are replaced by High Temperature (HT) Polymer Electrolyte Membrane (PEM) fuel cells fueled by methanol. The fuel cells are capable of supplying power for hotel load as well as slow steaming, thereby reducing carbon dioxide emissions at anchor and harbor conditions. The architecture installed at stage 1 accommodates a second fuel tank for methanol storage.

Finally, at stage 3, Aeolus's 'end state', sees the main diesel prime movers replaced with MTU's methanol internal combustion engines to enable fully methanol-powered operations for minimized CO2 emissions both at anchor and at sea. At this stage, the vessel is entirely diesel-combustion engine free, with both fuel tanks storing methanol.

While Onboard DC Grid™ is the architectural backbone of the Energy Transition Platform, ABB's Power and Energy Management System (PEMS™) provides the digital core, acting as the critical interface between power sources. "In a hybrid system like this, the power from the batteries must be coordinated with the power from the engine and fuel cells to best serve the yacht's needs depending on the operational profile," says Repetto. "The PEMS™ ensures optimal use of total power sources for safe, efficient and environmentally friendly operations whether the vessel is idle using dynamic positioning or sailing at full power."

Lateral thinking for superyachts

Although the Energy Transition Platform emerged from the Aeolus concept, it is applicable to any future-focused superyacht project and can be adapted to serve other vessel segments. The essence of the platform, says James Roy, Managing Director, Lateral Naval Architects, is its ability to offer owners a 'compelling' means of future-proofing their vessels.

"Superyachts built today will operate over a broad time frame spanning multiple phases of energy transition, meaning they will need several upgrades over the course of their lifespan," he notes. "However, owners don't want their yachts, as such valuable assets, to undergo major structural surgery at great cost. What they want is a compelling way to future-proof their vessels, to allow seamless upgrades when the time comes – and that's exactly what the platform offers them."

Addressing owners' requirements and desires is a central theme of the Aeolus concept and calls for the synchronization of technical and aesthetic factors, adds Roy. "Like any superyacht, Aeolus is designed to deliver luxury, so while following the Energy Transition Platform is crucial, we also adhere as closely as possible to Giles Taylor's aesthetic vision," he says. "Of course, there is always a degree of push and pull between engineering and design in superyacht projects, but in this case, given the extensive technical space required to accommodate solutions covering a decades-long transformation, striking the right balance is particularly tricky."

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This is a vessel concept designed to stand the test of time.

Here, the frank and open discussion stimulated by Oceanco's roundtable – and the close relationships it helped to nurture between participants – is proving pivotal. Through cooperation and compromise, the project partners are able to conceive a visually and technically sophisticated design that pushes boundaries in terms of both lifestyle and sustainability.

According to Baloumis, this marriage of style and substance is integral to meeting the demands of the modern superyacht owner. “A yacht is an extension of its owner’s brand, and owners want to be seen as living their values through their vessels,” he says. “Previously, the average yacht owner’s primary concerns were how the vessel looked and how fast it could cruise, but today, Oceanco serves a growing cohort of what we call ‘young-minded’ clients, so while aesthetics and lifestyle will always be crucial considerations, environmental responsibility is now equally important.”

Guided by the winds of change

As the Aeolus concept so convincingly demonstrates, sustainability and luxury are not mutually exclusive. Exemplary is the vessel’s recycling of waste heat to warm the pool – a staple of Oceanco superyachts. Even its eye-catching silhouette – sleek, smooth and perfectly balanced – helps to optimize hydrodynamic efficiency. Again, ABB’s electric Azipod® propulsion system, the most advanced of its kind on the market, reduces fuel consumption and emissions while minimizing noise and vibrations for a more comfortable onboard experience.

The harmony between environmental credentials and lifestyle achieved through technology is echoed in the vessel's interior design. Materials painstakingly selected by Njord include a premium plant-based leather alternative sourced from climate-positive cacti and organic linens made using non-toxic processes and dyes.

"In Greek mythology, Aeolus was the keeper of the winds," explains Baloumis. "Just as its namesake would help seafarers safely on their journey by directing the winds in their favor, our visionary superyacht seeks to guide the industry towards a more efficient and sustainable future."

Commercial interest in the Energy Transition Platform is building fast, he adds. "We see no reason why Aeolus can't set the standard in future-proof yacht building for decades to come – after all, this is a vessel concept designed to stand the test of time." •

Introducing the FLAGSHIPS Zulu vessel

Paving the way for hydrogen-powered operations on inland waterways

Hydrogen-related technologies have developed significantly during the past years and are now becoming ready for piloting also in waterborne applications. With the deployment of two hydrogen-powered vessels, the FLAGSHIPS project aims to significantly increase the market potential of hydrogen fuel cells in the marine sector. The project is expected to generate business cases for various stakeholders in the marine, ports, and fuel cell industries, with an anticipated impact on the industry as a whole.

Dr. Arber Haxhiu,
Business Line
Technology
Manager,
ABB Marine & Ports

The shipping industry is under pressure to improve efficiency and reduce environmental impact, driven by demands from customers, investors, and regulators alike. Strict targets have been set by institutions such as the International Maritime Organization (IMO) and the European Union (EU) to reduce greenhouse gas (GHG) emissions and regulate pollutants.

The IMO has set targets to reach net-zero GHG emissions by shipping by or around 2050. It is not yet fully known how this target will ultimately be met, but the general understanding is that it is not achievable by conventional means alone, such as improving the efficiency of internal combustion engines, optimizing vessel and propeller hydrodynamics, or reducing sailing speed.

Hydrogen has been considered as one of the most potential technologies to achieve a zero-emission shipping industry. It can be produced locally using renewable electricity, such as wind and solar power, which makes it a clean, low-carbon fuel option. Onboard vessels, hydrogen can be used with fuel cells which convert it into electricity to power electric motors, producing only water and heat as by-products. Since inland waterway vessels typically operate on short, fixed routes and have regular access to ports, it is feasible to establish local hydrogen supply chains to support their operation.

Figure 1: The self-propelled barge Zulu 06

However, like any new technology, hydrogen and fuel cells have their critics, especially when it comes to financial and technical challenges related to hydrogen production and storage. Production of green hydrogen is dependent on the availability of low- or zero-emission-generated electricity, while to achieve reasonable energy density, hydrogen must typically be stored using high compression (typically 200–700 Bar) or liquification at very low temperatures (< -253°C).

Historically these challenges have hindered the adoption of hydrogen and fuel cells, especially in waterborne transport, due to relatively high cost of hydrogen compared to traditional oil-based fuels and limited space onboard vessels. Nevertheless, hydrogen-related technologies have developed significantly during the past years and may now be ready for piloting also in waterborne applications.

The consortium of 11 partners [1] behind the EU-funded FLAGSHIPS project believe hydrogen-powered vessels are commercially viable and hope the project will prove the benefits. The aim is to design, build, and deploy two commercially operated, inland-waterway vessels equipped with hydrogen fuel cells as demonstration cases.

One of the vessels, named Zulu 06 (Figure 1), is a self-propelled barge that will operate on the River Seine in the center of Paris, France. The other one is a container ship that will operate between Rotterdam, Netherlands and Duisburg, Germany. Both demonstration cases will run on compressed hydrogen produced from electrolysis, thus enabling zero-emission operations. These demonstrations will showcase the benefits of using hydrogen-based powertrains for waterborne applications. The vessels are expected to start operating at the end of 2023, and after the 18-month demonstration period the shipowners aim to continue with commercial operations. This article discusses the Zulu 06 vessel and its fuel-cell powertrain designed for zero-emission operations.

A three-dimensional model of the upgraded Zulu 06 is displayed in Figure 2.

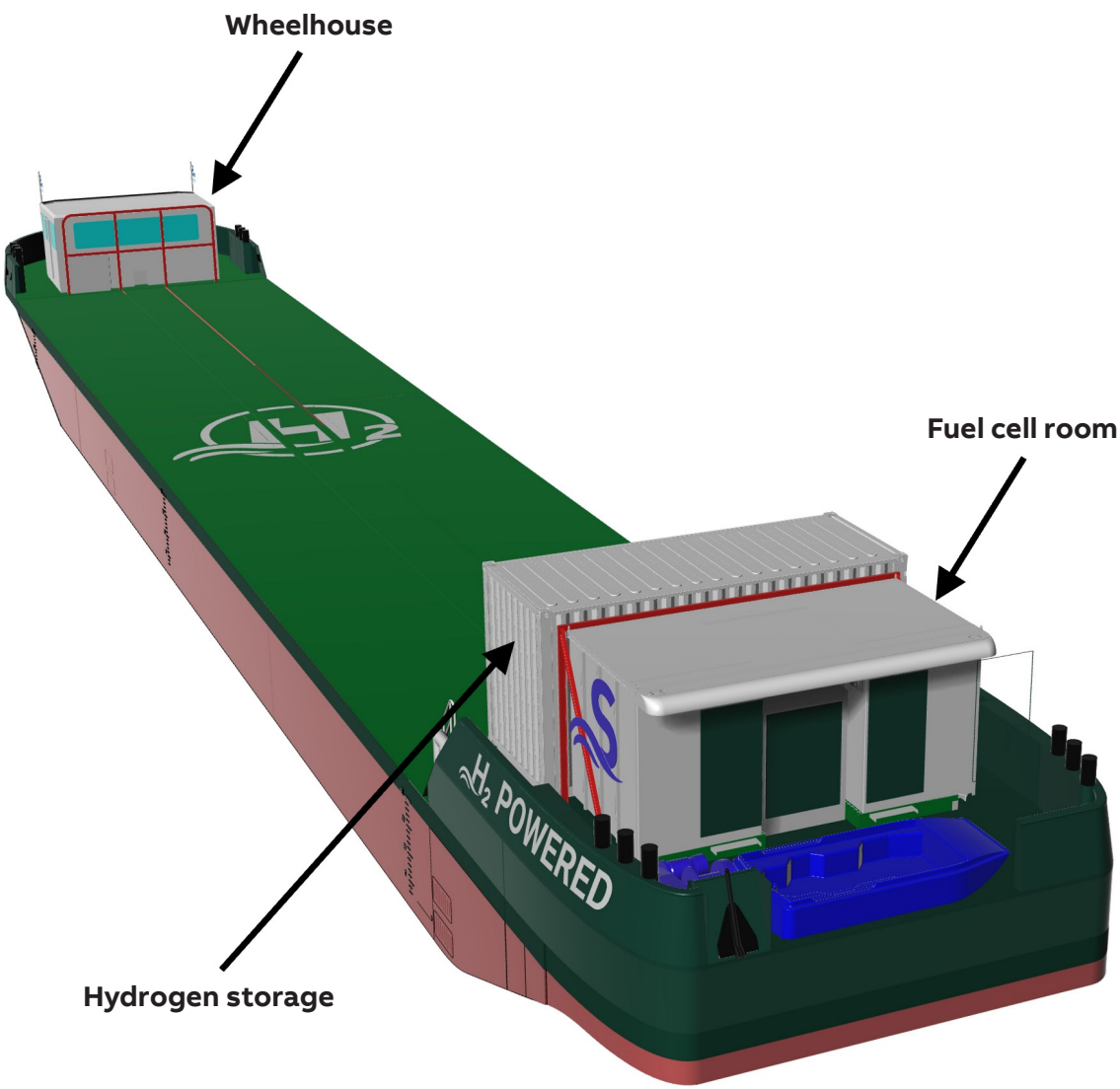

Figure 2: Hydrogen-based power system onboard Zulu 06

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Figure 3: FC Wave fuel cells

Originally, Zulu was designed and built as a diesel-electric vessel. However, under the FLAGSHIPS project, the vessel has been upgraded to fully electric powered by hydrogen fuel cells and lithium-ion batteries (retaining the capability to operate on diesel if necessary). The vessel's hydrogen storage has the capacity to store 350 kg of hydrogen compressed at 300 Bars. Being retrofit installations, both the storage and the fuel cells are installed above deck. The two FC Wave fuel cells (see Figure 3) are low-temperature proton exchange membrane fuel cells provided by Ballard Power Systems. Each has power capacity of 200 kW giving total power capacity of 400 kW. The primary role of the batteries is to provide dynamic performance enhancement for the fuel cells, which inherently provide optimal performance when operated at steady power loads. For example, whenever the shipboard power system experiences a large load power transient,

the batteries are configured to react rapidly by adjusting their power supply according to the transient requirements.

In addition to dynamic performance enhancement, the batteries also offer other system benefits, notably improved efficiency via strategic charging and discharging according to the vessel's power needs.

A generic illustration of the Zulu 06's power system is displayed in Figure 4. The primary power distribution method in the original diesel-electric system was AC (the diesel-electric section is highlighted with blue dashed lines). However, with the upgrade to hydrogen-electric, the system was expanded to include a fuel cell and battery-powered DC system, which interconnects to the AC system via DC/AC power conversion (the new system is highlighted with green dashed lines). In this system, the fuel cells and batteries are connected through DC/DC converters on a shared DC bus.

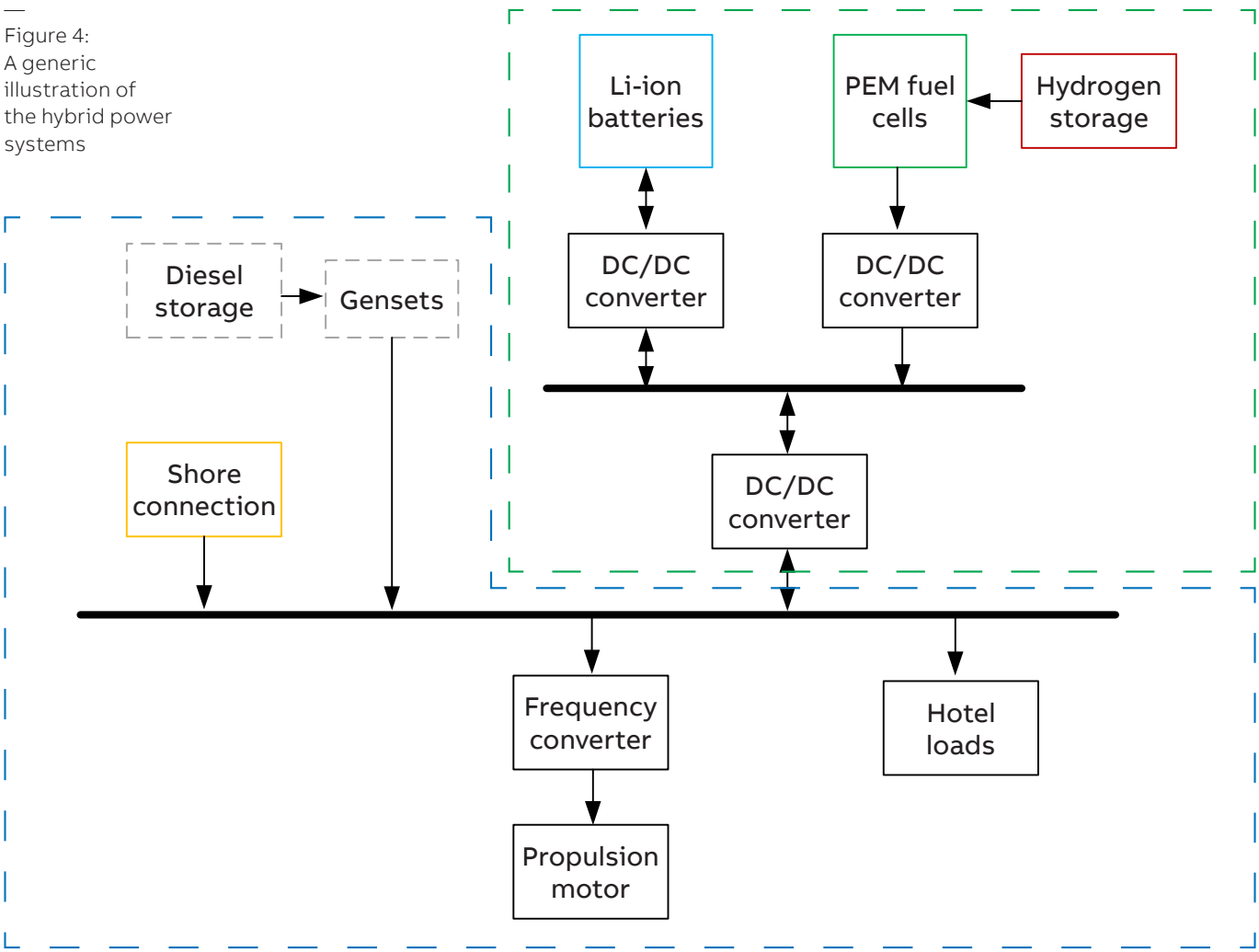

Figure 4:
A generic illustration of the hybrid power systems

The DC/DC and DC/AC converters are HES880 compact drives supplied by ABB. The power conversion devices are controlled by an ABB Power and Energy Management System (PEMS™), a new-generation power management system designed for seamless and efficient control of both new power sources (ie, fuel cells and batteries) and the more traditional ones (combustion-based generators).

The PEMS™ is a redundant control system that manages the power sources, distribution, and consumption. It is closely integrated with the electrical system and is based on ABB's industrial automation platform, the ABB Ability™ 800xA system, configured to meet the specific requirements of both the power sources and the vessel application.

The HES880-based powertrain and PEMS™ system prior to installation onboard are shown in Figure 5.

Currently, Zulu 06 is approaching the end of the approval process with classification society Bureau Veritas (BV). The ship has already undergone river trials for the diesel-electric part and is currently undergoing commissioning and testing of the hydrogen storage, fuel cells, batteries, and upgraded powertrain, including the PEMS™.

Prior to the commissioning process, the new hybrid power system underwent extensive hardware-in-loop (HIL) testing to optimize the operation of the hybrid power sources. HIL is a technology where real control hardware is connected to a simulated environment, such as the ship's power system model, and controlled to replicate the behavior of the end application. This method ensures that all control and automation algorithms of the hydrogen and battery-powered system are commissioned virtually before onboard installation. The system will consequently be ready for operation once remaining hardware-related tests are finalized and approved.

The FLAGSHIPS project aims to deploy two hydrogen-powered vessels by the end of 2023, with the goal of significantly increasing the market potential of hydrogen fuel cells in the marine sector. This technology has historically been lagging behind road transportation in terms of adoption. As part of the FLAGSHIPS project, once the vessels are deployed, the shipowners are committed to demonstrating their operation for 18 months, and expect to keep them in commercial operation after the demonstration period. The project is expected to generate business cases for various stakeholders in the marine, ports, and fuel cell industries, with an anticipated impact on the industry as a whole. The project partners have already

Figure 5: Fuel cell and battery power train skid installation

collaborated extensively with various stakeholders to complete the required safety assessment and approval for the two vessels, through the application and further development of existing regulations and codes.

The FLAGSHIPS project has received funding from Clean Hydrogen Partnership (previously Fuel Cells and Hydrogen 2 Joint Undertaking) under grant agreement No 826215. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation program and from Hydrogen Europe. •

FLAGSHIPS Consortium partners

[1] VTT Technical Research Centre of Finland, Espoo, Finland; Compagnie Fluviale de Transport, Le Havre, France; Future Proof Shipping, Rotterdam, Netherlands; Ballard Power Systems Europe, Hobro, Denmark; LMG Marin, Toulouse, France; LMG Marin AS, Bergen, Norway; ABB, Helsinki, Finland; SEAM, Norway; PersEE, Lyon, France; NCE Maritime CleanTech, Stord, Norway; Sogestran Group, Le Havre, France

Contact ABB Marine & Ports

Q4/2023

Setting sail for a green horizon

Sometimes inspiration from the past can help define the future. Jon Tarjei Kråkenes, Head of Orcelle Accelerator, Wallenius Wilhelmsen, explains how a trailblazing newbuilding project is looking to harness the potential of mother nature to propel cargoes across the oceans.

Jon Tarjei Kråkenes, Head of Orcelle Accelerator, Wallenius Wilhelmsen

"It's free, it's powerful, it's everywhere, it's not taxable, and there's no reliance on global supply chains to deliver it!"

Jon Tarjei Kråkenes answers a slightly incredulous question about the viability of wind to power enormous hunks of floating steel with complete poise. It's possibly not the first time he's been quizzed on this point.

Kråkenes is the recently appointed Head of Orcelle Accelerator at Norwegian-headquartered Wallenius Wilhelmsen, the world leader in car transportation and roll-on/roll of cargo. The company operates around 130 vessels, across 15 trade routes (to six continents), in addition to 120 global processing centers handling its mainly 'rolling' cargo, predominantly cars.

His team's role is to help accelerate the company's drive to decarbonization, assessing new energy sources, targeting green newbuilds, and working towards an initial goal of a 27.5 percent reduction in emissions by 2030 (compared to 2019).

But today he's discussing one key initiative - a true "lighthouse project" creating waves right across the world of shipping: The Orcelle Wind.

Oceanbird takes flight

Orcelle Wind is a voyage in inspiration – with a glance to the past as it sets sail for the future.

Scheduled to arrive in 2027, the ship is a 7,000-car capacity, 220-meter long, 40-meter wide Ro-Ro vessel that will use wind as its main form of propulsion.

—
Orcelle Wind

Boasting six 40-meter high composite recyclable plastic (PET) and glass fiber laminate sails – more akin to airplane wings than 'traditional' sails – the 70-meter high ship will operate at speeds of 10-12 knots under sail, reducing emissions to air by as much as 90 percent. Underwater radiated noise, a major issue for sea life, will also be dramatically reduced, with less activity from generators, engines and propellers.

Orcelle Wind will be the first 'Oceanbird' vessel, a concept developed by Sweden's Wallenius Marine, with an ingenious sail design that can be 'folded' to reduce surface area in strong winds, or when entering harbors and passing under bridges. The entire sail apparatus can be tilted to ensure adequate clearance for the ship.

In January 2023 the EU announced nine million euros funding for the project, from Horizon Europe. Kråkenes is adamant that this proves the project is far more than a headline-grabbing idea to market the company's green ambitions: "This is rapidly moving from concept to reality," he states, with complete conviction.

But, to ask an obvious question, what if there's not enough wind?

His answer explains why the vessel's emissions reduction is "up to 90 percent" rather than the promise of zero.

Positively pragmatic

"We have to have a back-up engine," Kråkenes comments, adding that discussions are ongoing as to exactly how this should be powered, with assessments of methanol, LNG and other alternative fuels underway.

“That’s essential if there’s too much wind as well as too little – for example, if the vessel has to maneuver away from a storm – or for operations moving in and out of ports. In addition, our customers have clear supply chain demands and need reliable transit times to meet their own delivery schedules, so we can’t be 100 percent reliant on wind.”

So, the reality is not zero emissions, but the climate gains are still compelling for an industry under pressure to meet increasingly ambitious goals.

“If we compare apples with apples here, a conventionally fueled car carrier might transport its cargo across the Atlantic, for example, at an average speed of 16 knots. If we’re going to aim for 10-12 knots then we need customers to be onboard with slightly longer transit times. The 90 percent headline scenario is for a single sailing across the Atlantic (compared to the conventional carrier), but over longer periods – such as a year of operations – we can still deliver the same cargo at 10-12 knots with emissions reductions in the range of 50-60 percent.”

This, he argues, is “a huge saving” and – when future fuel prices and potential carbon taxes/penalties are taken into consideration – a “super interesting” commercial proposition as well as an environmental boon.

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It’s free, it’s powerful, it’s everywhere, it’s not taxable, and there’s no reliance on global supply chains to deliver it!

Testing times

The eye-catching Oceanbird wings are, arguably, the project’s main attraction – combining a flavor of shipping’s past with a strong focus on the future. Consisting of a main sail and flap just like an airplane wing, the towering structures will be constantly adjusted and optimized, thanks to an array of sensors and an automated control system.

“It’s not like the old days,” Kråkenes smiles. “Manually controlling six wings of this size together, to both exploit the wind and meet commercial objectives, is out of the question, so automation is a must.”

As is testing. This is the first concept of its kind, so rigorous testing is a prerequisite for development, and classification, with a full-scale sail rig due to be put through its paces on land later this year. This will be followed in 2024 by a retrofit of a single sail on an existing ship to gain operational insight of the system/s at sea.

“This in itself represents an interesting challenge,” Kråkenes comments, explaining how a newbuild design can be optimized for wind power in an entirely different way to a legacy build: “You can’t just stick it on the deck,” he smiles.

Instead, the rig will be attached to a frame that fits over the vessel, stabilizing the wing and carrying the considerable weight, whilst not impinging on cargo capacity.

Which raises the interesting question; would retrofitting sails on the existing fleet of over 100 ships be an Oceanbird possibility?

“We need to begin testing and get some real-world data and insights before answering that,” he says. “Once that’s underway we’ll have a better idea of how wind fits into our wider energy mix going forwards.”

Collective commitment

Although momentum is clearly building, the project is still in its early stages, making it difficult for Kråkenes to disclose too many details. A shipyard has yet to be finalized, he notes, while the actual routes the Orcelle Wind will ply are under discussion. Here he does stress the ship will be very flexible in its operational capabilities, but suggests the Atlantic would be a natural home for the company’s first pure wind car carrier.

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Retrofitted WALWIL vessel

As far as the reaction to the concept is concerned, it has been overwhelmingly positive.

“It helps that Wallenius Wilhelmsen has a model of working in partnership,” he states. “When you’re looking at projects of this nature – and overall objectives of decarbonizing the shipping industry – you have to work in partnership. No one can do this alone. So, from the early days we’ve been clear about what we want to do and our desire to engage with like-minded stakeholders and partners for this journey. That has been very successful so far.”

Partners include research and academic institutions from Belgium, Sweden and Greece (University of Gent, Kungliga Tekniska Högskolan, National Technical University of Athens and RISE Maritime), cluster organizations (Maritime Clean Tech), weather experts (StormGeo), and key suppliers (AlfaWall Oceanbird, DNV and Wallenius Marine). Crucially, customers also appear to be onboard for the shift to wind.

“Forward-thinking cargo owners are eager to minimize carbon footprints and Orcelle Wind can be a key link in more sustainable supply chains,” Kråkenes says. “We were fortunate to have Volvo sign with us from the outset as a partner and recently Mercedes-Benz has signed a letter of intent for participation. We’re confident more will follow.”

—

This is rapidly moving from concept to reality.

Fighting on many fronts

But don’t make the mistake of thinking Wallenius Wilhelmsen will be switching to full wind power across its entire world fleet anytime soon. Kråkenes opines that that’s probably a step too far and that ships like the Orcelle Wind are just one piece in the wider decarbonization puzzle.

“We’re considering a broad spectrum of alternatives and working with the fleet today to reach our goals tomorrow,” he states. This includes, he explains, optimising hulls and propellers, refining operations, for example adjusting speed, and looking at how to integrate new energy sources to reduce emissions.

The company has also recently become the first major global shipowner to adopt a fully AI-based approach to vessel optimisation, with a solution developed in partnership with Athens-based AI specialist DeepSea. This harvests real-time data – covering parameters such as fuel consumption, shaft power and speed – utilising an algorithm to deliver analysis to both onshore teams and instructions to vessel captains on optimising routes and operations.

This could reduce fuel consumption on existing ships by up to 10 percent.

“We’re considering all possibilities, fighting on many fronts, to reduce our environmental impact and help customers, and society, decarbonize supply chains,” Kråkenes concludes. “We want to lead the way and help accelerate the transition to a more sustainable future. With Orcelle Wind you could say we’re sailing in the right direction.” •

Partnering for progress

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Jostein Bogen, Global Product Line Manager Electric Solutions, ABB Marine & Ports

Traditionally, we’ve seen shipping transition from one ‘silver bullet’ to another, moving from manpower and wind power to coal/steam, and from there to oil. In the absence of one catch-all power source to fuel today’s transition, we’re excited to see ambitious shipowners such as Wallenius Wilhelmsen embracing bold, sustainable solutions such as wind in their future energy mix.

As Jon Tarjei imparts, even on the most feasible trades and segments, wind alone might not be the answer for all large, deep-sea vessels, but it could be a very interesting piece of the energy puzzle for some. Innovations like the Oceanbird sails will no doubt help put wind firmly on the industry agenda in the years to come.

Here at ABB we’re working to deliver the flexibility owners and operators need when considering future fuels. With an emphasis on solutions that enable electric and hybrid propulsion – helping drastically reduce emissions – we see wind, and other renewables, as complementary, rather than competing, power sources.

Going back to Jon Tarjei, he talks about the importance of working in partnership to accelerate change, and we couldn’t agree more. That means collaborating with stakeholders throughout the industry value chain, but it also encompasses bringing different technologies and fuels together so they can work in unison towards the goal of greener shipping.

There may not be a silver bullet, but we can still hit our targets if we approach this challenge collectively. ABB is committed to playing its part.

Variable speed shaft generator systems

A versatile and cost-efficient way to save energy and reduce emissions

In June 2021, the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) adopted new amendments to the IMO's MARPOL Convention, including new energy efficiency requirements – the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII).

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Eason Xiong, Global Product Manager – PTI/PTO, ABB Marine & Ports China

—
Vista Feng, Global Product R&D Manager – PTI/PTO, ABB Marine & Ports China

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Ray Qiu, R&D Engineer, ABB Marine & Ports China

The EEXI requires calculating CO2 emissions during transport work, considering only the design parameters of the ship. It does not require any measurement or reporting of actual CO2 emissions during actual operations. While both the EEXI and the Energy Efficiency Design Index (EEDI), which came into effect in 2013, apply the same criteria, the EEDI is applicable to new ships and the EEXI for existing tonnage. The CII, which is used to measure actual CO2 emissions during vessel operations, also came into effect in January 2023, coinciding with the implementation of the EEXI.

Shaft generator systems – simply defined as rotation electrical machines that take power from the main propulsion engine to produce electricity – have been installed on small and medium-sized ships since the beginning of the direct current (DC) era. However, they have only become 'standard' equipment in larger merchant ships, especially container ships, in the past few years. The shaft generator system has made significant advances with regard to efficiency, weight, and size with improved functionality being enabled by the development in power electronics technology, generator design including permanent magnet machines, and higher performance control systems. However, it is their inherent simplicity, high efficiency, and energy-saving capability (enabling lower fuel consumption and avoidance of CO2 emissions) that make shaft generators a viable and cost-effective system to help ship owners and designers meet ever-more stringent efficiency and emission limits.

System structure overview

The structure of a shaft generator system is relatively simple. In its simplest form the generator is mechanically connected to the main engine, usually through a gearbox and operating at a fixed speed in order to produce a constant frequency to the electric installation. As the main engine typically has a lower specific fuel consumption than the smaller auxiliary engines, the overall fuel efficiency can be improved. Although the direct mechanical connection is simple, it sets some limitations to the application of the shaft generator and the rest of the propulsion system. For example, in the case of fixed-pitch propeller propulsion, the frequency of the shaft generator changes in tandem with speed fluctuations of the main engine. This necessitates either a higher design requirement for the power plant or simply limits the use of the shaft generator. A constant frequency can be produced with controllable-pitch propeller propulsion where the engine speed is maintained constant, however the propeller will not work in the most efficient way, in particular during low thrust operations.

Given the limitations of using direct mechanical connection of shaft generators, variable speed shaft generator systems have gradually become the preferred solution thanks to the evolution of power electronics technology and generator design, including permanent magnet machines, enabling enhanced versatility and performance control. The setup consists of the shaft generator, frequency converter, transformer (if applicable), and control system.

The shaft generator machine itself can be of the permanent magnetic (PM), synchronous excitation, or induction type. A simple comparison of PM and excitation machines is presented in Figure 1:

Type item	Synchronous excitation	Permanent magnetic (PM)	Remarks
Excitation	Electric, rotor windings	PM material on rotor	
Weight	Heavier	Lighter	Similar stator but different rotor design
Dimension	Larger	Smaller	
Air gap	8–10 mm	6–7 mm	Smaller air gap leads to smaller footprint
Efficiency	Approx. 93% - 94%	Approx. 96%	PM has more constant efficiency under full operation rpm and loading conditions
Maintenance	More often	Less	The use of carbon brushes is necessary for excitation machines, which need to be replaced regularly

Figure 1: Comparison of PM and excitation machines

As the comparison shows, PM generators have technical advantages compared to synchronous excitation generators, and are today the most commonly used type.

Frequency converters form the core of variable speed shaft generator systems. ABB uses the latest low-voltage frequency converter technology, which has the following characteristics:

- Wide power range, up to 6 MW
- State-of-the-art control methods, common options, tools, and components
- Robust and reliable; meets all marine compliance requirements
- Modular, with fast maintenance and easy serviceability
- Suited to both liquid cooling or air-cooling methods

The system drive consists of motor-side and grid-side inverters. The motor side inverter will be either a diode rectifier or IGBT inverter depending on the motor type and required functionality, while the grid-side IGBT inverter is used to provide power to the AC grid with constant voltage and frequency.

The frequency converter is configurable to single- or multi-drive with the possibility to connect several energy sources and loads to the same DC link. This allows designs where auxiliary engines may easily be integrated with other power sources that produce electricity like fuel cells, solar panels, shore connection, wind power, or energy storage. As regulations and requirements for emissions reduction become stricter, the shaft generator system can be relatively easily extended with new and emission-free energy sources.

Operation modes

Variable speed shaft generators can be used operationally as a power generator (PTO) for the vessel's electrical network, optimizing the use of the large engine, while reducing the need to run auxiliary generators; booster motor (PTI) for the main propulsion shaft, to cover peak power or 'worst-case scenario' needs; or alternative propulsion system (PTH) providing redundancy and safety for unexpected situations. Typical and illustrative configurations are shown below.

Power Take-Off (PTO)

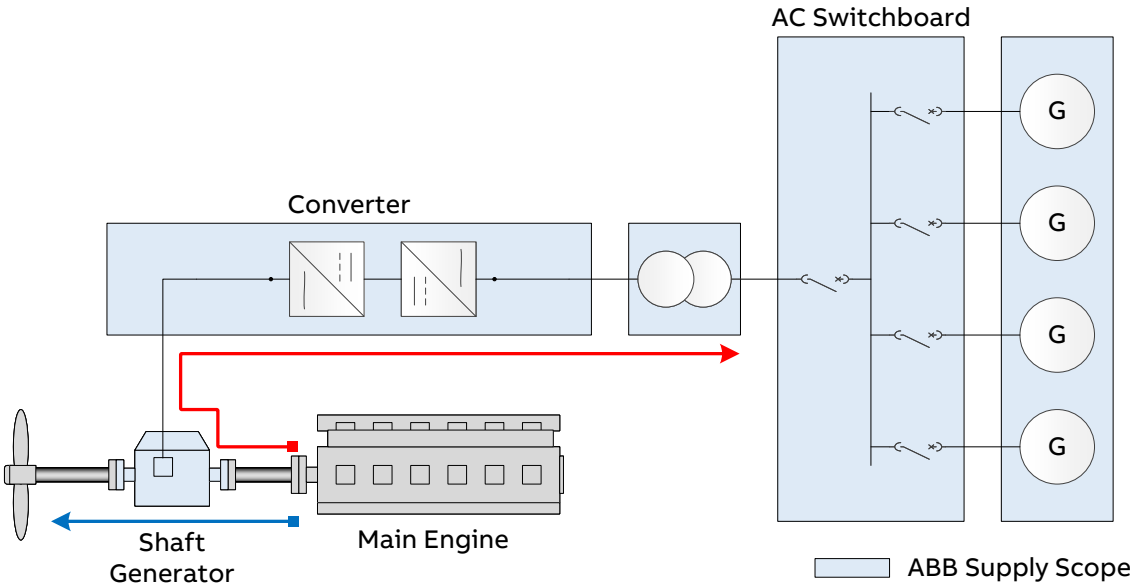


Figure 2: PTO uses the main engine to generate power to the ship's grid via a frequency converter. It can operate alone or in continuous parallel with other generators. It uses droop control for active and reactive load sharing.

Power Take-In/Power Take Home (PTI/PTH)

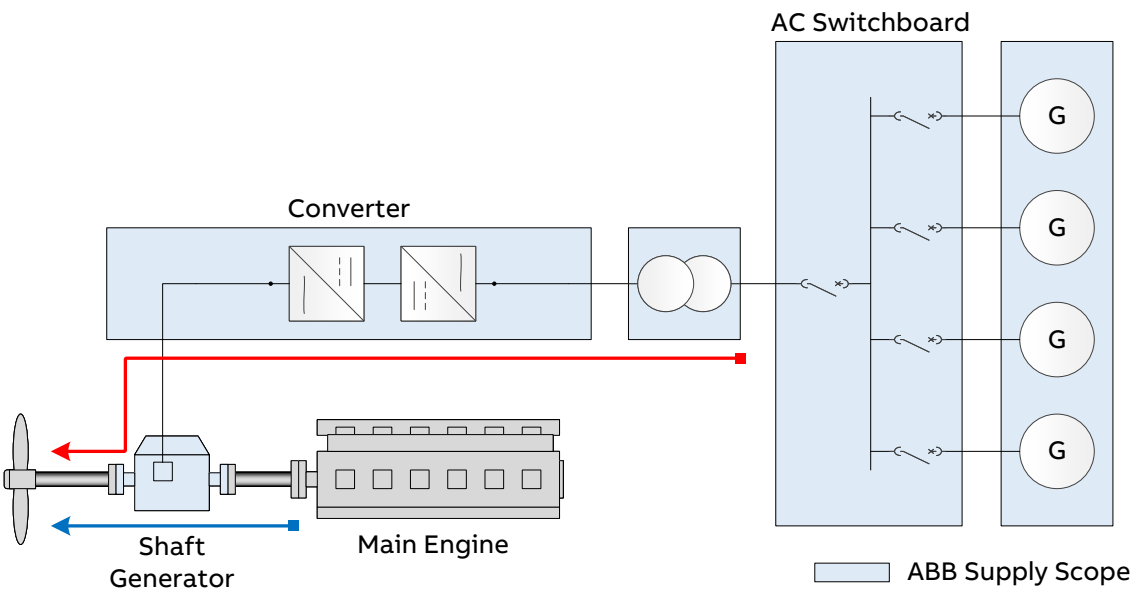


Figure 3: In PTI mode, the shaft generator operates as an electric motor to boost the main propeller with the power supplied from the ship's grid via a frequency converter. In case of main engine failure or if it is stopped, the shaft generator can drive the main shaft individually, ie, PTH (Power Take Home).

Shore connection

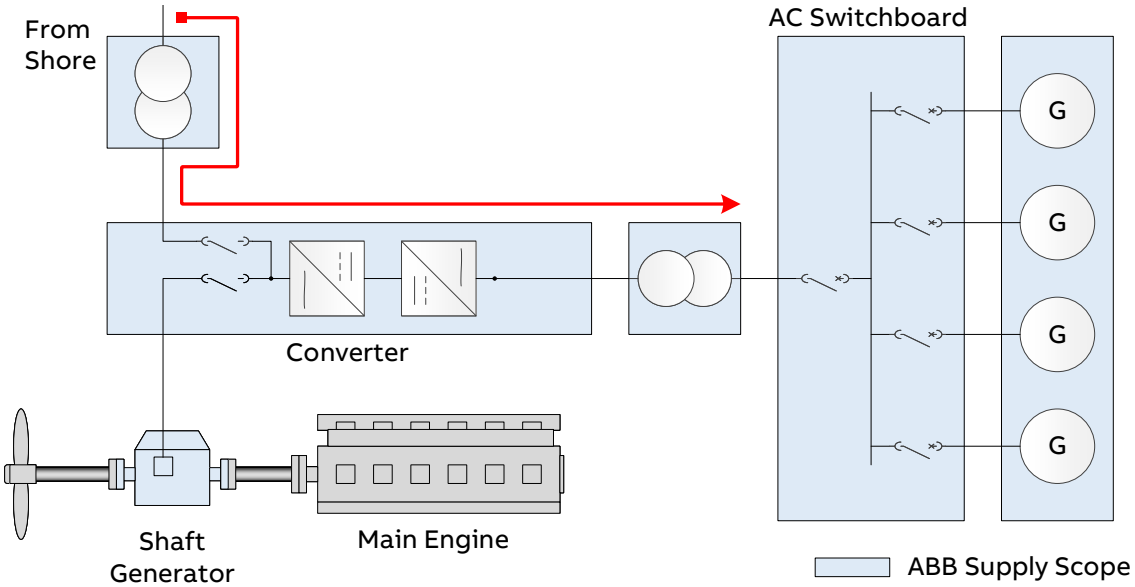


Figure 4: Shore connection is an optional function of ABB's variable speed shaft generator systems. It supports both 50Hz and 60Hz shore power and can use the same shaft generator inverter with a change-over switch since the main engine will be stopped when the ship is berthed. The shore transformer may be installed either onboard or onshore.

Integration of new energy sources

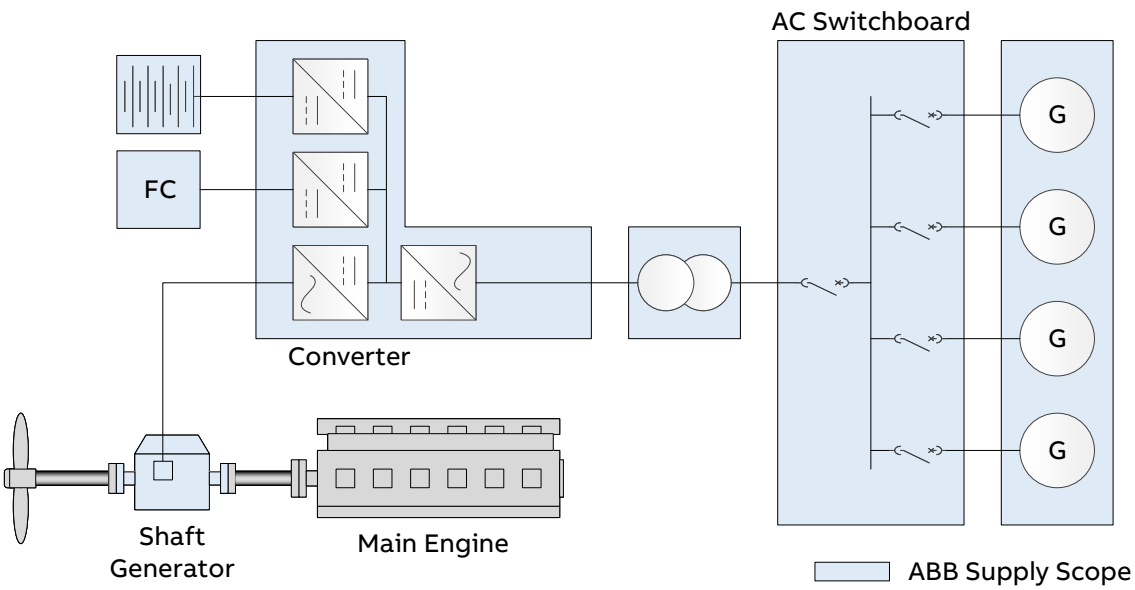


Figure 5: Thanks to the modular design of the shaft generator frequency converter, new energy sources such as fuel cells and wind and solar power can be easily connected to the converter's DC link with DC-DC converters to adapt the voltage and control the power flow. This allows the vessel to utilize current low- or zero-emission technologies or integrate new technologies that may become available during its lifetime.

System performance and features

Although the operation modes above are simple enough to define, this is insufficient for the successful delivery of a system. ABB variable speed shaft generators have always been designed to satisfy the highest leves of safety and reliability. Key system performance features with illustrations are shown below. These include short circuit protection capability in case of faults; managing harmonic distortions to protect the ship's grid; equalized loading across parallel auxiliary generators; fast compensation capability to handle rapid load changes; encoder-less control of the rotor pole position for motor control purposes; advanced synchronization with the ship's grid on start-up; and power factor compensation for shore power connection. While the system is customized to the requirements of each vessel project, these features combined are designed to ensure safety, efficiency and low volume footprint.

Short circuit (SC) current contribution

In case of an SC in the AC power system, the power source can provide enough current lasting for a certain time in order to secure that the grid's SC protection system functions selectively according to the current protection principle. The same applies to shaft generator applications. ABB's frequency converters can deliver the defined SC current for up to four seconds to serve this purpose.

Figure 6 below records a real-life on-site test where the shaft generator converter supplies nearly two times the rated current (as required for this specific installation) for two seconds in order for the grid's SC protection to clear the fault. Note that the DC voltage of the converter is stable during the significant grid disturbance with only a minor fluctuation. A reliable SC protection is required to protect the system and personnel from physical damage, and to prevent total system blackout.

SC performance

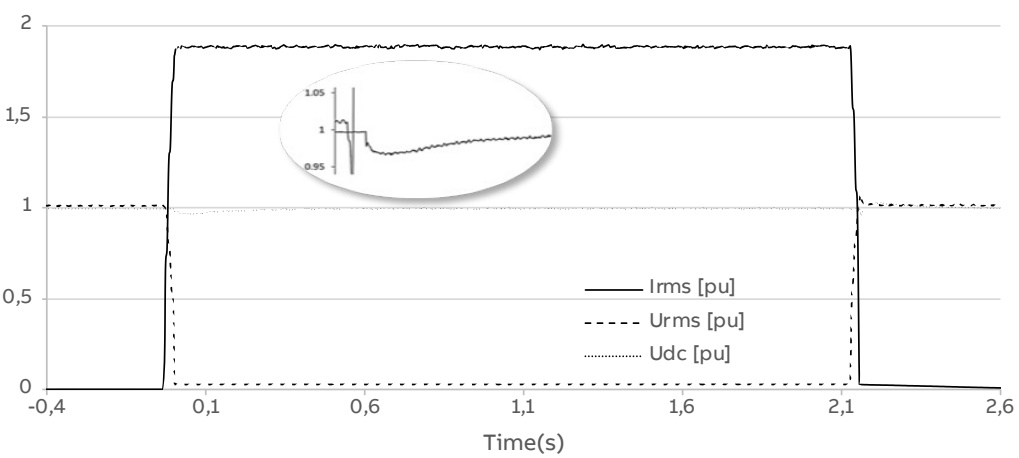


Figure 6: DC voltage performance during SC

Ultra-low harmonic drive

Causes and effects of harmonic voltage distortion are well known, and unavoidable when using non-linear loads such as frequency converters. The objective of managing the harmonic distortion is to avoid the electric equipment in, and connected to, the electric ship grid malfunctioning or being damaged. The level of harmonic distortion can be expressed in Total Harmonic Distortion, THD (%).

Figure 7 below shows a real-life project measurement, where the total THD level was less than 1.2 percent at no-load condition. THD less than 5 percent is often considered to be acceptable as long as the equipment connected has been designed and dimensioned accordingly. Lower levels will contribute to less heating and less impact on equipment lifetime.

The ultra-low harmonic drive converter may also be used for harmonic cancellation, where it can compensate for the harmonic distortion of other non-linear loads, and avoid installation of extra harmonic filters.

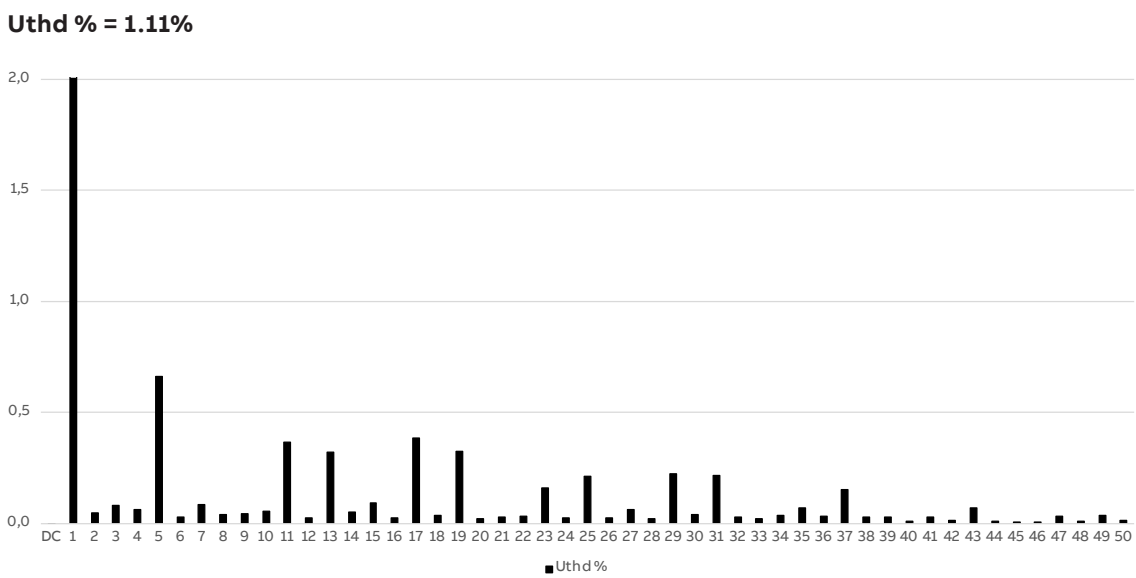


Figure 7: Ultra-low harmonic voltage output

Parallel operation of gensets

ABB's shaft generator system can be paralleled with auxiliary generators for both short time power transfer, or continuously. The active and reactive power droops are implemented in the shaft generator frequency converter. The droop control ensures that the loading is shared equally among paralleled power sources relative to the individual source's rating.

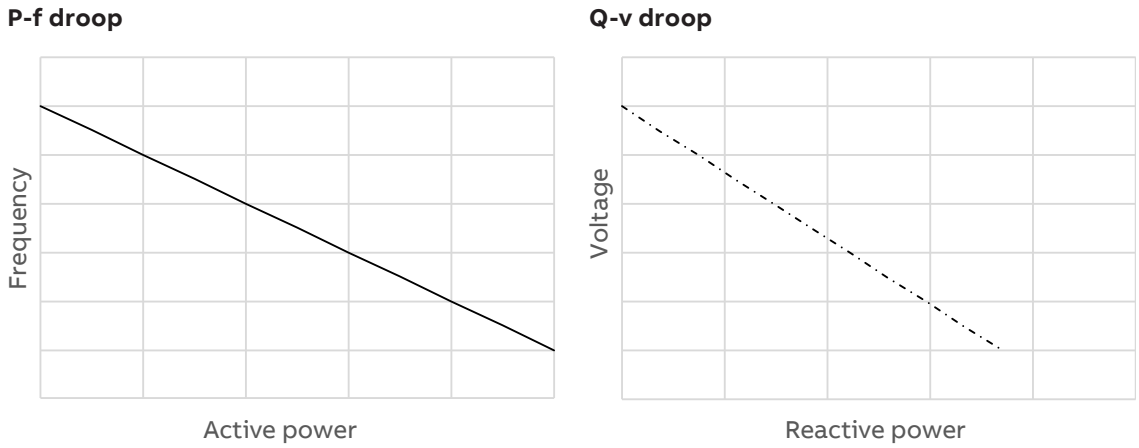


Figure 8: Active and reactive power sharing through droop

Transient load handling

Large electric load variation in the ship's grid may originate from different events, eg, starting of heavy consumers, tripping of a paralleled power source, or from the actions of the protection system in the grid. In order to ensure voltage stability and that the voltage variations are within required tolerance, the shaft generator system must react fast and accurately to compensate for rapid load changes. ABB shaft generator systems are typically designed for transient load variations starting from 50 percent to 100 percent. Figure 9 records a transient load test in one delivered project: with a 50 percent load injection, the transient voltage varied with only ±7.5 percent and went back to normal in 1.5 seconds; with a 50 percent load reduction, the voltage variation is too small to be noticed at this scale.

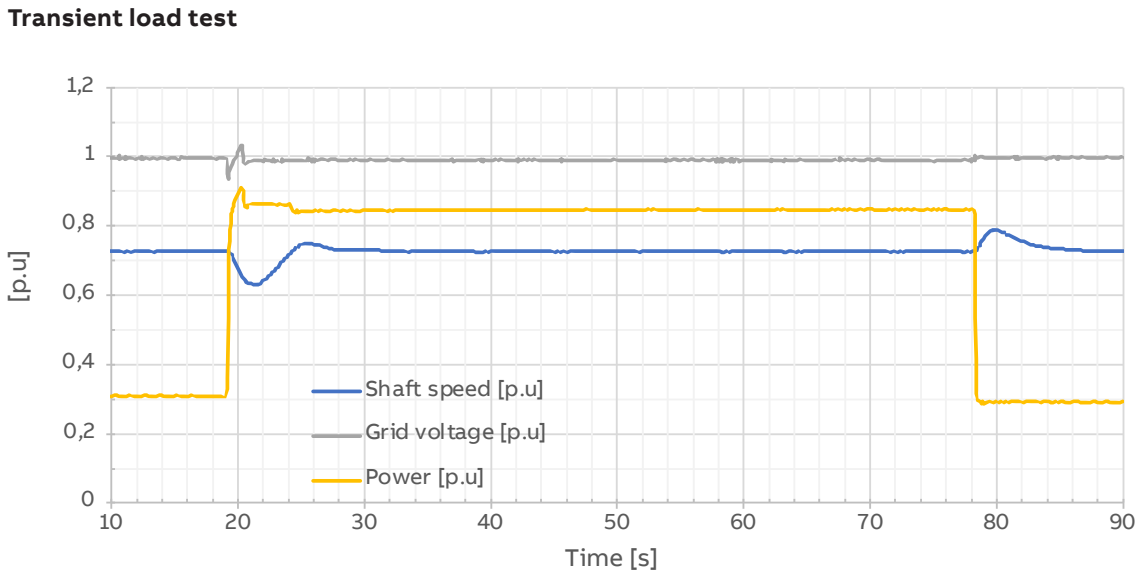


Figure 9: Transient load test record for a real-life project

Encoder-less control

Typically, an encoder for measuring the speed and angular rotor position is needed by the inverter control for shaft generator applications, especially for the PM type. The position encoder is used to determine the rotor pole position for motor control purposes, and the speed encoder is needed for realizing close loop control to maintain a constant DC link voltage. For inline shaft generator applications, the encoder will be installed around the intermediate shaft, which increases the complexity, the cost of hardware, installation efforts, and maintenance.

ABB's frequency converter supports encoder-less control in PM shaft generator applications. The rotor pole positioning is made on each start by implementing an Auto Phasing function, with sufficient speed accuracy to stabilize the DC voltage. Figure 10 illustrates an encoder-less flying-start moment of an inline PM shaft generator in a delivered project.

PM shaft generator starting without encoder

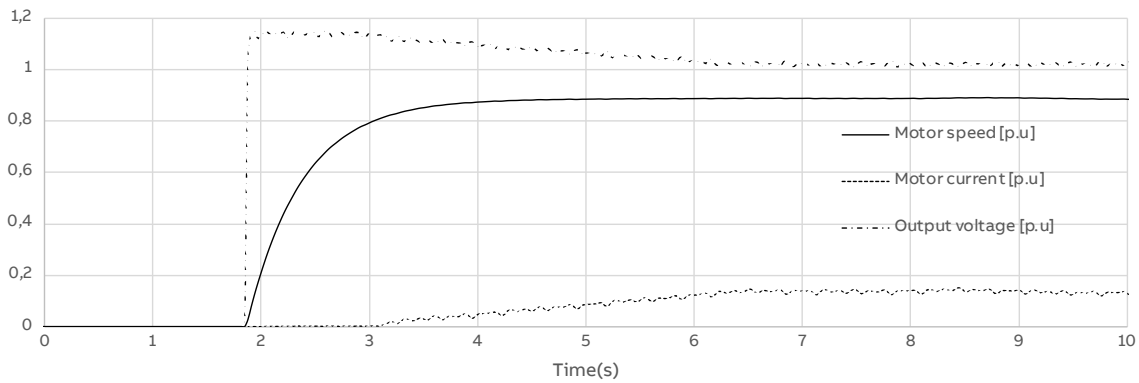


Figure 10: PM shaft generator encoder-less control

Advanced synchronization

The ABB shaft generator solution is designed to synchronize to a live AC grid. The synchronization function is implemented in the inverter control. When the converter starts, the inverter IGBT will pre-magnetize the isolation transformer to reduce the inrush current and voltage transient in the ships grid when closing the transformer incomer in the main switchboard without the need for a pre-magnetization transformer. In addition to the cost and space savings, this will also simplify the process for startup and grid connection.

Synchronization with pre-magnetizing function

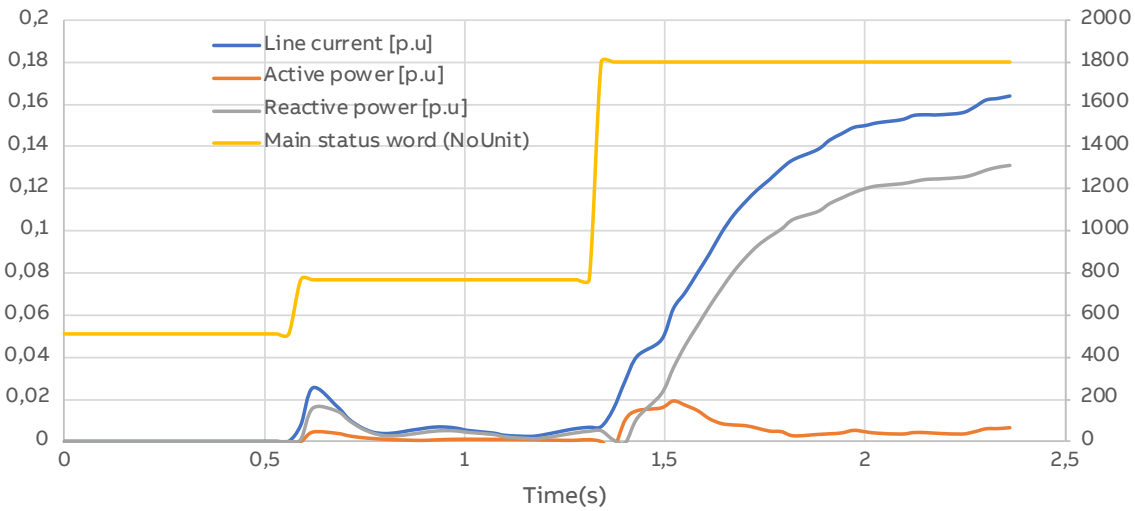


Figure 11: System performance during synchronizing

Power factor compensation

When the ship is connected to shore power, the shore supply current can be minimized by using the shaft generator converter to compensate for the power factor, by producing reactive power to the ship grid corresponding to the reactive power in the ship electric load. Hence the observed power factor from shore can be controlled to unity, 1.

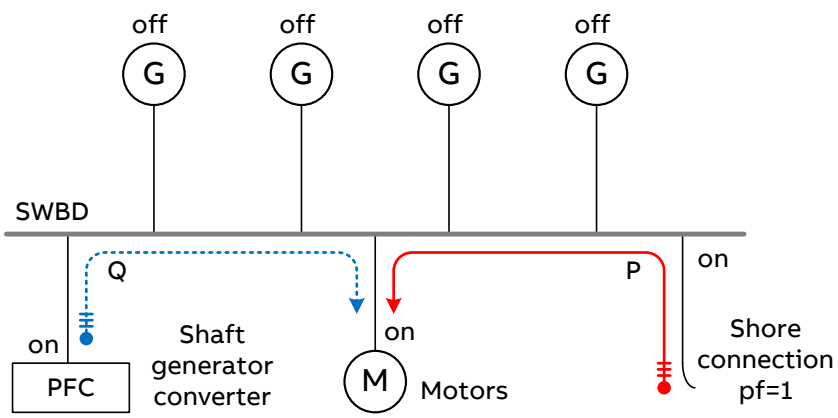


Figure 12: Power factor compensation for shore power

Conclusion

As regulations and requirements for emissions reduction become stricter, ABB's variable speed shaft generator system provides a simple, efficient, and cost-effective way to help shipowners and designers to meet emissions targets. It can also be easily extended for use with new, emission-free energy sources. •

Note: A special thanks to Mr. Hyne-Tek Nam, Service Engineer, for providing the on-site measurement records.

Oh buoy!
Can we sink our big carbon problem?

Meeting global climate goals calls not only for reducing emissions, but also for removing carbon we've already released into the atmosphere. It's a complex problem but, according to ocean health company Running Tide, there may be a beautifully simple solution. Ari Ratner, VP of Strategic Communications, explains how we can give carbon 'that sinking feeling'.

—
Ari Ratner, VP of Strategic Communications, Running Tide

At first glance it seems like a counterintuitive way to help the environment. Load tons of waste wood balls onto a raft, tow it almost 200 nautical miles south of Iceland, and release the payload into the ocean.

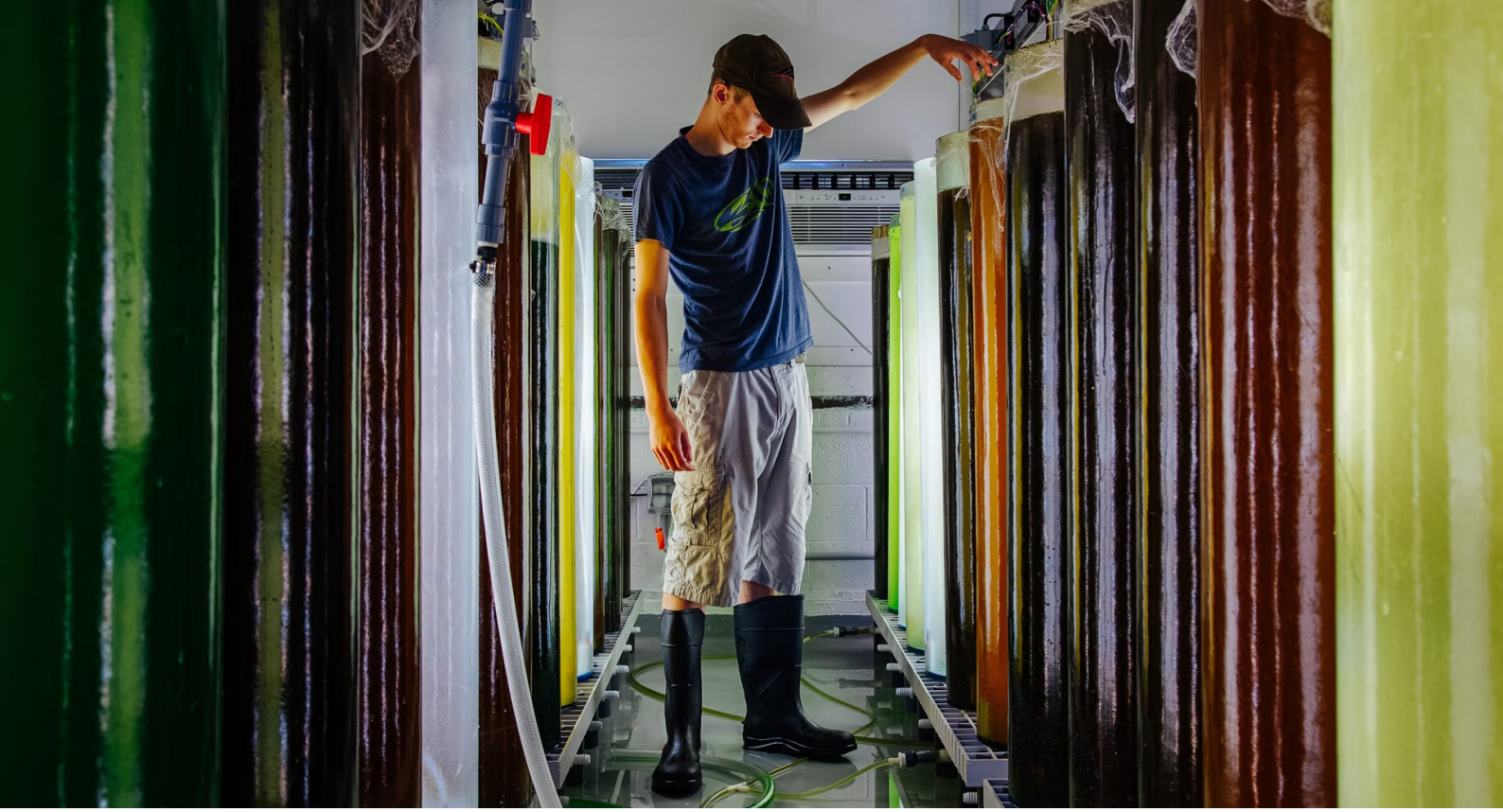
Normally you'd think this would be the kind of endeavor to invoke the wrath of environmentalists, not their support. But this is exactly what's been happening over the summer months of 2023, with the backing of scientists, Icelandic authorities, environmental campaigners, and paying corporate customers eager to offset carbon footprints.

As Ari Ratner, VP of Strategic Communications at global ocean health company Running Tide, explains, this could be the start of a very simple way to tackle one of humanity's gravest problems – the colossal quantity of carbon transforming our climate.

Removal job – cleaning up past problems

"Since the industrial revolution mankind has released over two trillion tons of carbon into the atmosphere," Ratner states. "The Intergovernmental Panel on Climate Change (IPCC) has called for the removal of 660 gigatons – and note, that's removal, not reduction of emissions – to mitigate ocean warming and acidification.

"We have to do this to preserve the health of our planet. And Running Tide is committed to playing its part."



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Atlantic

Formed in 2017 by CEO Marty Odlin, the US-headquartered company has grown into a team of over 100 people, including more than 60 scientists and engineers, focused on devising breakthrough ocean carbon removal solutions and ecosystem restoration projects, such as restoring coastal wetlands and rewilding. By combining science, engineering, and ocean and ecosystem expertise, the company has attracted significant private equity investment and partnerships with names of the order of Shopify and Stripe. Microsoft is one of its first, and major, paying customers, with a contract signed early in 2023.

But, you may ask, a contract for what? This is where those little balls of waste wood come in.

Fast tracking carbon to the slow cycle

Microsoft has contracted Running Tide to move 12,000 tons of carbon dioxide equivalent (CO_2e) from the ‘fast carbon cycle’ to the ‘slow carbon cycle’. The floating ‘carbon buoys’ are the solution, as Ratner makes clear:

“The fast carbon cycle can be explained by, for example, something like a tree. It grows, sucks in carbon from the atmosphere, then it dies and releases it. So, it’s on a lifetime scale. A slow carbon cycle is a plant dying, sinking to the bottom of the ocean, getting covered in sediment and turning into rock. The carbon becomes stored, for eons, until it’s spewed out by a volcano or, in the case of organic matter that’s been transformed into coal or oil, humans burn it.

Our buoys take carbon and sink it in the deep ocean – below 1000 meters – transferring it from the fast to the slow cycle."

The buoys, Ratner explains, are made from wood waste, or residue derived from the forestry industry. This would usually be burned, releasing carbon into the atmosphere. They're coated with a limestone layer that has a dual purpose – enabling each buoy to capture more carbon and then, when it dissolves, counteracting ocean acidification. The next step, still under testing, is to seed the buoys with macro algae, which then grows and captures more CO2, before eventually – as the coating dissolves and the weight of seaweed grows – each unit sinks to the sea floor and the age-old process of slow carbon transferal begins.

The test buoys were tailored to float for weeks, whereas the algae/seaweed seeded balls will grow their 'gardens' for two to three months before diving downwards.

"According to our models, at the depths we're working at, the carbon will then be stored for at least centuries to millennia and, if it becomes sedimentary rock, far, far longer than that," Ratner says, adding: "In a way all we're doing here is partnering with nature, using the same processes it's always used to tackle a very manmade issue. It's a nature-based solution."

—
Satellites in the ocean

Scaling up operations

The process is being lauded as creating a carbon-negative supply chain, utilizing waste biomass and relying on ocean currents and gravity to empower the switch from one carbon cycle to another.

However, the scale of operations needed to make an impact on the IPCC's 660 gigatons target is mind-boggling. Raising the question, is this a viable, scalable solution for corporate customers, and the wider world, targeting net-zero?

"Yes, but there are certainly some hurdles to overcome," admits Ratner "The system itself is very scalable. It's simple and it's cheap to produce the buoys and deploy them. However, we need to get permission to operate from a number of territories and that's not always straightforward. The Icelandic government has taken the lead in enabling us to secure our first permit, and we're in talks with a number of others. And yes, there's a capacity issue, but as soon as we prove the concept, raise awareness and attract more customers, like Microsoft, then I think that can move quite quickly."

In terms of proving efficacy, and winning that business, Running Tide uses sensors to capture data on buoy performance, as well as qualified scientific modelling from its international team and partner institutions. The tests this summer, with Shopify as the first operational customer, removed 275 tons of CO2 from the fast cycle, feeding invaluable information back into further concept development.

And, as Ratner makes clear, there are additional ripple effect benefits to unlock.

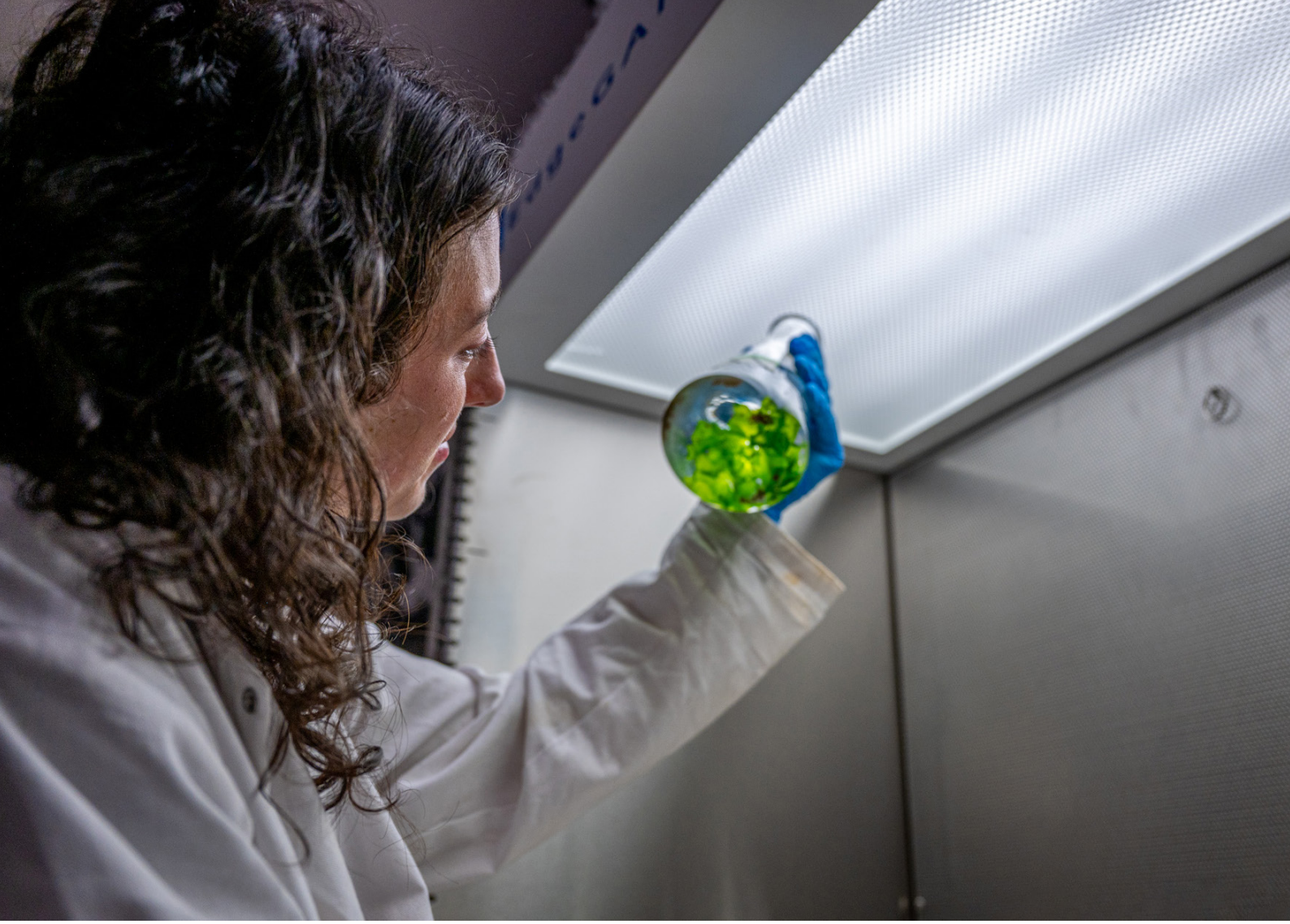
—

Our buoys take carbon and sink it in the deep ocean.

Community impact

"Carbon removal is an industry that's just starting out, but an absolutely vital one to develop, given the ever more apparent climate crisis we face," he notes. "So, it's important to show this is possible and inspire other companies, solutions and potential customers. This is a green industry waiting to explode.

"Then you have the impact on local and regional communities through new revenue streams. For example, in Iceland we're working with a fishing community that lost its quota – they've essentially been economically sidelined. We, and others like us, can give them a new purpose, a noble/green goal, and an income based on repurposing existing skills and assets. In that way this project isn't just restoring ocean and global health, it can restore the health and well-being



—
Nursery

of coastal communities through the creation of local carbon-negative industrial hubs. I'm really excited about the possibilities."

Ratner isn't alone here. Running Tide founder Odlin said in the aftermath of the summer tests that he hoped to scale up quickly to remove multiple gigatons of carbon per year with the system. An ambition the IPCC, and the rest of us, should be very happy to hear about.

"We need to remember addressing the climate question is not just about emissions today, we also have to deal with legacy emissions to have any hope of reaching our goals," Ratner concludes. "It's almost like building the energy industry in reverse – repackaging the carbon we've released and putting it back where it belongs.

It's time to restore a sense of natural balance… while we still have the chance to do so." •

The big carbon question – the view from ABB

—
Tommi Lempiäinen, Head of Sustainability, ABB Marine & Ports

Big questions rarely have one, simple answer. And this is absolutely the case with carbon emissions. How can we tackle them, both the current and legacy emissions, in the most effective manner? You can join the queue to have your say… but it's a long one.

Some issues aren't up for argument though. The first is that we need to drastically reduce current emissions; using alternative power sources, driving electrification, developing digital tools to enable efficiency, and moving as one – both through regulations/legislation and incentives – to achieve a meaningful change.

Carbon capture and storage (CCS) is an essential piece of this equation. As we can't wave a magic wand and transform all our activities to clean energy, we must look at ways of working with what we have now, at least for the near- and mid-term.

As such, CCS development projects are a priority, and ABB is proud to support a growing number of them through the provision of services and solutions encompassing power, electrical, instrumentation, analytics, control, telecommunication, and industrial software-as-a-service (SaaS). If we can work to capture what we produce today, and tomorrow, we can give ourselves the 'breathing space' required to make more fundamental changes for long-term industrial sustainability.

As for dealing with legacy emissions, we applaud the determination, innovation and action of pioneering companies and organizations such as Running Tide. It's clear that this probably won't be the solution to a task of this magnitude, but it's certainly one part of a bigger puzzle, and the knock-on benefits for both coastal communities and the ocean itself (through combatting acidification) appear truly compelling.

One of the most inspiring elements of the solution is the fact that it uses nature as a partner – harnessing natural processes to power a manmade clean-up. We look forward to seeing how this idea develops, as well as the complimentary ideas other players are working on.

Resilience in maritime transport for the next decade

This vision paper covers the increased complexity of navigational environments and presents an innovative navigation system that can support the human in this task. Shipping in general also requires a mean to support navigators reduce the risk of accidents due to smaller passing distance or a shorter reaction time. An innovative approach, called Velocity Obstacles might help the operator to avoid intruding into an object's protected zone by visualizing the problem space in relation to the maneuvering potential of the Own Ship.

Alina Colling,
ABB Marine & Ports

Stephan Procee,
NHLStenden

Conventional vessel navigation thus far has always made use of the various tools at hand to determine the best navigational solution for an individual vessel. Limited consideration is taken of the entire situation as that is a very complex task to perform. With more computational power available and the navigational environments becoming more multifaceted with not only increasing numbers of vessels, but also additional obstacles such as wind farms becoming more prominent on the navigational routes, a need for improved situational awareness is rising. To optimize the navigational performance of an individual vessel and reduce the navigation risk, a shift of the navigation perspective from an own vessel-centric perspective to a situation-centric perspective taking into consideration the constraints of all participants has to take place.

This article advocates for this shift by explaining the problem of stress creation during conventional sailing by guiding the reader through a real scenario of Automatic Identification System (AIS) recordings. It then explains the concept of the Protective Zone around vessels and their use within Velocity Obstacle (VO) diagrams, as a stepwise solution to gain a better visualizing and understanding the consequences of navigational changes in complex navigational situations. To do so, the article provides a step-by-step time-lapse of a real navigational recording from two different vessel perspectives and explains how the VO

could have helped reduce the navigational risk. It is also addressed how such visualization tools enabling transparent monitoring supporting the integration of automated or autonomous navigational systems.

Velocity Obstacles a novel approach to avoiding danger for collision

ANALYSIS OF CONDUCT

The conduct of vessels is regulated by the IMO's COLREG [1]). Due to the absence of external traffic control, i.e. outside Vessel Traffic Service (VTS) areas in a nation's territory, this conduct can be regarded as self-regulated. Based on formal education, training and licensing, the professional mariner behaves responsible and prudent, and applies the rules. Hence it can be expected that danger for collision is mitigated at all times.

However, individual ships have their individual constraints and each Officer On Watch (OOW) has its individual interpretation of a safe passing distance. The dimension of a Protected Zone (PZ) or a safety limit, like Distance Closest Point of Approach (dCPA), is neither exchanged nor mutually agreed. This can result in a stressful situation for the stand-on vessel that has to wait for measures from the give-way vessel with a smaller safety limit.

Although some general idea about safe passing distance exists it can be analyzed that in reality, this distance shows quite some variation. From observed AIS data during four months in 2021, a selection of 113 encounters in the area east of the F-3 buoy were analyzed. The F-3 buoy functions as a central point in the Belgium - UK bound traffic and the North Sea – English Channel traffic. All of these encounters consisted of two vessels with a dCPA less than three miles, and one of the two, the Northbound vessel, showing an action. (see Figure 1).

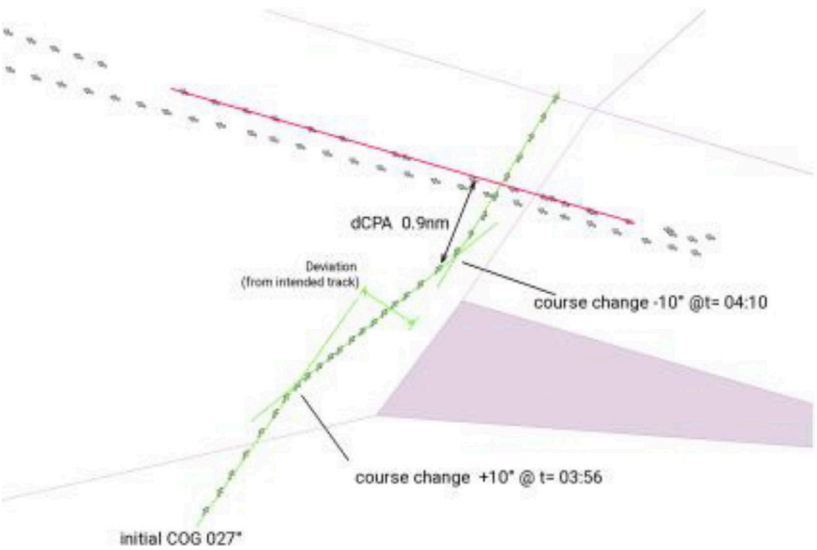


Figure 1:
Typical Selected Encounter

It was found that practically all reacting vessels applied only a course change to starboard. This change varied from 5° to 60° (m=15°). The resulting safe passing distance (dCPA) varied from a third nautical mile (about 660m.) to two miles. The amount of course change and the safe passing distance appeared not to be correlated. From this analysis, it might be concluded that neither a common safe passing distance nor a common course change seems to exist. This makes predicting the other vessel's behavior difficult. The assumption that reaction time, i.e. the time between the moment of course change and the moment of CPA, relates to the amount of course change (e.g. a late reaction requiring a drastic maneuver) could not be proven. This corroborates the hypothesis that a common method to conduct in accordance with the Rules does not exist.

DIMENSION OF PZ

Many studies have been spent on the required protected zone, also referred to as ship domain. Apart from these theoretical approaches there actually exists an area around the Own Ship (OS) that inhibits an emotion of uneasiness by the OOW. From research carried out by cadets at sea, it was found that the often intuitive ship domain has a dimension of about one and a half mile in front of OS, half a mile astern of it and one mile abeam. This research was carried out on merchant vessels underway with lengths between 150 and 200m.

Analyzing traffic based on AIS broadcasts can also determine the area that a ship apparently wants to keep free from other traffic. Several studies, Fujii and Tanaka [2], Goodwin[3], Pietrzykowski and Magaj [4], Procee, Borst, van Paassen, and Mulder [5] a.o., show all slightly different dimensions than the intuitive area based on the cadets' research. They all, however, provide proof of the very existence of an area around the OS that the OOW wants to keep free from dangers.

It might be striking to observe that, in the marine world, collision avoidance as well as the ship's domain is almost uniquely approached from the OS's perspective, meaning, the self-imposed obligation to keep traffic outside OS's own domain. Aviation, on the other hand, uses a uniformly defined horizontal Protected Zone (PZ) of five nautical miles radius around the airplane in which another should not intrude. This different perspective is interesting for marine navigation and might promise a solution for the stressful situation where the stand-on vessel is forced to wait for action of the give-way vessel. In case the latter vessel uses a much smaller domain than the stand-on vessel it might enter, unintentionally, the other's domain and cause great stress for the waiting OOW potentially resulting in unexpected action or illogical behavior. An example of this can be found in [6].

Ships are, different from airplanes, not highly standardized. Applying a uniformly defined protected zone for shipping might not be feasible due to lack of acceptance, nor be effective due to the variety of ships and their individual operations. However, if the required PZ of a ship would be shared with the environment directly around the OS, e.g. by a dedicated field in the AIS broadcast, than a novel approach for resolving danger for collision becomes available. This approach visualizes the required PZ of the target with which one is engaged with and predicts whether one is going to intrude into that PZ. In case intrusion is imminent than action is required, if not, than course and speed can be maintained by all vessels involved. The tempting simplicity of this novel approach is that when intrusion can be avoided by e.g. a minor course change long before any engagement can be defined, than the size of the required maneuvers will be minimal, which impacts efficiency, and traffic shows a less chaotic, i.e. better predictable, pattern. Although in this paper it is called a novel approach, a taught strategy at nautical colleges, e.g. in the Netherlands, also refers to taking a preemptive measure, i.e. a minor course change long before the situation starts to be 'collision avoidance' in order to avoid that situation at all. So the principle is known and effectively used since long, the planning by visualizing the PZ of the other vessel is not. The latter is also known as Velocity Obstacles (VO). In the next paragraph the method of visualizing is explained based on some realistic examples.

As pointed out in this paragraph, the dissemination of the dimension of one's PZ to vessels that are directly involved in the situation, e.g. within a radius of three to six miles, would provide a number of opportunities. First, it avoids the situation that a vessel with a relatively small PZ unintentionally enters the PZ of a vessel that has a much larger PZ. Because the PZ's dimension of one's own ship is usually not formalized, i.e. intuitively present only, the awareness of a PZ of the target is even less likely. By visualizing the target's PZ and its associated conflict zone it is expected that stressful situations will be reduced because ships can avoid, unintentionally, intruding into the target's PZ. It is expected that this reduced stress level leads to better decision-making. An example of a stressful situation leading to a collision can be found in [6]. Secondly, by visualizing the solution space, the time it takes to decide and reach a resolving action is expected to diminish, hence providing opportunity to increase the quality of decision-making. Based on Wickens, Hollands, Banbury, and Parasuraman [7] their information processing model of decision making it can be motivated that a repetition of the Diagnosis->Confirmation->Selective Attention->Cue Filtering->Diagnosis cycle, enhances the quality of the assessment and its subsequent decision-making process. Kahneman's [8] -slow thinking- refers to a similar process in decision-making.

Planning with Velocity Obstacles

SOLUTION SPACE VS PROBLEM SPACE

In their initial paper, Degré and Lefèvre [9] pointed out that predicting the OS's position relative to the target's domain, even based on the simplest form of a circular zone, will provide useful information for OS's OOW. Their visualization differentiates between the 'room to manoeuvre', a.k.a. the solution space and the 'danger zone' which is commonly referred to as 'problem space'. Visualizing the solution space provides multiple combinations of course and speed that will guarantee a passing distance greater than the critical distance, i.e. the circumference of the target's domain. In particular, when two or more targets are to be dealt with, the prediction of the combined solution space helps to choose an evasive course and speed that solves all problems at the same time. Also, Huang, van Gelder, & Wen [10] and Westrenen & Ellerbroek [11] provide evidence that the method of VO, i.e. visualizing the problem space and solution space, enables the OOW to resolve complicated traffic situations with multiple targets involved.

An example of traffic conduct that is observed during the four months of AIS data collection is shown in Figure 2.

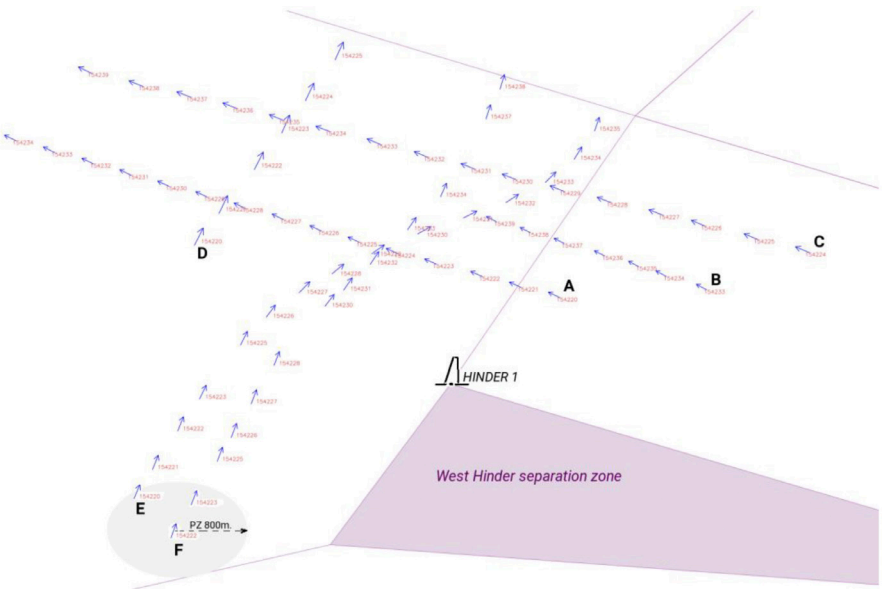


Figure 2:
Example Maneuver

In the given example there are six vessels sailing near the exit of the Traffic Separation Scheme (TSS) West Hinder into the Dover Strait TSS. Every AIS broadcast is considered to be a vessel underway, its position is reflected in the position of the arrow (in blue). The direction of the arrow corresponds with the

course over ground and the speed over ground is expressed by the length of the arrow. The time interval is limited to one minute, the relative time stamp is shown as number in red with one minute time resolution.

Three vessels, i.e. A, B and C, are leaving the West Hinder TSS on a westerly course, and three vessels, D, E and F, are heading for the North Sea on a northerly course. According to collision regulations the three ships on the northerly course are to give way when risk for collision is deemed to exists. Apparently, the north bound vessel sailing in the western part of the area, vessel D, did not assess the situation as 'risk for collision'. The other north bound vessel, vessel F, assesses the situation as risky and decides to change course to starboard at about time stamp 154228. The third northbound vessel, vessel E initially time stamped 154220, assessed the situation as such that a drastic course change, i.e. 35°, to starboard was executed, which resulted in a bow crossing of the second northbound vessel. Ultimately both vessels, E and F, passed the three westbound vessels astern. This situation developed in the early morning around half past three GMT. Weather analysis showed there was a declining ridge of High pressure from Scandinavia to the Iberian peninsula. As the wind gradient was weak at the F-3 location, there is no reason to expect much wind. Some disturbances in the southern North Sea and NW Europe hint at vertical movement of the atmosphere, hence, a small chance for low visibility at the surface. This means that it is likely that the ships in this example sailed in sight of each other and the normal rules, i.e. not Rule 19, were applicable.

It is assumed that each of the ships in the given example has a circular protected zone with a tentatively chosen radius of four cables, i.e. ±800m. This is illustrated as the gray-shaded oval in Figure 2 for vessel F only once. The explanation for the apparent oval shape is the scale difference between the major and minor axis at this latitude in the Mercator projection. Buoys and fairway markers, usually referred to as Aids To Navigation (ATON), can be dedicated to have a protected zone as well. The dimension of this dedicated PZ depends on the navigator because no formal rule applies. In the given example the Hinder-1 buoy is to be avoided by applying a PZ with a tentatively chosen distance of 185m., i.e. a tenth of a mile.

A third feature that determines the navigable space is Routing Measures, also known as Traffic Separation Schemes. In this case, the Separation Zone, the light magenta shaded area in Figure 2 is a forbidden area, the northbound vessels are not allowed to enter the exit of the West Hinder TSS, i.e. the traffic lane where the west bound vessels are coming from. This fairway restriction is not shown in the following example.

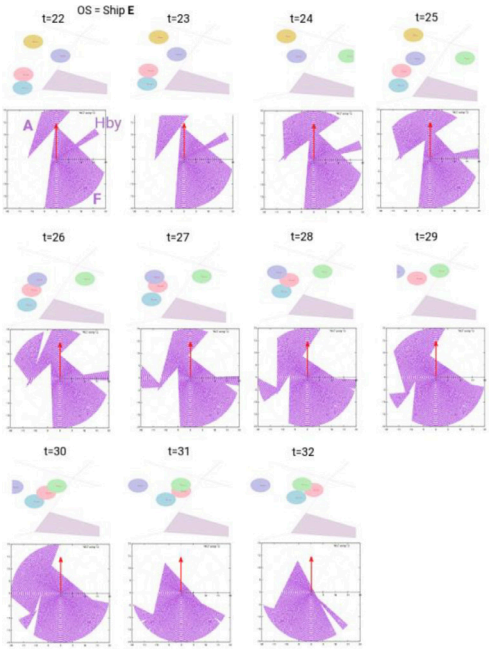


Figure 3: Velocity Obstacles from Vessel E's perspective (vessels B C D are not shown)

The developing traffic situation is illustrated in Figure 3 and Figure 4. Each of these Figures shows the same situation albeit from two different perspectives. Figure 3 refers to vessel E which is represented by the pink protected zone. Figure 4 refers to vessel's C perspective. Vessel C is represented by the green oval.

The top half of each row shows the developing situation in the chart, the lower half of the row shows the orthogonal projection of the conflict zones of each target from either, vessel's E perspective (Figure 3), or vessel's C perspective (Figure 4).

At t=22 vessel E is northbound underway with a speed of 14 knots over ground. It has one northbound vessel, i.e. vessel F with blue shaded PZ, on its starboard quarter. Also, there is a northbound vessel on E's port bow, i.e. vessel D with a yellow shaded PZ, and there is one westbound crossing vessel, i.e. A with the purple PZ. The Hinder-1 buoy is on the northwestern corner of the West Hinder Separation zone (See Figure 2).

From the perspective of vessel E, the Conflict Zones (CZ) of vessel F, vessel A and the Hinder buoy (Hby) are shown (See Figure 3 t=22 lower half). The CZs are displayed relative to the OS's bow, a.k.a. the Head Up orientation, the red arrow in this diagram indicates the OS's speed and course. From this diagram it becomes clear that vessel E has no conflict with vessel F as long as E keeps its speed. It also is clear that E does not have a conflict with A as long as E does not speed up. There is neither a conflict with The Hinder buoy at this course.

Hence there is no need to take action at the present moment (t=22), and if vessel E should want to change course, it finds potential combinations of course and speed to do so, i.e. without intruding in someone's PZ, in the solution space. The vessels B C D are not shown in the diagram for the reason that their CZs are outside the area of interest which in this case is limited to 3 miles.

At t=24 the CZ of vessel C shows up in the diagram, and from the position of the OS's arrowhead, that is located inside C's CZ it becomes clear that intrusion into C's PZ will happen at some time. At t=25 vessel E has started to change course to starboard, at t=27 the effect of this course change becomes noticeable as the OS's arrow head shifts gradually to the border of the CZ. At t=29 it becomes obvious that vessel E will not intrude into C's PZ because of its course change. The course change was found in the solution space, meaning that no conflict arose as a result of the action to resolve the first conflict.

The identical situation is presented from the perspective of vessel C in Figure 4. At t=22 the CZ is shown for vessel D (to starboard of OS) and for vessel E. Also, the CZ of the Hinder buoy (Hby) is shown, to port, originating from OS. From the head of OS's vector (red) it appears that intrusion in the PZ of vessel E is not expected. As the situation develops over time, the CZ of vessel D shifts and increases in dimension. At t=24 the head of OS's vector is inside the CZ of vessel E, indicating that intrusion in its PZ is expected (in time). At t=26 a part of the CZ of vessel F appears separate from the overlapping part with E's CZ. It also appears that the head of OS's vector shifts gradually toward the margin of E's CZ indicating that E's course change to starboard (at t=25) has an effect. The apparent continuation of the effect is illustrated in the subsequent fragments until t=29 where it can be seen that OS is neither expected to intrude into the PZ of vessel E nor into the PZ of vessel F.

If OS (vessel C) assesses the situation as danger for collision, e.g. at t=24, it might be tempted to take action. Objectively, OS might be tempted to find any combination of course and speed that will result in a position of OS's vector head outside the presented CZs, i.e. inside the solution space. Changing course, however, might have the greatest effect in a limited time due to the maneuvering potential of vessels. As shown in the fragments a course change to port is also part of the solution space. However, this would result in a heading towards the target(s) that ship C wants to avoid, hence the preferred change to starboard if such a maneuver is desired by the OOW of ship C. From the viewpoint of ColRegs there would only be reason, for vessel C, to maneuver when danger for collision is deemed to exist and the give way vessel, i.e. ship E here, is deemed to be unable to avoid the collision on its own.

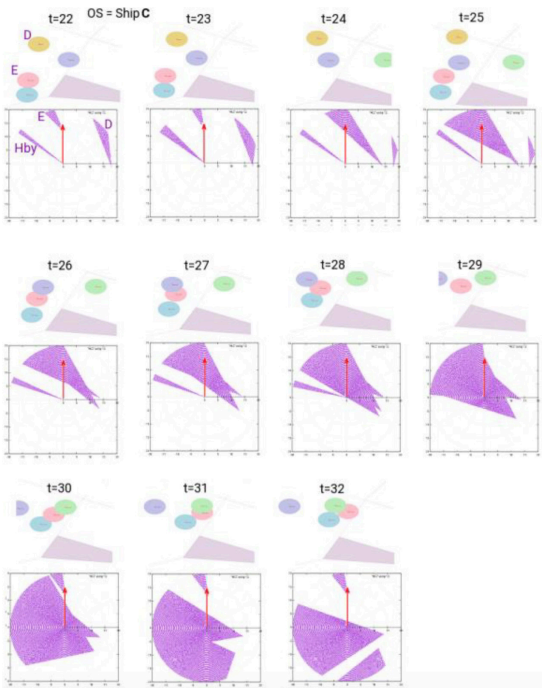


Figure 4: Velocity Obstacles from Vessel C's perspective

Using the VO in automated system settings

The use of tools such as the VO play a key role in conveying trust to automated and future autonomous systems. They enable sufficient interpretation and transparency in the decision-making process of the system. It is vital for the users to judge whether they are willing to trust the system and not simply intervene at every instance where the system does not perform the same way a human operator would. The visual simplification of the situation with the VO is needed to allow effective monitoring and also enables a faster situational awareness overview when coming from a temporary mind-off navigation task. In an emergency situation, the effective human-to-machine takeover capability forms the foundation to demonstrate safe operation a pre-requisite to regulatory compliance of highly automated or autonomous systems.

The accurate visualization of the collision scenarios surrounding the vessel is reliant on the sensor data available. The merger of different sensors information isn't new, as superimposing radar and AIS on the ECDIS is a common practice on most vessels, however, the processing of this data for the decision-making process of systems is the new aspect in navigation and control systems.
The uncertainty of sensors measurements in for instance GPS positioning is commonly accounted for through Kalman filters in control systems. Yet, for situational awareness systems the strengths and weaknesses of different target identification methods AIS, X-/ S-/W-band radars, LIDAR or cameras need to be carefully considered for different operating conditions. Not only are the HW

components of varying cost levels thereby not making each applicable for all applications, yet even if they are all available, they each have varying update rates and operational envelope/performance which affects their data reliability. For instance, in time-critical situations in busy waters surrounded by vessels not all vessels have AIS. Also the 25 rotations per minute for standard marine radar and the target following algorithm translates to an ARPA target in 1-2 minutes. This is too slow to perform reliable risk assessments based on only this sensor data for the moving targets that surround the vessel. Even though one could interpolate the estimated position based on the data history, there is no certainty that this data of this interpolation is accurate. In these situations, the continuous object detection using machine vision can support. In turn, the machine vision system has limited operational envelopes based on the visibility conditions and is not as accurate when for long-distance target estimations. Thus, based on the type and the movement of the targets the sensor fusion needs to be able to decide which data information is the most trustworthy.

Conclusions

This article has provided a concrete example of stress creation in a commonly encountered situation and explained the importance of Protective Zones for not only manual operations but also as a commonly used principle in autonomous collision avoidance. While the topic of PZ and VO are not new in research and are used in the aerospace industry. They have not yet taken off in the maritime context. The authors believe that the increased technology available combined with the greater navigational complexity for today's navigational needs shines a new light on the concepts making their benefits more visible and tangible to support the navigational crew in their tasks.

To illustrate this use, a collision avoidance scenario was analyzed from two different vessel's perspective using the aid of VO diagrams to emphasize how such visual support can reduce stress and collision risks and, in the future, become a vital monitoring tool for partially unmanned bridges. To enable such concepts to be realized the authors suggest a technical adaptation to the AIS messaging or any future kind of communication technologies to include Protective Zone dimensions of individual vessels.

It is acknowledged that this proposed solution is not a silver bullet. There are numerous valid weaknesses of the AIS including reliability that are not to be denied. Additionally, as was addressed by other authors (Zhang, Kujala & Wang [12] , Rawson & Brito [13]) also PZ have their limitations being influenced by the geographical factors surrounding the vessels as well as the operating mode the vessels are operating in. More limitations will reveal themselves as the

application roles out and becomes common use in the daily navigation, some of which will be addressable with machine learning technologies individualizing the parameters for different navigational participants. Yet, the step of the AIS message adaptation can be the first step in creating a mindset change and enables advisory systems such as VOs to become more reliable than being based only on the assumption of the technology developers. •

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Change the way you look
How a vision system can tirelessly support ships' lookouts

Ports are busy, and getting busier. Merchant vessels are getting bigger. According to figures published by the United Nations Conference on Trade and Development (UNCTAD), between 2020 and 2021, median vessel turnaround time in port increased by 14 percent [1] while the average annual growth rate of cargo shipping is estimated at around 2.1 percent between 2023 and 2027 [2]. An ABB research program helps navigate the uncertainties.

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Congested ports and crowded shipping lanes bring higher risks to vessels and added pressure on crews. Augmenting the crew's skills with technology brings safety benefits both to commercial vessels applying the technology and pleasure crafts sailing the same waters.

Modern navigation is heavily reliant on human perception. However, human senses are sub-optimal for slow, continuous, or wide-angle observations [3]. Research shows that despite their excellent ability to handle uncertainty, solve problems with creativity, and apply their knowledge and experience in making judgements, mortals are, nevertheless, fallible. A significant percentage of marine accidents are, to some extent, caused by human lapses[4]. Causes include crew fatigue, which can be improved by adopting new technology. To enable ships to see and monitor their surroundings – a pre-requisite for remote control and autonomous operations – several technologies are employed together to deliver a viable and trustworthy solution. Such solutions further enhance human experience and support crews in their safe vessel handling and accident avoidance.

One central navigational task is the lookout: the continuosly observing the surroundings with the purpose of early detection of any hazard to navigation.

Human lookout is done by the crew, aided by binoculars. Other technologies contributing to safe navigation include Automatic Identification System (AIS) and marine radar. The current practice has some evident limitations. The lookout on duty may miss a nearby vessel due to the challenges of detecting slow and gradual change, or by having to focus on multiple targets simultaneously or for an extended time. Small craft may not be equipped with an AIS and may also be missed by the radar due to a low radar signature. Moreover, bigger vessel's radars typically have blind areas in close-range around the vessel since the radar is meant to detect targets far and early rather than close and last-minute. Radar is most often positioned on top of the bridge and has limited vertical field of view (FOV), so it will inevitably have a minimum range that is typically several hundreds of meters. History shows us that to increase safety, we need to look at things differently. As the author Wayne Dyer wrote "If you change the way you look at things, the things you look at change [5] In Figure 1b a smaller vessel is depicted docked alongside a larger vessel and is therefore difficult to distinguish with a marine radar, but by changing the way we look at the scene, the things we are looking at have changed: the vision-based system is able to detect both the small and the large vessels.

Leveraging machine perception and automation systems can change the way we look at things, enabling safer, more efficient maritime operations. A system of cameras and machine perception algorithms can fill current gaps by providing continuous, relentless, lookout, water clearance functionalities (WCF), detect small obstacles and cover blind zones not visible from the bridge.

An important task vital to navigation is accurate determination of water clearance: calculating the distances from the hull outline of the ego-ship to obstacles. This is particularly relevant during maneuvering in the harbor or navigating in confined waters. This could be done by relying on a global navigation satellite system (GNSS) and accurate charts. However, loss of GNSS would leave the ship without vital information and, depending on the frequency and precision of survey data, charts can vary greatly in their accuracy. Restricted bridge visibility requires additional crew during docking and tug operations; the bridge crew relies on subjective data about size and distance of obstacles, communicated via walkie-talkie.

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If you change the way you look at things, the things you look at change.

WAYNE DYER

Monocular-vision system

Today, novel algorithms empowered by modern hardware allow machines to process visual input and to perform complex perception tasks. State-of-the-art deep learning methods rely on neural networks with millions of parameters. The architecture of neural networks is tailored to the specific detection task. Modern hardware enables training of such huge neural networks. The resulting model can fulfil perception tasks including object detection and semantic segmentation. Machine learning methods are then used in combination with computer vision and signal processing techniques to bring value to the end user and support crew safety.

This research focuses on a monocular-vision system, ie, a single-camera system. This technology has been chosen in order to focus on bringing additional value to existing onboard cameras. Often a single camera is already installed and ABB's technology can utilize this. This simple and relatively inexpensive hardware has the benefit of being easily understood by humans, as well as being usable by computers. The systems presented here are comprised of multiple components, and one of the main challenges was to ensure that all of them operate in real time. This kind of functionality requires careful management of data flows from multiple sensors and balancing of algorithm execution between the main CPU and graphical processing units.

Convolutional neural networks

Object detection and semantic segmentation technologies are related to computer vision and image processing. The cutting-edge of these technologies are models based on convolutional neural networks. These networks are based on many convolution kernels that slide along the input feature maps and provide the output feature maps. As these kernels have many parameters that need to be tuned, a large quantity of images are required. To address this challenge, ABB collected and annotated tens of thousands of domain-specific images [PAT-1]. To improve the generalization, the images were recorded in different conditions and locations, both onboard and offboard. The vessel from which the onboard recordings are made and where the electronic lookout and WCF are operating is referred to as the 'ego-vessel'. When possible, a proprietary software was used to record images. The time of the day, the location and speed of the ego-vessel were used to start and to stop the recording process.

The goal of object detection is to detect all instances of objects from one or more classes. When it comes to marine applications, object detection is often used to detect different types of vessels and marine objects. They include but are not limited to sailing vessels, passenger vessels, and cargo vessels. Furthermore, sailing vessels may include engine and non-engine powered vessels. Differentiation between them is important for collision avoidance applications since engine and non-engine powered vessels behave differently and should be treated differently in line with the COLREGs rules.1)

Semantic segmentation is of vital importance for WCF as it enables the assigning of a class label for each pixel in the image. For example, this technology allows to the differentiation between pixels that belong to the following classes: vessel, water or land. Segmentation of water is used to estimate the water clearance, while joint segmentation of vessels and water is used in combination with object detection for vessel-water interface localization [PAT-2]. This interface is used to estimate locations of target vessels in the world coordinate system.

Camera calibration

A monocular imaging system is used to estimate locations of target vessels in a world coordinate system. As this system is calibrated with respect to the sea plane, image points on the vessel-water interface are back-projected from the camera to the sea plane. The back-projected points define the location of each target vessel. In this step, it is important that the camera is calibrated. Camera calibration entails both intrinsic and extrinsic parameters. Intrinsic parameters are usually calibrated in a lab. Extrinsic parameters need to be calibrated after installing the camera onboard, during commissioning of the system [PAT-4]. Any

Figure 1: Examples of images recorded by the lookout camera installed on Suomenlinna II, a small passenger ferry connecting Helsinki to Suomenlinna Island.

Figure 1a: Many targets, some small and not transmitting AIS, are moving ahead of the navigating vessel.

Figure 1b: Ahead, a small support vessel is docked on the side of a larger navy vessel.

Figure 1c: Small and very fast recreational jet skis are unpredictably maneuvering in the vicinity of the navigating vessel.

ship motions during operation need to be accounted for to ensure accurate back-projection. This may be done by utilization of an inertial measurement unit (IMU) or with a vision-based attitude estimation algorithm [PAT-5].

The locations of the target vessels are fed to a multiple target tracker. Each target is tracked with a filter able to capture target dynamics and provide estimates of target position, speed over ground (SOG), and course over ground (COG). Such estimated quantities can be used, for example, to determine the closest point of approach (CPA) and time to closest point of approach (TCPA) of target vessels in relation to the ego-vessel.

The marine environment poses some unique challenges to a digital vision system. Atmospheric conditions including harsh light conditions, dense fog, and heavy rain limit the capabilities of cameras. Other sensing technologies including non-visible wavelengths could be chosen in such scenarios in the future.

Electronic lookout

The images at Figure 1 are from the Suomenlinna II, a small passenger ferry connecting Helsinki, Finland, to Suomenlinna Island. The camera is installed on the vessel at a height of approximately 10 meters above the water line and has a horizontal field-of-view of approximately 60 degrees. The images exemplify some of the situations where an electronic lookout can bring significant value: in Figure 1a many targets are moving ahead of the own vessel, several of those are small targets which are not transmitting AIS and may be undetected to radar; Figure 1b ahead a small support vessel is docked on the side of a larger navy vessel. A radar would hardly be able to distinguish the two targets, but the vision-based system is able to do so. On the left a ferry ship is detected despite being partly occluded by an island; Figure 1c small and very fast recreational jet skis are maneuvering unpredictably in the vicinity of the ego-vessel, electronic lookout can monitor them continuously.

At Figure 2, depicted are a sequence of images from the lookout camera of Merchant Ship (MS) Finlandia, a ROPAX (roll on – roll off passenger vessel) that operates between Tallinn, Estonia and Helsinki, Finland. The camera is installed at a height of approximately 30 meters and has a horizontal field-of-view of approximately 115 degrees. In the sequence, a motorboat navigates from the port to the starboard side of the ego-vessel. The motorboat is detected. Bounding boxes depict the corresponding detections. Furthermore, the detected vessel is tracked by the vision system while within the field of view. The resulting track is compared to the corresponding AIS track. The comparison of range and bearing can be seen at Figure 3, while Figure 4 shows the comparison for

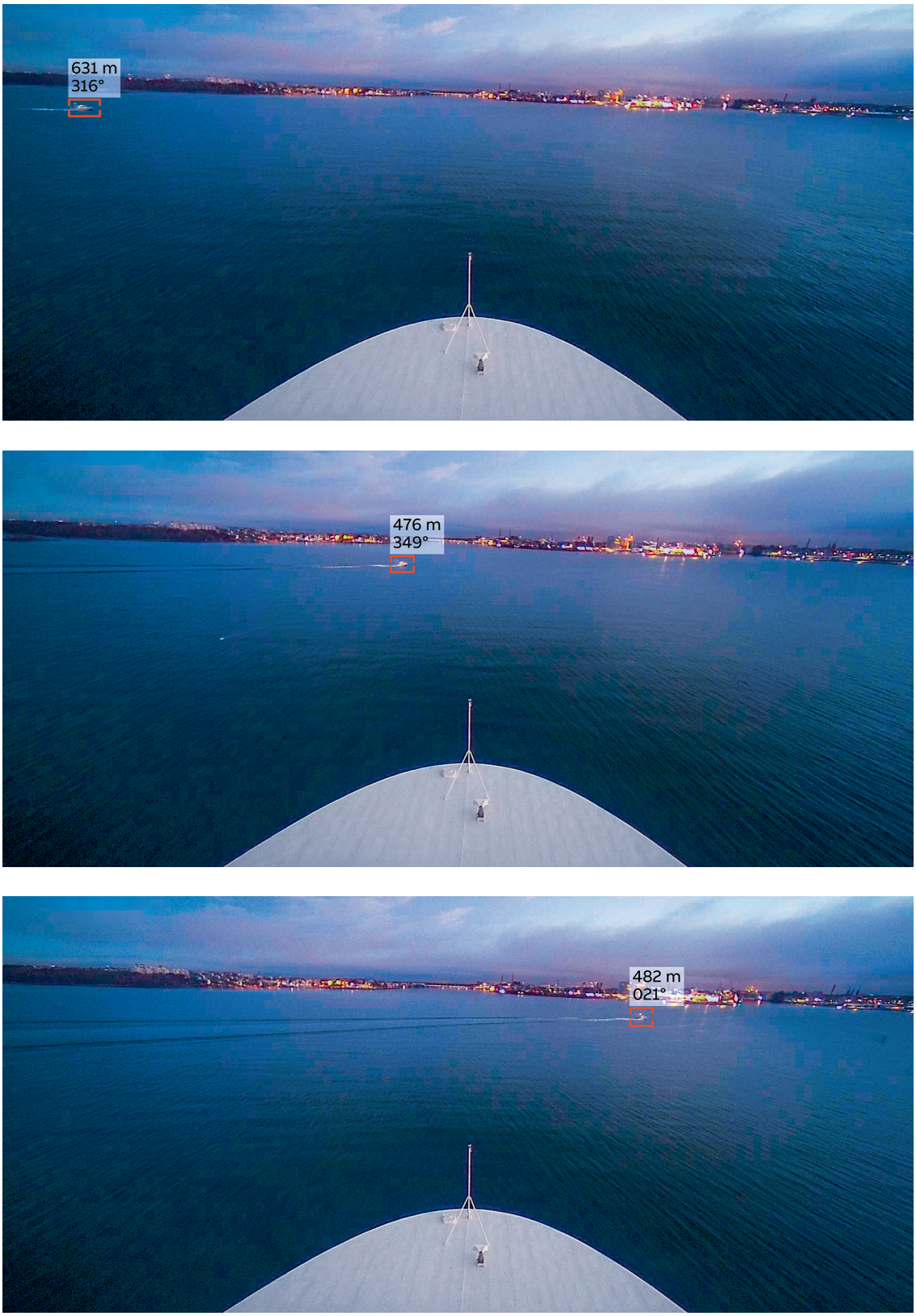

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Figure 2: Example of images from MS Finlandia while approaching Helsinki, in which a vessel navigates from the port to the starboard side of the ego-vessel.

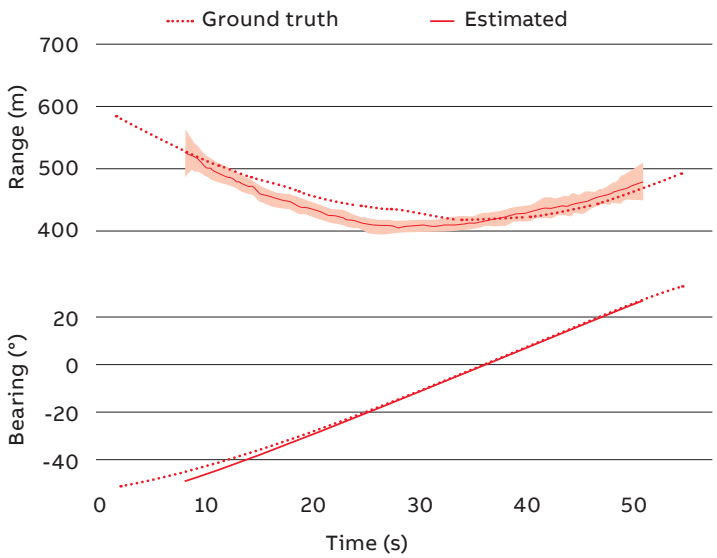

Figure 3: Range and bearing estimated with the monocular system. Comparison of estimated value with AIS-based ground truth.

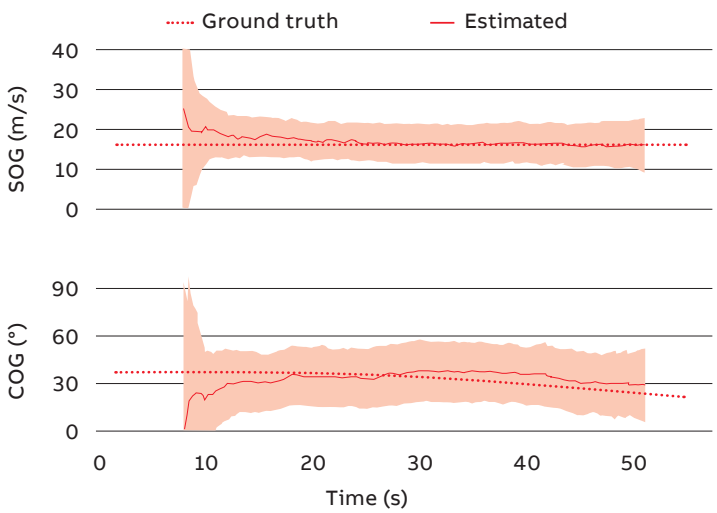

Figure 4: SOG and COG estimated with the monocular system. Comparison of estimated value with AIS-based ground truth.

SOG and COG. In both Figure 3 and Figure 4 the shaded area represents the uncertainty from the tracking filter (one standard deviation). The distance of the target vessel in this example ranges from approximately 400 m to approximately 600 m, while the SOG of the target vessel is approximately 15 m/s. The error in the estimated range is below 10 percent. SOG and COG estimates provide the input needed for CPA and TCPA calculations.

Water clearance

A sequence of images captured from the lookout camera of MS Finlandia while leaving Tallinn harbor are shown at Figure 5. The ship is docked bow first and while exiting the harbor, she reverses and makes a 180 degree turn within the harbor. In the sequence of figures, the water is depicted in green, corresponding

Figure 5: A sequence taken from the lookout camera of MS Finlandia while leaving one of Tallinn's ports. The water clearance map and the directional clearances are computed in real time from the camera stream.

Figure 5a: MS Finlandia about to cast off.

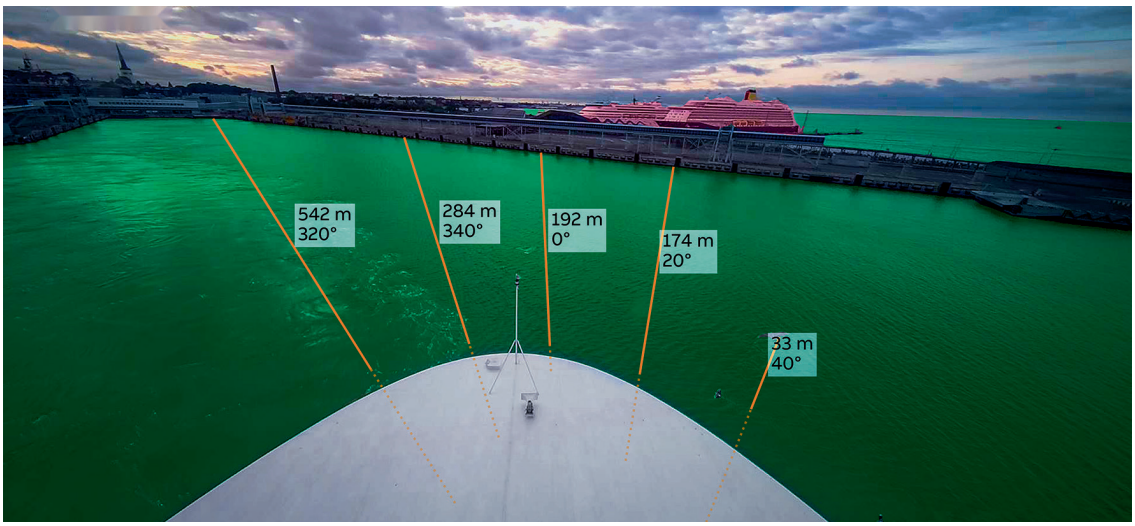

Figure 5b: MS Finlandia just after casting off.

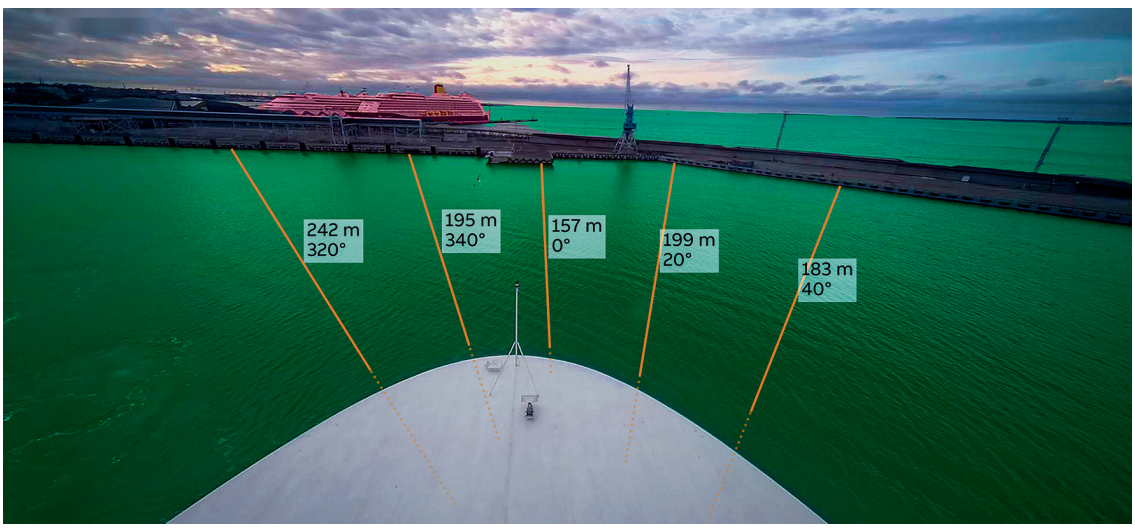

Figure 5c: MS Finlandia commencing turn to starboard, within one of Tallinn's ports, towards exit.

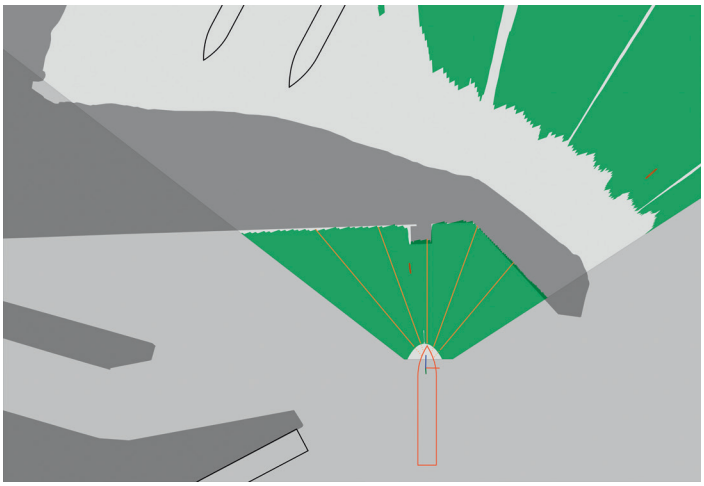

Figure 6: Water clearance map corresponding to Figure 5b. Water is depicted in green. For comparison, harbor structures from the nautical chart are shown in dark gray.

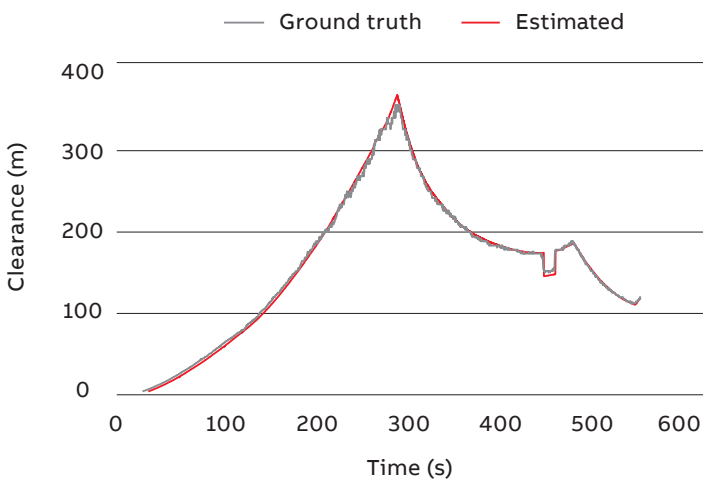

Figure 7: Estimated water clearance and ground truth along centerline for the sequence shown in Figure 5.

to the output of the segmentation network. Orange lines and their respective labels show the clearance between the hull and the first obstacle along pre-defined directions. Figure 6 shows a map of the water overlaid with the harbor structures. Such visual and numerical information about water clearance can provide valuable input to the crew during maneuvering or it can be used to further improve safety of autonomous operations.

The estimated clearance along the centerline is compared with the ground truth in Figure 7. Ground truth is computed from charts and GPS-based ego-vessel position. The relative error is below 5 percent, accepted as more than sufficient in many applications. The small discrepancy, around 300 seconds, is due to a loading ramp that is not present in the charts used for the evaluation. This shows an advantage of this technology compared to relying on charts, which may be outdated at the time of use. Another advantage lies in the reduced cost of this technology compared to a LIDAR-based alternative.

Marine Pilot Vision

The research presented in this article is central to the development of more autonomous solutions for vessels. ABB Ability™ Marine Pilot Vision is part of the ABB autonomous solutions portfolio. It provides enhanced situational awareness by combining information from a range of sensors and other information sources for both the human operator and for autonomous control functions.

ABB Ability™ Marine Pilot Vision can provide a solution that does not rely on any external infrastructure. Image stream from cameras can be analyzed, and the map of the water clearance around the vessel can be calculated. Clearance from the hull to the closest quay or floating obstacle can be defined [PAT-3].

Vision-based water clearance is used for docking assistance and harbor maneuvering, providing clearance measurements from desired points on the hull's waterline towards desired directions. Docking cameras allow monitoring of areas not visible from the bridge. Water clearances can be visualized in Marine Pilot Vision's Chart and Camera Views. Vision-based vessel detection is used to support other target sensing functions (eg, AIS and radar), to extend detection coverage to vessels without AIS, vessels with low radar signature and to sectors which the human user is not observing constantly. Detections can be used for Lookout Assistance and for Target Tracking in short ranges. Localized detections are visualized as part of Lookout Assistance in Marine Pilot Vision's Chart and Camera Views.

The way ahead

The first functionalities resulting from this research are already being demonstrated in pilot projects on ferries in Scandinavia and tugs in the US. These projects allow a great deal of data to be collected and learning to be made to further the development of these systems, enabling a wide-scale commercial use of such products. There is a clear interest of progressive vessel operators to support the day-to-day operations of their crew with situational awareness systems. Yet, there is still a way to go from a regulatory standpoint before such technology can be viewed as a tool that can be considered as a full crew member.2) The research will enable the potential of vision-based solutions, in this case a monocular-vison system, and their benefits when integrated into the suite of marine safety systems. In addition to bolstering marine safety, such vision-based solutions are an enabler for increasing future autonomy in the shipping industry. •

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[PAT-2] “Method for determining a vessel-water interface, and method and system for determining a positional relationship between an ego vessel and a target vessel”, European Patent Application no. EP22180131.9, Filed June 21, 2022.

[PAT-3] “Method and system for determining a region of water clearance of a water”, European Patent Application no. EP22212496.8, Filed Dec. 9, 2022.

[PAT-4] “Method and a system for calibrating a camera”, European Patent Application no. EP22200130.7, Filed Oct. 6, 2022.
[PAT-5] “Method and system for determining a precise value of at least one pose parameter of an ego vessel”, European Patent Application no. EP23158743.7, Filed Feb. 27, 2023.

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Footnote:
2) ABB and the One Sea partners use the expertise they gain through the development of these technologies to identify regulatory requirements of electronic lookouts and other situational awareness systems towards the International Maritime Organisation (IMO). This supports the development of the regulatory framework that will be released in 2028. One Sea Association is a non-profit global alliance of leading commercial manufacturers, integrators and operators of maritime technology, digital solutions and automated and autonomous systems. The association engages in the development of the international legal framework and participates in the standardization work [6].

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